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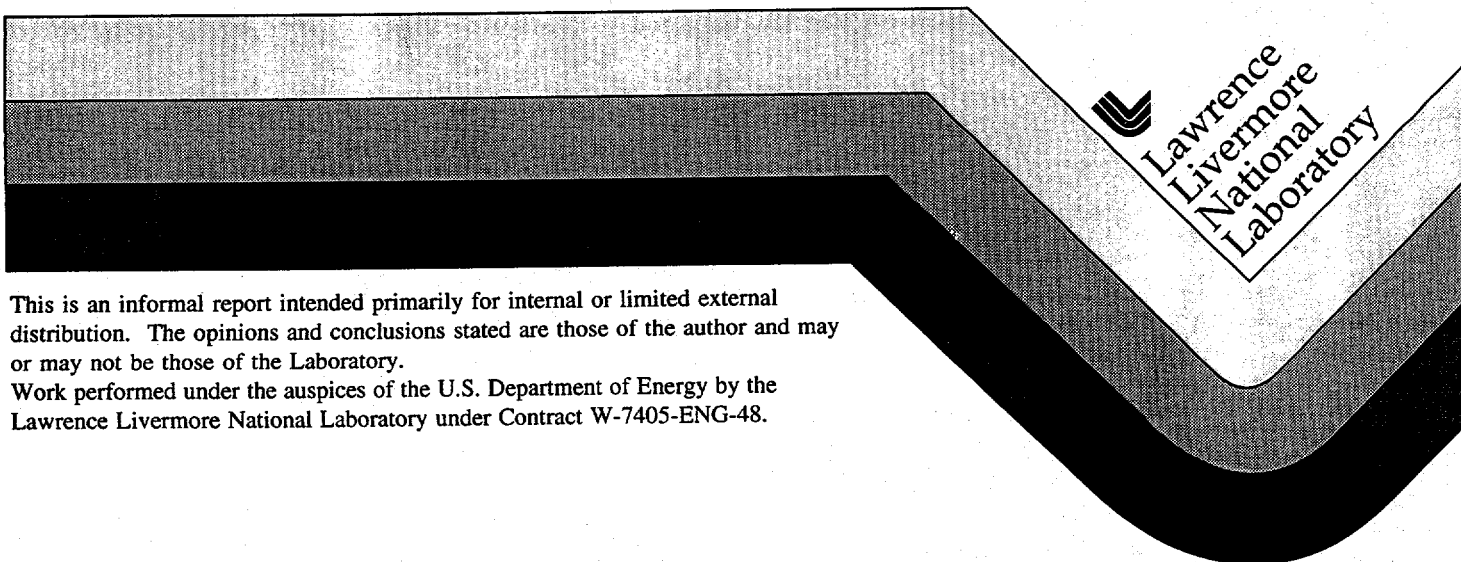
Dose Reconstruction for the Urals Population

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DOSE RECONSTRUCTION FOR THE URALS POPULATION

Joint Coordinating Committee on Radiation Effects Research Project 1.1—Final Report

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INTRODUCTION

The purpose of this report is to present the results of the first year's collaborative work on Project 1.1 on "Dose Reconstruction for the Urals Population," which is part of Direction 1 on "Medical Aspects of Radiation Exposure Effects on Population." This work is being carried out as a feasibility study to determine if a long-term course of work can be implemented to assess the long-term risks of radiation exposure delivered at low to moderate dose rates to the populations living in the vicinity of the Mayak Industrial Association (MIA). This work was authorized and conducted under the auspices of the U.S.-Russian Joint Coordinating Committee on Radiation Effects Research (JCCRER) and its Executive Committee (EC).

The MIA 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 technological failures that resulted in the release of large amounts of waste into the rather small Techa River. There were also gaseous releases of radioiodines and other radionuclides during the early days of operation. In addition, there was an accidental explosion in a waste storage tank in 1957 that resulted in a significant release (the Kyshtym explosion). The "Techa River Cohort" has been studied for several years by scientists from the Urals Research Centre for Radiation Medicine (URCRM), and an increase in both leukemia and solid tumors has been noted (Kossenko and Degteva 1994). This cohort is the primary focus of collaborative studies, but other cohorts have been suggested for study; these cohorts will be considered in this report.

This study was undertaken on the basis of a proposal from the Russian side to the JCCRER. This proposal and its accompanying proposal for epidemiological research (Project 1.2) are reproduced here as Appendix 1, which is taken from the JCCRER (1994) report of its October 1994 meeting. At this October 1994 meeting the JCCRER agreed to the following as concerns Direction 1 (JCCRER 1994).

"For Direction 1, both parties agree to these research proposals with the stipulation that the EC should modify proposals 1.1 and 1.2 to 1) ensure data identification, quality assurance and preservation and to 2) accommodate the closer integration of the dosimetry (dose reconstruction) with the risk estimation for defined residential populations. Both parties agree that initial epidemiological studies of residential populations should focus on, but not be limited to, stochastic effects in the South Urals populations."

Following this decision Russian and American scientists met at the URCRM in January 1995 to define a more detailed proposal for the work to be conducted under Project 1.1. The resulting proposal is reproduced as Appendix 2. This proposal was provided to the EC and was considered at the EC's meeting in Moscow in February 1995 (JCCRER 1995a). The EC did not adopt the full context of the proposal, but defined a more narrow set of objectives for the first year's collaborative research in terms of a feasibility study. The results of the EC's decision are provided in Appendix 3 for both Projects 1.1 and 1.2. Of particular interest for this report are the four Milestones that were identified for Project 1.1 (JCCRER 1995a):

* General information on the releases is contained in Akleyev and Lyubchansky (1994).

1. Preserve and verify the existing database and design a searchable database structure, including software and hardware needed. Include the available archived information related to dose reconstruction. Prepare a report describing the data base design by December 31, 1995.
2. Begin calibration of the URCRM whole body counter. Construct a phantom, begin calibration of the counter with the phantom, and prepare a progress report on this milestone by February 29, 1996.
3. Prepare a report that will include the methodology for and an assessment of the feasibility of reconstructing the doses for persons in the cohort considered in Project 1.2 by February 29, 1996.
4. Establish conceptual and mathematical models for sources and pathways of exposure for the Mayak Region population at the St. Petersburg Workshop (June 1995).

Final reports on all milestones are included within this report. An informal report on Milestone 1 was prepared during a visit of two scientists each from the URCRM and the MIA to the Hanford Works, WA, and Washington, DC. A progress report on Milestone 2 was prepared during the JCCRER St. Petersburg Workshop held in July 1995; this progress report was supposed to have been included in the Proceedings of this Workshop. A final progress report on Milestone 2 is provided in this report. The final report on Milestone 3 is provided here for the first time. The final report on Milestone 4 was prepared during the St. Petersburg Workshop; it was supposed to have been published as part of the Workshop Proceedings. As the authors of the present report cannot verify the existence of such Proceedings, the Milestone 4 report is reproduced within the body of this report.

BACKGROUND

Population exposure in the Urals occurred as a result of failures in the technological processes at the MIA plutonium facility in the 1950's. Construction of the Mayak facility began in 1945 and was completed in 1948. Initially this complex consisted of three main parts: Reactor plant, radiochemical facility, and waste-management facilities (Fig. 1). The major sources of radioactive contamination were the discharges of 2.7×10^6 Ci of liquid wastes into the Techa River (1949–1956); an explosion in the radioactive waste-storage facility in 1957 (the so-called Kyshtym Accident) that formed the East Urals Radioactive Trace (EURT) due to dispersion of 2×10^6 Ci into the atmosphere; and gaseous aerosol releases (about 560,000 Ci of ^{131}I in total) within the first decades of the facility's operation (Fig. 1). The significant portion of activity for the Techa River and EURT consists of long-lived radionuclides, mainly ^{90}Sr (Fig. 2 and Table 1). These releases resulted in the long-lived contamination of surrounding territories (Fig. 3). The predominant radionuclide for operating gaseous aerosol releases was short-lived ^{131}I that resulted from the processing of nuclear fuel for the extraction of Pu. The maximal annual rates, which occurred in 1952–1953, were reconstructed on the basis of technological records by the Mayak team supervised by Dr. E. Drozhko (Khokhryakov et al. 1992) (Fig. 4).

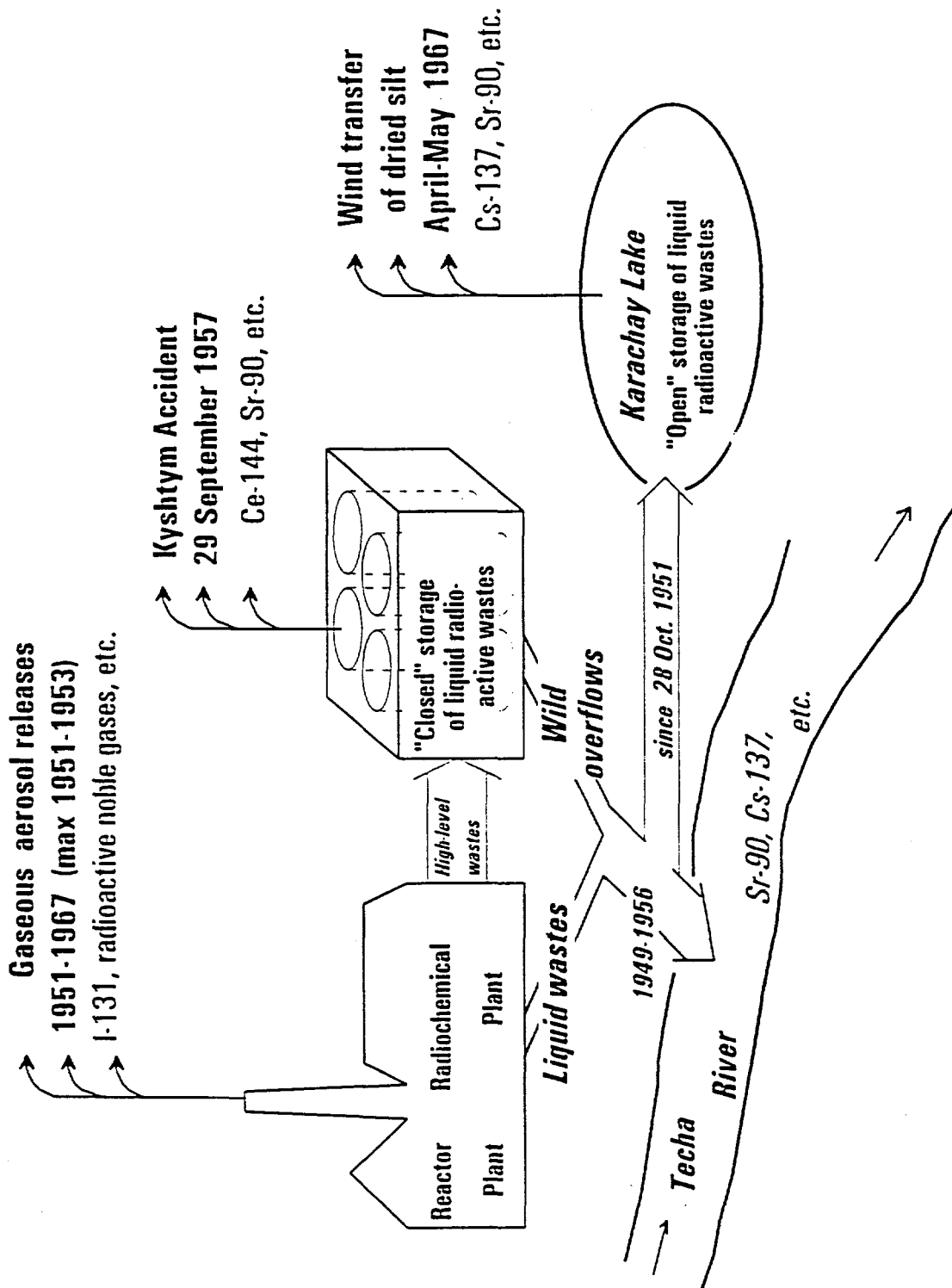


Fig. 1. The Mayak complex and main releases of radioactive materials.

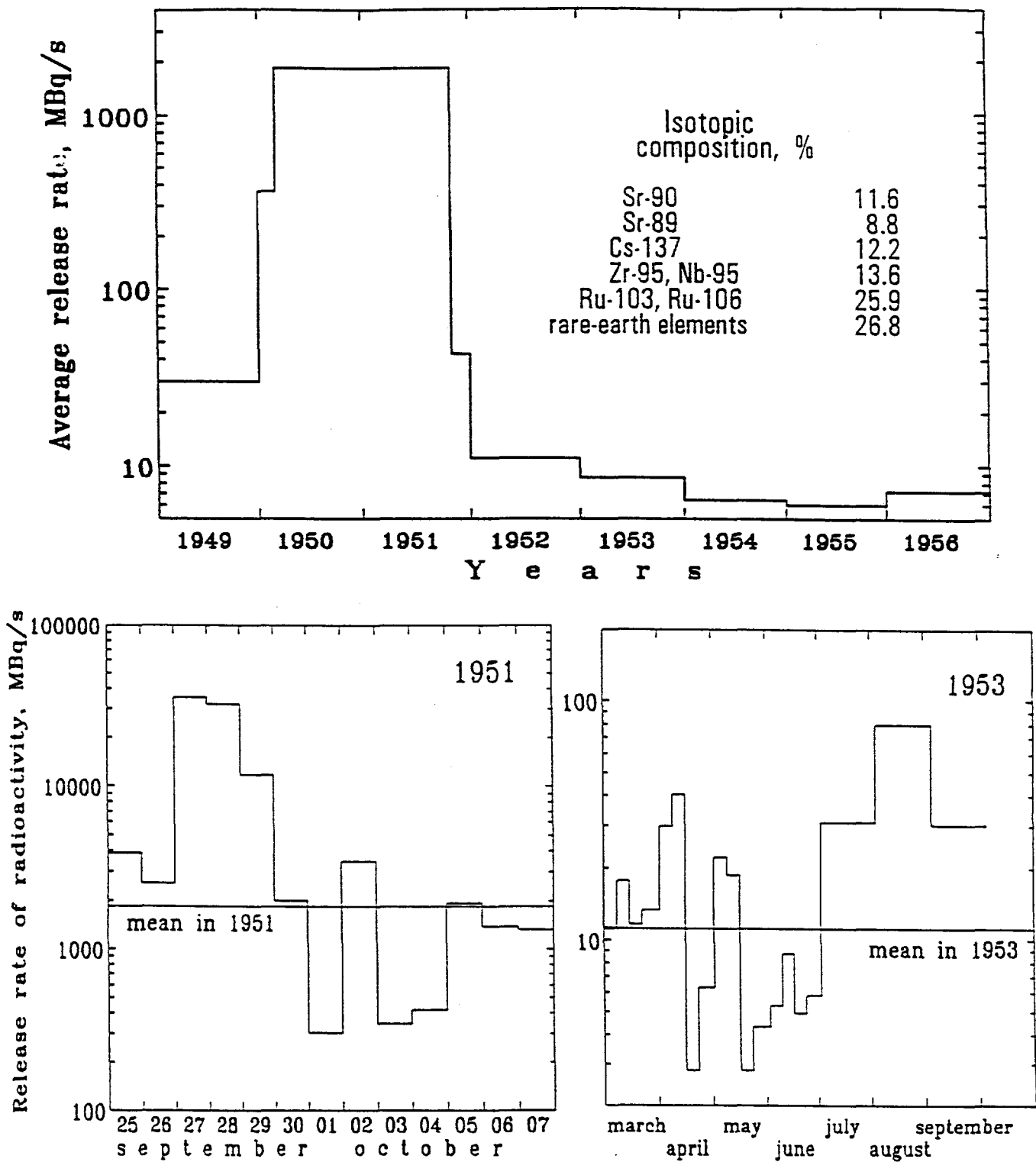


Fig. 2. Releases into the Techa river (according to the data of the Mayak Laboratory, project director D. Ilyin).

THE MAP OF THE URALS REGION SR-90 Contamination, Ci/km²

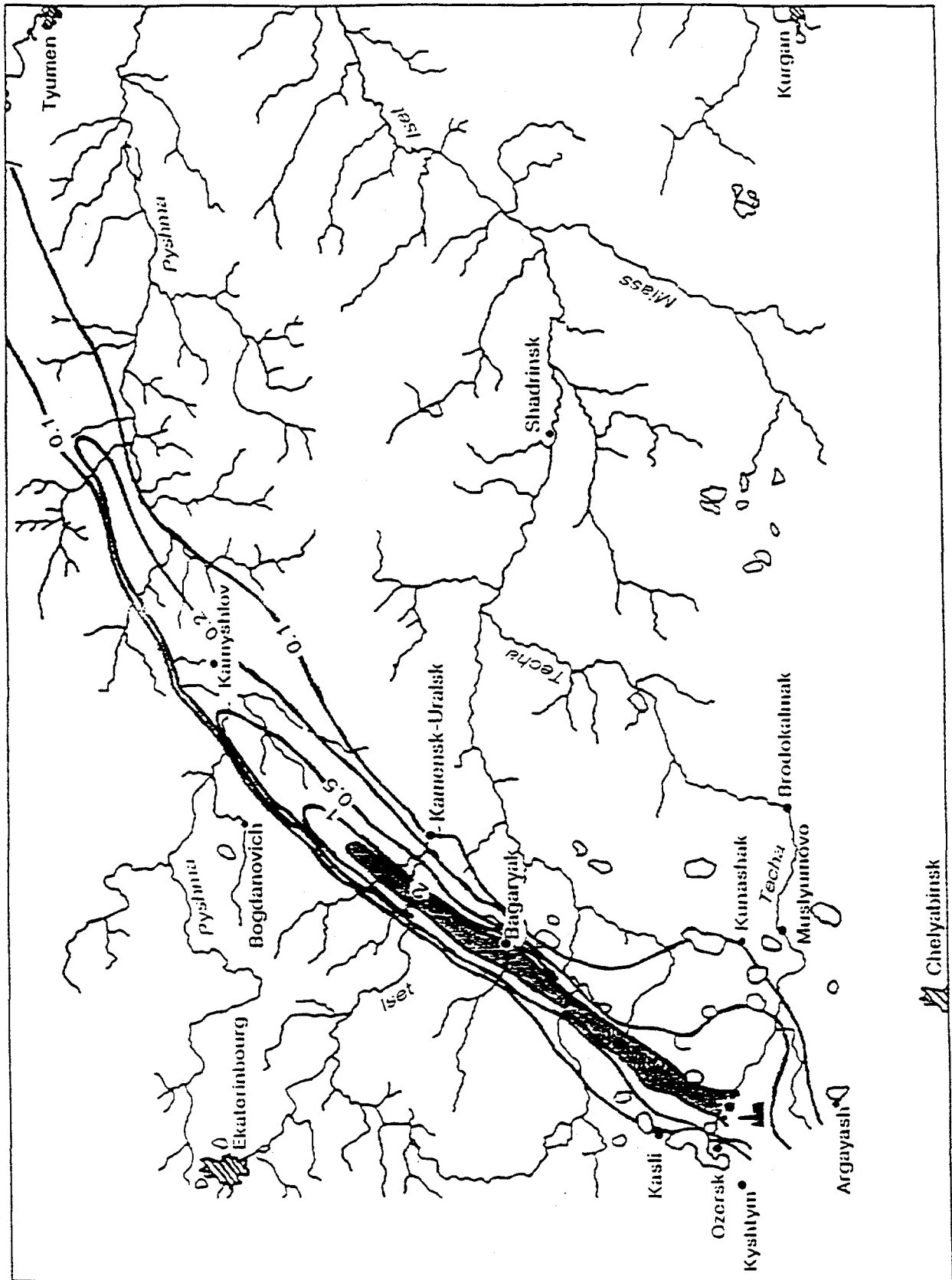


Fig. 3.

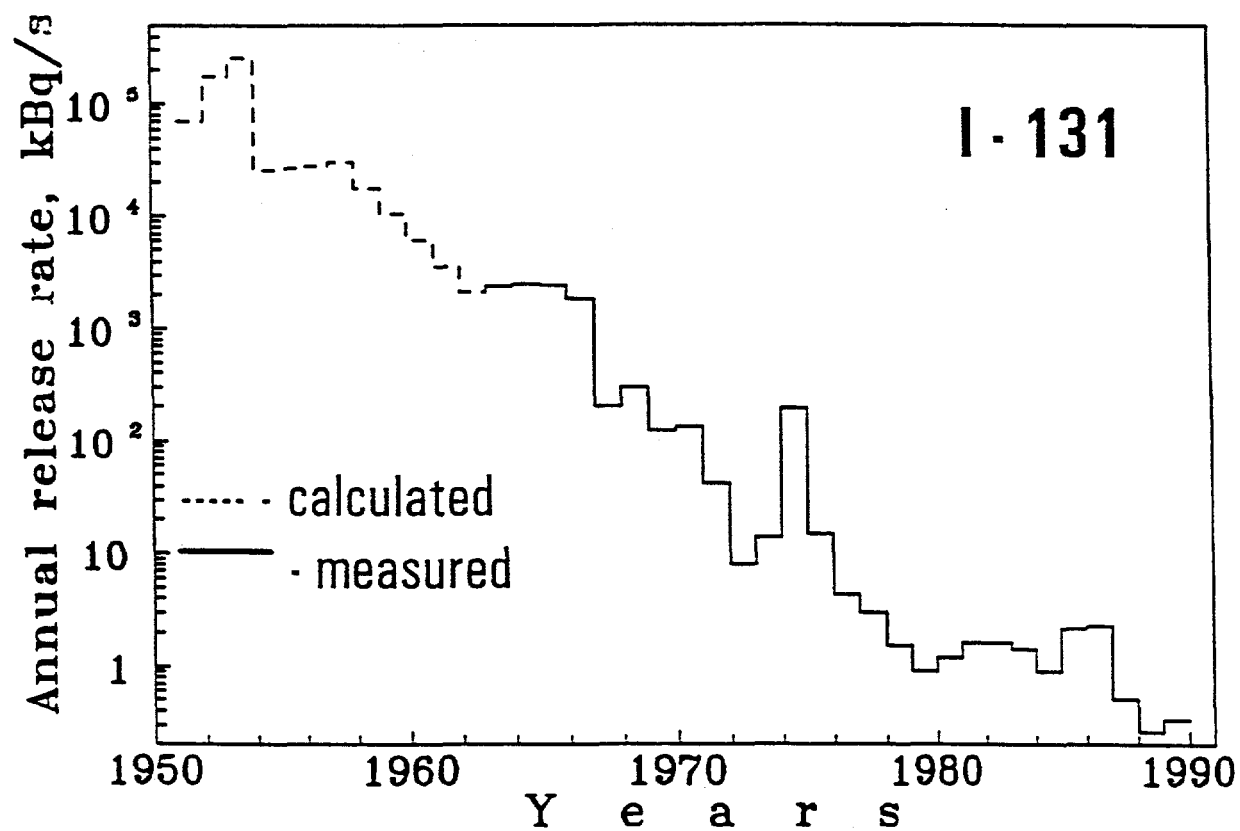


Fig. 4. Releases into the atmosphere (data of E.Drozhko et al.).

Table 1. Isotopic composition of waste ejected in the Kyshtym explosion (according to Dr. G. Romanov et al. 1990).

Radionuclide	Isotopic composition, %
^{89}Sr	trace
$^{90}\text{Sr}/^{90}\text{Y}$	5.4
$^{95}\text{Zr}/^{95}\text{Nb}$	24.9
$^{106}\text{Ru}/^{106}\text{Rh}$	3.7
$^{137}\text{Cs}/^{137\text{m}}\text{Ba}$	0.036
$^{144}\text{Ce}/^{144}\text{Pr}$	66
^{147}Pm	trace
^{155}Eu	trace
$^{239,240}\text{Pu}$	trace

Systematic measurements of radioactive contamination in and near the Techa River started in the summer of 1951. The contamination of the river water, bottom sediments, flood-plain soils, vegetation, fish, milk, and other food stuffs, and external gamma-exposure rates were measured. In 1957 the monitoring was expanded to include the area covered by the EURT. Systematic control of the MIA operating releases and measurements of ^{131}I concentration in food stuffs started only in 1962. For the town of Ozersk (which was the living place of the workers at the MIA and which was mostly affected by gaseous aerosol releases) regular measurements of ^{90}Sr and ^{137}Cs started in 1956, and the monitoring of exposure rates began in 1964. The results of all these measurements are kept in archives at the MIA and the URCRM, mainly on paper media (maps, working notebooks, technical reports, etc.). Some of them are still classified.

The population of the contaminated territories was exposed to external and chronic internal irradiation. Medical checkups of people living in the Techa Riverside communities had been started by 1951. In addition to medical examinations, individual data on the conditions of contact with the contaminated river (the distance of the house from the water's edge, the source of drinking water, fishing, etc.) were collected. Also, radiometric measurements of bioassay and autopsy samples were performed. Medical checkups of the population of the most contaminated area of the EURT were started in autumn 1957. Later, a registry numbering 90,000 subjects in the accidentally exposed population (the residents of the Techa Riverside communities and the residents of the area covered by the EURT) was established at the URCRM. All places and terms of residence inside the contaminated area were collected for the members of this registry for the purposes of individual-dose reconstruction. Also, extensive measurements of ^{90}Sr content in teeth were performed beginning in 1960 and in forehead bone beginning in 1976; whole-body counting for ^{90}Sr has been performed since 1974. Now the main part of this information is contained in a computerized data base at the URCRM. The registry for the population exposed as a result of the operational releases at the MIA is not established yet, but this work has been started at Branch 1 of the Moscow Biophysics Institute (FIB-1). Also, the results of measurements of ^{90}Sr and Pu in samples collected at autopsy for the residents of Ozersk and nearby territories number several thousand and are kept in the archives of the MIA and the FIB-1. So, three cohorts of exposed populations can be selected based on the nature of exposure and according to the history of follow-up and available data. These are the Techa River Cohort, the

EURT Cohort and the Ozersk Cohort (not yet established). Some efforts addressed to dose reconstruction and risk assessment for the first two cohorts were taken in the URCRM and the results have been published in the open literature.

Techa River Cohort

The Techa River cohort (TRC) is important, because some of its members have received relatively high doses and a significantly increased risk of leukemia in this group has been observed (Kossenko and Degteva 1994). There is some evidence that solid tumors may also be in excess. The residents of the villages along the Techa were exposed to both external irradiation (from contaminated river water, sediments, flood-plain soils) and internal irradiation due to ingestion of radionuclides with drinking water and diet. The original dose-reconstruction methods for the TRC have been described in detail elsewhere (Degteva et al. 1994).

The absorbed doses due to external exposure were estimated on the basis of systematic measurements of gamma-exposure rate along the banks of the river and the typical life-style patterns of the inhabitants of the riverside villages. This approach has given the average annual absorbed doses from external sources for different age groups in each village. The data available do not provide information on the variations in individual-dose levels among the residents of a village. Instead the average value for specified age groups living in a specified settlement has been assigned to each member of cohort. Also, it was assumed that the total dose due to external exposure was accumulated during the period 1950–1955. This approach has a number of limitations that result in both random and systematic errors in individual-dose estimates.

The main contributor to the internal exposure among the radionuclides released into the Techa River was ^{90}Sr , which is accumulated in bone tissues and retained there for many years. In vivo beta-ray measurements on teeth, which have been performed since 1960, and a large number of ^{90}Sr measurements in whole body have been the basis of internal dose reconstruction (Kozheurov 1994). The reconstruction of internal dose depends on both estimates of the intake and models for metabolism of ingested radionuclides. Beta-ray measurements on teeth are utilized to deduce the annual levels of intake of ^{90}Sr in the different villages in the different age cohorts. The ingestion of other radionuclides (^{89}Sr and ^{137}Cs predominantly) occurred mostly with water in the first three years of the river contamination. The intake rates of ^{89}Sr and ^{137}Cs were therefore derived from estimates of the ingestion of ^{90}Sr scaled in terms of the radionuclide composition of the river water. These data were used to estimate age-dependent intake rates for all Techa River villages (Kozheurov and Degteva 1994). Calculation of absorbed doses in tissues due to radionuclide incorporation is based on age-dependent metabolic and dosimetric models and the corresponding ingestion rates. A large number of measurements of ^{90}Sr -body content made with a whole-body counter (WBC) has been utilized for the validation of the metabolic model for strontium retention in human bone (Degteva and Kozheurov 1994). Absorbed doses in red bone marrow (RBM) and bone surfaces (BS) have been calculated for all age cohorts. The absorbed doses in RBM and BS are substantially higher than those in other tissues, because of ^{90}Sr was the main radionuclide of interest and strontium is a bone-seeking element. The upper limit of total doses absorbed in RBM is estimated as about 3 Gy.

EURT Cohort

Initially a sub-cohort of the population evacuated from the most contaminated territories of the EURT numbering 7,854 people was established at the URCRM (Kostyuchenko and Krestinina 1994). Average-dose estimates for the residents of different villages were taken from two independent sources of information (Romanov 1990 et al.; Skryabin et al. 1985), which gave different assessments. Dose calculations were undertaken on the basis of the levels of radionuclide contamination of soil (a significant non-uniformity of contamination being noted) and known isotopic composition of local fall-out. The range of effective doses for this part of the population was from 40 to 500 mSv. No statistically significant changes in cancer mortality as compared to the control group have been reported for this sub-cohort (Kostyuchenko and Krestinina 1994). Analogous results for another sub-cohort of 8,000 non-evacuated EURT residents who received effective doses from 50 to 66 mSv were reported in 1994 in Ekaterinoburg (Krestinina et al. 1994). The formation of the EURT Cohort is not finished yet, and only tentative dose assessments have been done.

FINAL REPORT FOR MILESTONE 1.1.1 "PRESERVE AND VERIFY THE EXISTING DATABASE AND DESIGN A SEARCHABLE DATABASE STRUCTURE, INCLUDING SOFTWARE AND HARDWARE NEEDED. INCLUDE THE AVAILABLE ARCHIVED INFORMATION RELATED TO DOSE RECONSTRUCTION"

The first major, critical goal is to create a searchable data base of the available archived information that would be essential and useful to perform individual and collective dose calculations for the populations effected by the routine and accidental releases from the MIA. Such information would include the data needed to determine the releases to the environment via all pathways, with emphasis on the releases to the Techa River, from the Kyshtym tank explosion, and routine and accidental airborne releases. Also included would be all environmental monitoring data; all bioassay data; and all previous estimates of releases and doses. It is especially important that this information include working notebooks from the MIA, as well as contamination maps and technical reports. Such bibliographic information will be entered into a data base that would include the author(s), title, and summary with key words.

It is not possible to accomplish this large task during the feasibility phase. Rather, the first proposed effort is to establish the optimum conditions for the conduct of this task. It is recognized that this task could become very consumptive of manpower, if not controlled and limited. The feasibility phase was limited to the design of the hardware and software systems needed to accomplish the larger overall task. The first step was a visit of four staff members from the URCRM/MIA to the United States in order to visit similar systems that have already been successfully demonstrated for the purpose of collecting information for dose-reconstruction (Trip Report is given as Appendix 4). The first priority for visit was the Pacific Northwest National Laboratory (PNNL), which is the best US analog of the MIA and which has just completed a similar bibliographic data base and dose-reconstruction project for the Hanford Works, which is the best U.S. analogue of the MIA. At the end of the visit U.S. and Russian experts consulted and determined the optimum hardware and software requirements to implement such a system. It is anticipated that this system will operate on a PC platform and will use commercially available

software. Two sets of software and hardware, with appropriate backup storage and protection, were purchased during the early phases so that work could proceed promptly on the implementation of this process. One of the early goals of this process is to identify all data sets that will be useful during the dose-reconstruction phases and to identify some unique data sets that might be saved for use in model-validation studies.

We have initially determined that there are three groups of data necessary for dose reconstruction: (1) Data on given individuals (place and times of residence on a polluted territory, measurement of the radionuclide contents in the human body, etc.); (2) Primary information on environmental contamination at the places of residence; and (3) Archival bibliographic information that describe the radiation situation and methods of research (technical reports, methods of measurement, working journals, etc.). In order to fulfill the needs three computer-compatible databases should be supported; these are named MAN, ENVIRONMENT and ARCHIVE.

Database MAN

The development of the structure of database MAN and the special hardware and software for its support were started in the URCRM prior to the beginning of Project 1.1 in the framework of scientific and research work financed by the Federal Agency of Medical and Extreme Problems. The information contained in this database is necessary for dosimetry as well as for epidemiology. Therefore, this part of work is common for the projects 1.1 and 1.2. The basis of the MAN database is the Registry of the exposed population (Fig. 5), which contains personal data on 90,000 individuals, including those who were exposed from radioactive releases into the Techa River and/or on territories of the EURT, as well as the children of exposed people. For each person included in the Registry there is the following information (Fig. 6): The surname, name, pedigree, date of birth, ethnicity, place of primary irradiation on the Techa River and EURT, places and times of residence on a given territory, status (living or dead), date of the status determination, and mailing address. Also included are any medical diagnoses, the results of measurements on a whole-body counter (SICH-9.1) for those examined at URCRM, and the causes of death for the deceased. The detailed description of the structure of the database and of the software for working with the data is given in Appendix 5. The American participants of Projects 1.1 and 1.2 were acquainted with the database MAN during their visits into URCRM in January and July 1995. It was noted that the level of the developed system corresponds to world standards, and the entering and updating of data should continue with the present technology. Detailed information on the condition of the database MAN at the end 1995 is given in the Final Report on Project 1.2a on Data Preservation.

Database ENVIRONMENT

Development of the database ENVIRONMENT was begun in URCRM prior to the start of Project 1.1 within the framework of scientific and research work financed by Federal Agency of Medical and Extreme Problems. The database ENVIRONMENT concerning situation on the Techa River was created within the RDB database editor developed by A. Kozyrev (this is the same software as for database MAN and its description is given in Appendix 5). Now the database structure contains the following information blocks: Hydrologic characteristics of the

MAIN Registry

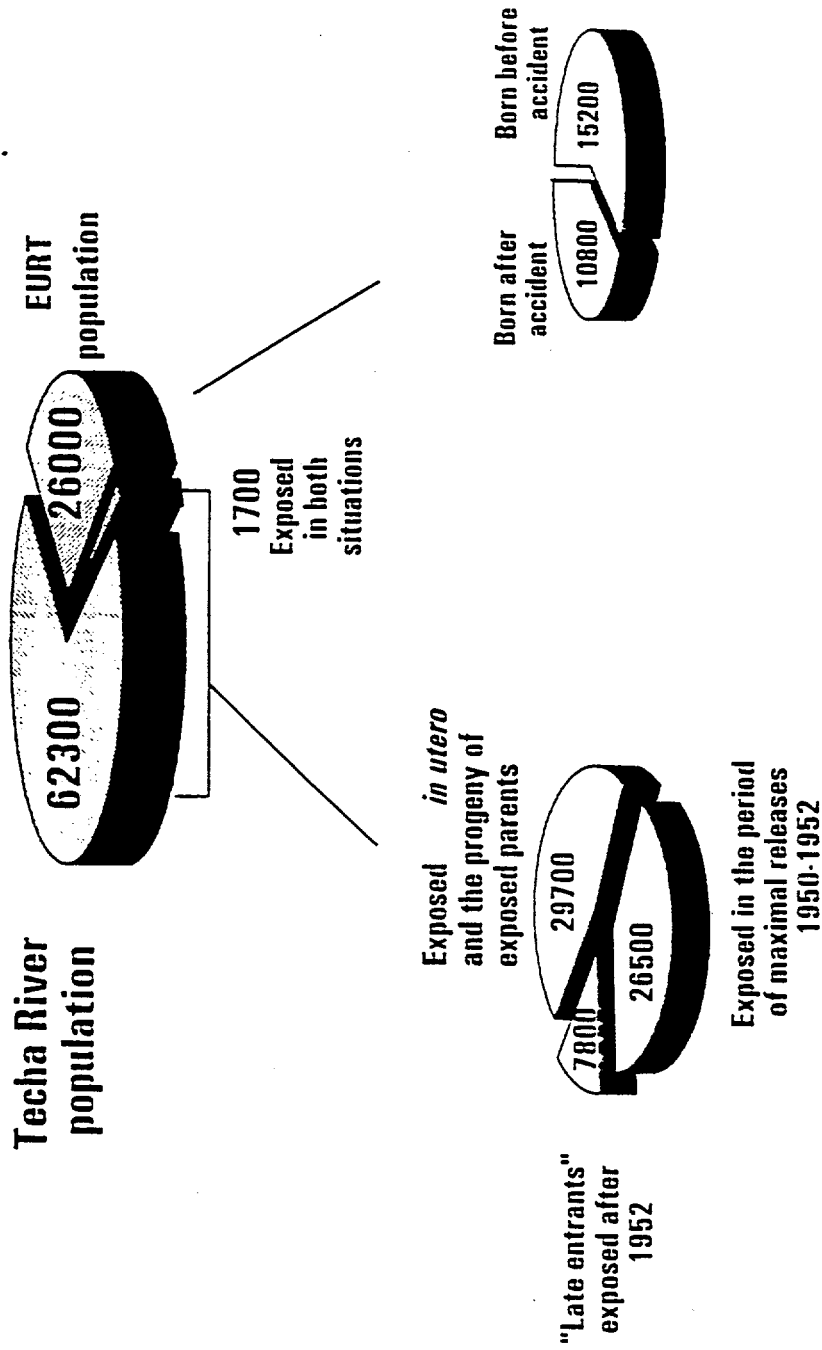


Fig. 5. The structure of the MAIN Registry.

Data Base MAN

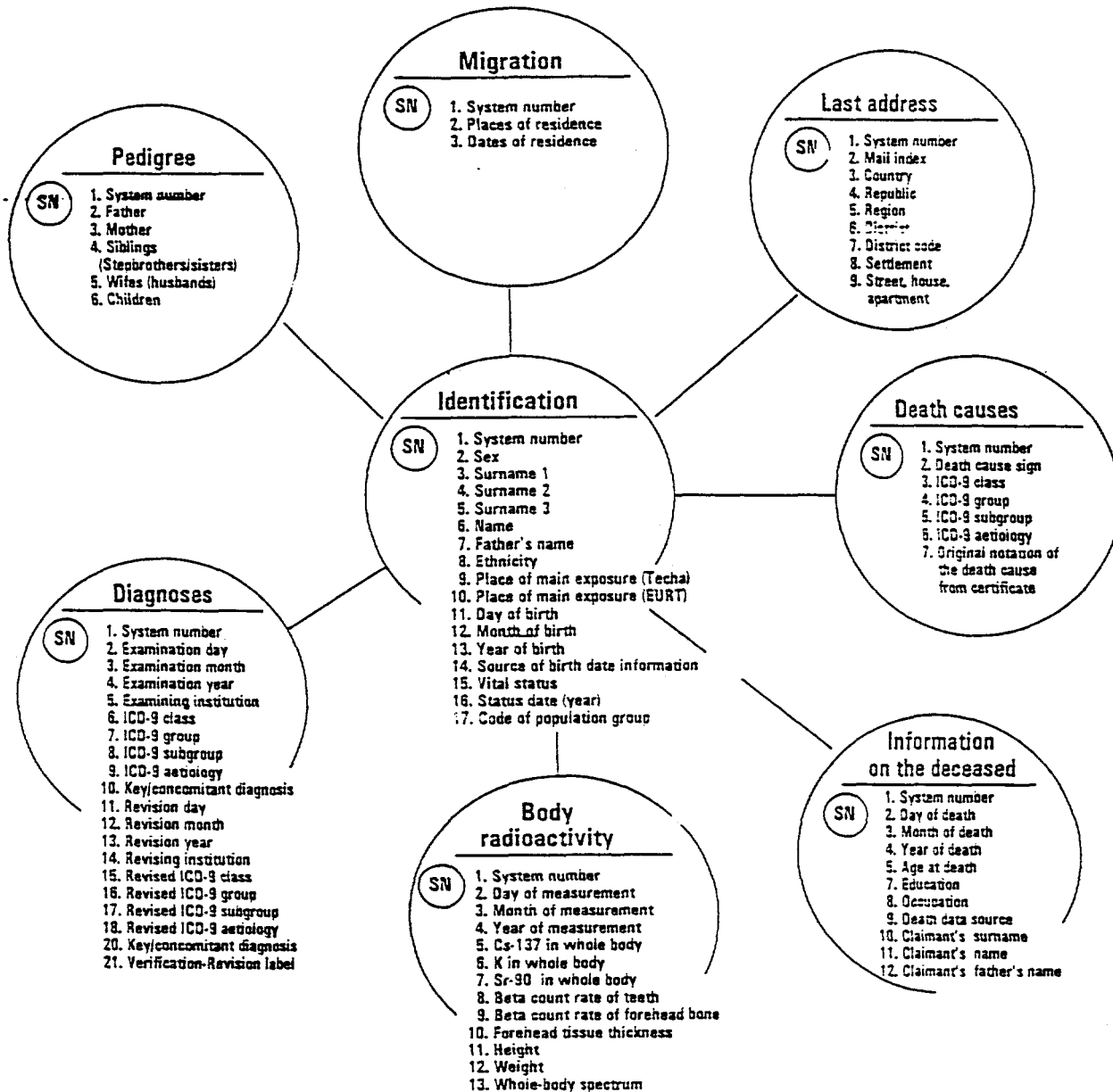


Fig. 6. The information on the members of the MAIN Registry.

river system—block HYDR; results of activity measurements for the main components of the river system (water, bottom sediments and flood-plain soils) during the time period when releases were occurring—block RIV_O; results of measurements of external gamma-exposure rates above the water and on the river bank—P_GAM; results of measurements of ^{90}Sr and ^{137}Cs contents in the main components of the river system in the time period following river contamination—RIV_N; and results of thermoluminescence analysis of brick samples—TLD.

The main link among specified blocks is the number of a "sample-collection point", that is, a code used to describe the location of the point within approximately one kilometer. The block POINTS contains the information about these points of sample collection, including distances of the current locations of the points from the site of release, character and frequency of sample collection, the features of the sample-collection point that can be used for subsequent identification of these points at the present time.

The hydrologic characteristics of the river system (block HYDR) include information about the relief of the location, geometric sizes of the river bed, character of bottom sediments, river velocities and flow rates. One additional major part of a specified block is information on changes of the characteristics of the river due to man (washing, creation of ponds and their capacity change with time) and due to natural processes (for example, temporary changes of the river bed). The large file FLOW of this block has been created and includes the information on flow rates in the river during the period 1936–1981. The structure of this file is indicated in Fig. 7.

Block RIV_O includes results of activity measurements in the main components of the river system: Water, bottom sediments and flood-plain soils during periods of releases (these data were provided by the MIA for the purposes of dose reconstruction). This block is subdivided into three files. The file WATER contains results of measurements of α -, β - and γ -activities of river water from the site of release up to the joining of the Techa River with the Iset River, including settlement-reservoirs (Koksharov and Metlinsky ponds) for a period from July 1951 to September 1953; included are the sample-collection point, date of collection, measured values of specific β -activity of natural and centrifuged water, results of measurements α - and γ -activities of river water, and notes (Fig. 8). The file SED contains results of measurements of β -activities of river-bottom sediments of the river and ponds for the period from August 1951 to July 1953 and includes the sample-collection point (for ponds also coordinates of the sample-collection place), date, depth of collection, specific β -activity of bottom sediments, references, and notes (Fig. 9). It is planned to include into the file SOIL results of measurements specific β -activity of flood-plain soils under the following regime: Number of sample-collection point (coordinate for ponds), date of collection, distance from the edge of water, depth of collection, specific β -activity of soil sample, and notes. Block P_GAM contains the results of researches of gamma-exposure-rate measurements on coastal territories and covers a temporal interval from August 1951 to September 1956. Also included are the point of measurement, date, distance from the edge of the water, exposure-rate value, source of the information, and notes (Fig. 10). It is planned to include into block RIV_N data on contamination of river water, bottom sediments and flood-plain soils of the Techa River during the period after 1956 according to the following scheme:

flow Wed Jan 17 13:45:58 1996

POINT	YEAR	MONTH	DAY	FLOW RATE, CUBIC METER PER SECOND	REFERENCES	NOTES
38	1936	3		0.67	1	*
38	1936	4		6.26	1	*
38	1936	5		3	1	*
38	1936	6		1.03	1	*
38	1936	7		0.75	1	*
38	1936	8		0.46	1	*
38	1936	9		0.42	1	*
38	1936	10		0.53	1	*
38	1938	1		0.33	1	*
38	1938	2		0.94	1	*
38	1938	3		0.41	1	*
38	1938	4		5.94	1	*
38	1938	5		2.8	1	*
38	1938	6		2.11	1	*
38	1938	7		2.75	1	*
38	1938	8		3.83	1	*
38	1938	9		2.4	1	*
38	1938	10		1.51	1	*
38	1938	11		2.05	1	*
38	1938	12		0.47	1	*
38	1950	5		3.56	1	*

Fig. 7. The structure of the file with hydrology data.

water Wed Jan 17 13:56:22 1996

POINT	YEAR	MONTH	DAY	DATE	BETA-ACTIV. NAT. WATER, MICROCI/L	BETA-ACTIV. AFTER CENTRF MICROCI/L	ALPHA-ACT. NANOCI/L	GAMMA-ACT. MICRO G. EQUIV. RA/L	REFERENCES
7	1951	11	26	19511126	3.11		0.7	0.55	3
7	1951	11	27	19511127	2.92		0.5	0.24	3
7	1951	11	28	19511128	3.48		0.43	0.12	3
7	1951	11	29	19511129	3.33		0.2	0.12	3
7	1951	11	30	19511130	3.36	2.6	0.3		3
7	1951	12	3	19511203	2.91	1.49		0.37	3
7	1951	12	4	19511204	3.25	1.1	0.12	0.1	3
7	1951	12	10	19511210	2.2	1.7	0.6	0.5	3
7	1951	12	11	19511211	1.82	1.32	1	0.3	3
7	1951	12	13	19511213	1.62	1.58	1	0.4	3
7	1951	12	14	19511214	1.78	1.72	0.5	0.15	3
20	1951	7	23	19510723	65.8				1
20	1951	8	4	19510804	2.6				1
20	1951	8	9	19510809	112				1
20	1951	8	13	19510813	80				1
20	1951	9	6	19510906	20.3				1
20	1951	9	10	19510910	15.6				1
20	1951	9	15	19510915	212				1
20	1951	10	7	19511007	18.02				1
20	1951	10	9	19511009	485				1
21	1951	7	5	19510705	63.4				1
21	1951	10	5	19511005	5.8		0.8		1
21	1951	10	7	19511007	4.2				1
21	1951	10	9	19511009	7.05				1
21	1951	10	25	19511025	9.4	9.4	1.1		3
21	1951	10	27	19511027	10.2	14.2	0.5	0.31	3
21	1951	11	1	19511101	17.1	12.7	0.9	0.12	3
21	1951	11	2	19511102	14.6		0.7	0.14	3

Fig. 8. The structure of the file with water contamination data.

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POINT	YEAR	MONTH	DAY	DATE		DEPTH, CM	BETA-ACTIVITY OF BOTTOM SEDIMENTS MICROCI/KG	REFERENCES	NOTES
1	1951	12	17	19511013		0	910	3	left
2	1951	12	17	19511013		0	3600	3	right
13	1951	12	17	19511013		0	19000	3	right
13	1951	8	18	19510818		0	9340	1	
14	1951	8	18	19510818		0	20000	1	
15	1951	12	17	19511013		0	920	3	left
15	1951	8	18	19510818		0	7400	1	
15	1951	12	17	19511013		0	1500	3	right
	1953	6	0	19530601	33	0	16272.7	8	Metlinsky pond
	1953	6	0	19530601	22	5	1872.7	8	Between Koksh. & Metl. ponds
	1953	6	0	19530601	22	0	1772.7	8	Between Koksh. & Metl. ponds
	1953	6	0	19530601	20	5	3777.2	8	Between Koksh. & Metl. ponds
	1953	6	0	19530601	20	0	2795.2	8	Between Koksh. & Metl. ponds
	1953	6	0	19530601	19	5	1406.7	8	Between Koksh. & Metl. ponds
	1953	6	0	19530601	19	0	3727.2	8	Between Koksh. & Metl. ponds
	1953	6	0	19530601	18	5	4559.1	8	Metlinsky pond
	1953	6	0	19530601	18	0	2909.1	8	Metlinsky pond
	1953	6	0	19530601	17	0	4818.1	8	Koksharov pond (near p. 14)
	1953	6	0	19530601	16	0	8909.9	8	Koksharov pond (near p. 14)
	1953	6	0	19530601	15	0	5568.1	8	Koksharov pond (near p. 14)
	1953	7	0	19530701	15	5	62	9	1.5 km from the release point
	1953	7	0	19530701	21	0	67	9	1.5 km from the release point
	1953	6	0	19530601	21	0	3863.6	8	Between Koksh. & Metl. ponds

Fig. 9. The structure of the file with bottom sediments contamination data.

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POINTS	YEAR	MONTH	DAY	DATE	BANK	DISTANCE FROM EDGE OF WATER, M	DOSE RATE, MICRO R/S	REFEREN- CES
20	1952	8	7	19520807	RIGHT	0	400	12
20	1952	8	7	19520807	RIGHT	20	8.5	12
20	1952	8	7	19520807	RIGHT	70	6.5	12
20	1952	8	7	19520807	RIGHT	100	5.5	12
20	1952	8	7	19520807	RIGHT	200	2	12
20	1952	8	7	19520807	RIGHT	300	1	12
20	1952	8	7	19520807	RIGHT	400	0.39	12
20	1952	8	7	19520807	RIGHT	500	0.18	12
20	1952	8	7	19520807	RIGHT	600	0.097	12
21	1952	8	7	19520807	RIGHT	0	14.5	13
21	1953	6	1	19530601	LEFT	10	2.25	13
21	1953	6	1	19530601	LEFT	50	0.45	13
21	1953	6	1	19530601	LEFT	100	0.56	13
21	1953	6	1	19530601	LEFT	200	0.31	13
21	1953	6	1	19530601	LEFT	300	0.11	13
21	1953	6	1	19530601	LEFT	400	0.05	13
27	1953	6	1	19530601	RIGHT	0	8.1	13
27	1953	6	1	19530601	RIGHT	10	4.3	13
27	1953	6	1	19530601	RIGHT	50	2.03	13
27	1953	6	1	19530601	RIGHT	100	0.9	13
27	1953	6	1	19530601	RIGHT	200	0.13	13
27	1953	6	1	19530601	RIGHT	300	0.04	13
27	1953	6	1	19530601	RIGHT	400	0.014	13

Fig. 10. The structure of the file with exposure dose rate measurements.

Water—sample-collection point; distance from the site of release; date; mineralization of water (dissolved solids), including contents of Ca and Mg ions; turbidity; specific β -activity; contents of ^{90}Sr and ^{137}Cs ; and notes (source of the information, methods of measurement and etc.).

Bottom sediments, flood-plain soils—sample collection point (coordinates); distance from the site of release; date; depth; character of sediments or soils; weight of sample; specific β -activity; contents of ^{90}Sr and ^{137}Cs ; and notes.

It should be noted that the indicated structure of database ENVIRONMENT can be improved as required during work on entering primary data. Information on database ENVIRONMENT is presented in Table 2.

Table 2. Database ENVIRONMENT.

Situation	Sample	Period of investigation	Measured value	Number of records
Techa River	Water	1951–1953	α -, β - and γ -activity	2979
		1961–1962	β -activity	83
		1968–1990	β -activity, content of ^{137}Cs and ^{90}Sr	5100
	Bottom sediments	1951–1953	α -, β - and γ -activity	512
		1961–1990	β -activity, content of ^{137}Cs and ^{90}Sr	1000
	Flood-plain soils	1951–1952	β -activity	77
		1951–1956	γ -dose rates	323
EURT	Soils	1959–1990	Content of ^{90}Sr	713

Database ARCHIVE

Pursuant to the main purpose of Project 1.1, "Dose Reconstruction for the Urals Population," the feasibility for information support of the project and development of the bibliographic database ARCHIVE were investigated. These researches were not previously performed or funded.

The researches on radioactive contamination of the environment in the zone of influence of the MIA were begun in summer 1951 and still continue. This has resulted in a large amount of information on the results of these efforts; this information is contained in scattered sources. There are technical reports, books and articles, sample-log notebooks, results of measurements, working notebooks, working maps, etc. Preliminary analysis of the sources of information and

the results of investigations has shown that a significant part of unique primary data useful for dose reconstruction is contained only in the sample-log books and working notebooks and, hence, may be easily lost. The large number of primary documents hinders search of the information necessary for dose reconstruction. In addition, manual searches of the data take a lot of time even for those employees who are rather familiar with the data; manual searches are not at all effective for persons needing the data for dose reconstruction. This situation makes it highly desirable to perform an inventory of all available primary documents of interest for dose reconstruction and to create a bibliographic database.

Proposed structure of ARCHIVE Database

Information necessary or desirable for dose reconstruction include data about routine and accidental releases from the MIA to the environment (routine and accidental airborne releases, releases of liquid radioactive wastes into the Techa River, and the release from the storage-tank explosion); all environmental monitoring data; all diet-monitoring data; all results of measurements of radionuclide content in the body of the inhabitants of a region under investigation; all bioassay data; all previous estimates of releases and doses; models; methods of measurement; characteristics of measurement devices; etc. The sources of this information must be located and entered into a database that would include authors and title of documents, date of publication, site of original and/or copy, abstract of the contents of the document, availability of information on the measurement methods and devices, availability of primary data, key words, etc.

The structure of the ARCHIVE database and the hardware and software necessary for its support were discussed and agreed upon by the Russian-American participants of the working group on Project 1.1 during the visit of Russian scientists to the U.S. in September 1995. During the creation of such a bibliographic system its structure concerning abstracted contents of the documents will be improved in order to maintain rapidity of information search.

One of the main requirements for a bibliographic database is unity of structure of the ARCHIVE databases for Projects 1.1 and 1.2. We plan to use the RDB database editor for input of information into the ARCHIVE database. RDB is being used in the URCRM for organization of databases MAN and ENVIRONMENT.

Archive URCRM

There are more than 400 documents that were officially registered (classified) prior to 1990, and which are concerned with researches on radioactive contamination of the environment and on health of the population in the region of influence of the MIA. The larger part (about 370 sources) consists of independent documents: Technical reports, theses, books and others that contain results of environmental contamination researches (~240; ~60% declassified) and clinical researches (~120; >80% declassified). The minor part of the archive consists of documents on techniques(methods), and half of these documents are stamped "classified." Almost all documents originated by scientists of the URCRM and which are interesting for dose reconstruction are declassified. Other documents transferred to the URCRM, but originated by other organizations (MIA, Institute of Biophysics, etc.), remain classified.

A significant part of the primary information is contained in notebooks containing sample logs and the results of measurements. These documents are presently located in the Environmental Department of the URCRM; included in this collection are working notebooks that had been declassified and returned to the researchers and other documents that did not have an independent registration number. The latter have been filed by date and include reports of expeditions, correspondence with local and MIA authorities, recommendations, etc. Special value is also in working maps that contain unique results of environmental contamination researches and which are not duplicated elsewhere. The reports originated by URCRM scientists on environmental monitoring data in the period from 1991 through 1995 are unclassified and are available in the Environmental Department of the URCRM.

Archives of other organizations

Up to the present time we have identified the complete name and the essential elements of approximately 60 reports of interest that are contained in the archives of the MIA. About 40 reports contain information concerning the releases of radioactive liquids into the Techa River and environmental monitoring of activities in the River during 1951–1959. More than 20 documents are concerned with the 1957 tank explosion and the results of environmental monitoring during the 1957–1958 period. Information includes the characteristics of the releases from the explosion and the results of measurements in the EURT.

There are at least ten technical reports of the Institute of Biophysics that cover the 1953–1959 period and which contain the results of investigation of territorial contamination and the health of the population of rivershore villages on Techa River. These documents are now in the archives of the Federal Agency of the Ministry of Health of Russia.

Preliminary analyses of the primary documents originated by the URCRM, the MIA and the Institute of Biophysics has shown that the documents of interest for dose reconstruction (particularly technical reports from the early period) do not contain enough information for complete entry into the structure of the ARCHIVE database; this is due to the absence of abstracts, key words and lists of references. An important fraction of the primary documents contains the stamp "classified," which pertains not only to the contents of the document but to the title of the document as well. Implementation of a complete dose-reconstruction study must involve the experts of the listed organizations to search for all pertinent documents, to update and expand the organized bibliographic database, and to declassify those documents (or partial documents) of interest for the dose-reconstruction study.

PROGRESS REPORT FOR MILESTONE 1.1.2 "BEGIN CALIBRATION OF THE URCRM WHOLE BODY COUNTER. CONSTRUCT A PHANTOM, BEGIN CALIBRATION OF THE COUNTER WITH THE PHANTOM, AND PREPARE A PROGRESS REPORT"

The URCRM whole-body counter (WBC), which is identified as SICH-9.1, has been used since 1974 to measure ^{90}Sr and other radionuclides in people exposed to the effluents released to

the Techa River. The detectors and electronics are obsolete and there are plans to replace them with modern equipment. For the original calibration of the WBC two surrogate-human structures were made by different laboratories. Both phantoms were made of natural human skeletons, paraffin imitations of soft tissues, and dry paper imitations of lung. Different methods of introducing ^{90}Sr into the bones of the phantoms were used. In one of the phantoms the nuclide was introduced by being dripped into uniformly distributed holes drilled into the bones. The bones of the other phantoms were impregnated with a ^{90}Sr solution in a vacuum chamber. Each laboratory performed independent experiments aimed at determining bremsstrahlung-yield relations and the influence of human soft tissues and the phantom paraffin on the absorption of bremsstrahlung. Independent activity measurements were carried out on each phantom. After scanning the phantoms and making the appropriate corrections the difference in calibration coefficients was determined to be 6%. This value represents the estimate of the systematic error in ^{90}Sr counting by means of the spectrometer. Water-filled phantoms made of plastic tanks laid out in such a way as to imitate a human body were used for calibration of ^{137}Cs and ^{40}K . The length of the phantom could be changed by removing one or two tanks. Such calibration was done in 1974 and has not been confirmed during the twenty-year period of the operation of the WBC.

More than 28,000 measurements were carried out during this period among more than 14,000 people. This data base of measurements is critical to the success of efforts to provide individual doses. There are plans to update this whole body counter with modern detectors and electronics. However, it is highly desirable to ensure that the old measurement system is once again calibrated in depth on the basis of measurements of a special anthropomorphic phantom. Also, the measurements of the special phantom with the new system will ensure the comparability of the results with the old and the new systems.

The data of concern are of major interest to the reconstruction of dose to the active bone marrow of the members of the Techa River cohort and to the completion of the major study of Sr metabolism that is being undertaken at the URCRM. The whole body counter will be used in the future for continuing measurements for these purposes, and it is important to note also that the whole body counter is now an integral part of the public-outreach program for the local residents.

Phantoms of two types, namely physical and mathematical, are required for the selection of optimum measurement geometry as well as detector type and for the calibration of the whole-body bremsstrahlung counter. A physical phantom is an anthropomorphic model of the body of an adult with an uniform distribution of ^{90}Sr in the skeleton. The error in the muscle-tissue equivalent, lung-tissue equivalent and bone equivalent of the materials used will be within 5% for the 0.015 to 0.060 MeV range of gamma energy. The activity error will be less than 5%.

A mathematical phantom is a computer model designed to simulate the spectral and angular distribution of the photon radiation, including bremsstrahlung, at the surface of the phantom resulting from the radioactive decay of incorporated radionuclides. Such a phantom is "constructed" with the use the Monte-Carlo method to simulate interactions of radiations with matter, and includes four units:

- the source term,
- the physical constants and probabilities of interaction for radiation transport,
- the geometrical description unit, and
- the result interpreter.

The limitations of the computer model stem from the complexity of the body structures. The mathematical phantom will be used primarily to study the effects of non-uniform distribution of ^{90}Sr in the different bones and structures of the skeleton, and to study the effects of variations in individual-body geometry.

Work on the development of an anthropomorphic physical phantom for calibration of whole-body counter SICH-9.1 was started in January 1995 in the Institute of Marine Transport Hygiene, St. Petersburg, under contract with the Federal Agency of Medical and Extreme Problems. The title of this contract is "Development and Manufacturing a Standard Phantom of the Human Body with Incorporated Strontium-90, FST-06T." The timeframe of this contract is from January 1995 through June 1996. Two stages of work were planned. The first one (January 1995–December 1995) is "the design of the phantom," which includes the exact determination of the requirements for the phantom, a study to determine the best composition of materials for the phantom (tissue-equivalent properties of different mixtures of plastics), the manufacture of a sculptural model of the phantom, and preparation of documents for a patent application. The second stage (January 1996–June 1996) is for "the manufacturing of the phantom," which includes: proper manufacture, testing and certification of the phantom. The first stage (1995) has been completed. Three milestones were accomplished:

1. The exact requirements for composition and construction of the phantom were determined. The more important of these are the following: The phantom should consist of three main tissue substitutes to simulate bone, lung and soft tissues (mass densities of these must be equal to 1.3; 0.26 and 1.04 g cm⁻³, respectively). The materials must be cold-cured products. The phantom must imitate adult man with height of 170 cm and body weight of 70 kg. The phantom must be flexible in order to imitate different positions (standing, sitting, and lying). Also, the range of permissible variations in phantom parameters and the technique of phantom testing were determined.
2. The compositions of tissue substitutes were found after testing different compounds based on epoxy resin, acrylics and polyurethane. The most suitable properties were found for epoxy resin compounds. For example, the composition of the plastics developed to imitate bone and soft tissues (BIP and STIP, respectively) is presented in Table 3. Physicochemical properties of BIP and STIP samples are presented in Table 4.
3. Sculptural model of the phantom was manufactured on the basis of exact copy of man skeleton developed in the firm "Meduchposobie", St. Petersburg (Fig. 11). The models of different parts of whole body were made according to Human Anatomic Atlas by R.D. Sinelnikov, Moscow Publisher "Maditsina" 1978. Phantom model consisting of 11 main parts is presented in Fig. 12.

Table 3. The composition of bone and soft tissue imitators.

Component	Percentage	
	BIP	STIP
Epoxy Resin EP-20	21.5	26.7
Hardener PO-300	12.9	16.0
Plasticizer DBF	4.3	5.3
Ionite KU-2-8	5.0	5.0
Apatite	24.7	3.8
Alveolar component	1.5	3.2
Starch	30.0	40.0

Table 4. Physicochemical properties of BIP and STIP samples.

Measured value	BIP	STIP
Linear coefficient of attenuation, cm^{-1} ($E = 31.6 \text{ keV}$, $p = 0.95$, $n = 4$)	0.93 ± 0.02	0.35 ± 0.02
Density, g cm^3 * ($p = 0.95$, $n = 10$)	1.31 ± 0.01	1.04 ± 0.01
Bulk activity, Bq g^{-1} * ($P=0.95$, $n=6$)	14.0 ± 0.06	

*These results were obtained for samples with volume of 10 cm^3 .

According to the above contract the manufacturing is scheduled to start in January 1996. Calibration of the physical phantom is scheduled to be completed in July 1996. Calibration of the whole-body counter is expected to be finished by October 1996. Work on development of mathematical phantoms was not started during the feasibility study as a result of limited financial support. The participants of the project agreed that it would be very useful to arrange a meeting for Dr. Alexander Kovtun (who is the supervisor of the work on creation of the physical phantom and calibration of the WBC) with Dr. David Hickman from LLNL, who is an expert on mathematical phantoms. The U.S. and Russian Principal Investigatorss will arrange such a meeting, as soon as the second half of money for the feasibility study is received.

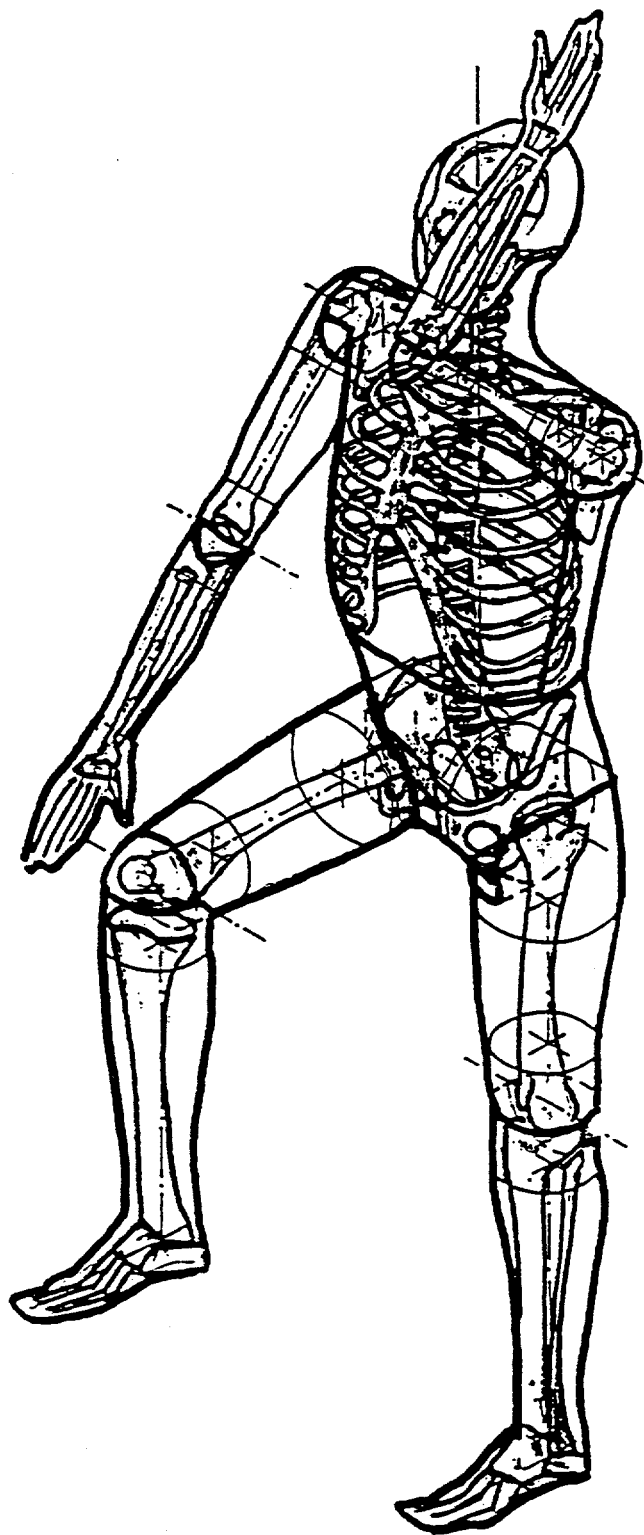


Fig. 11. Sculptural model of phantom skeleton.

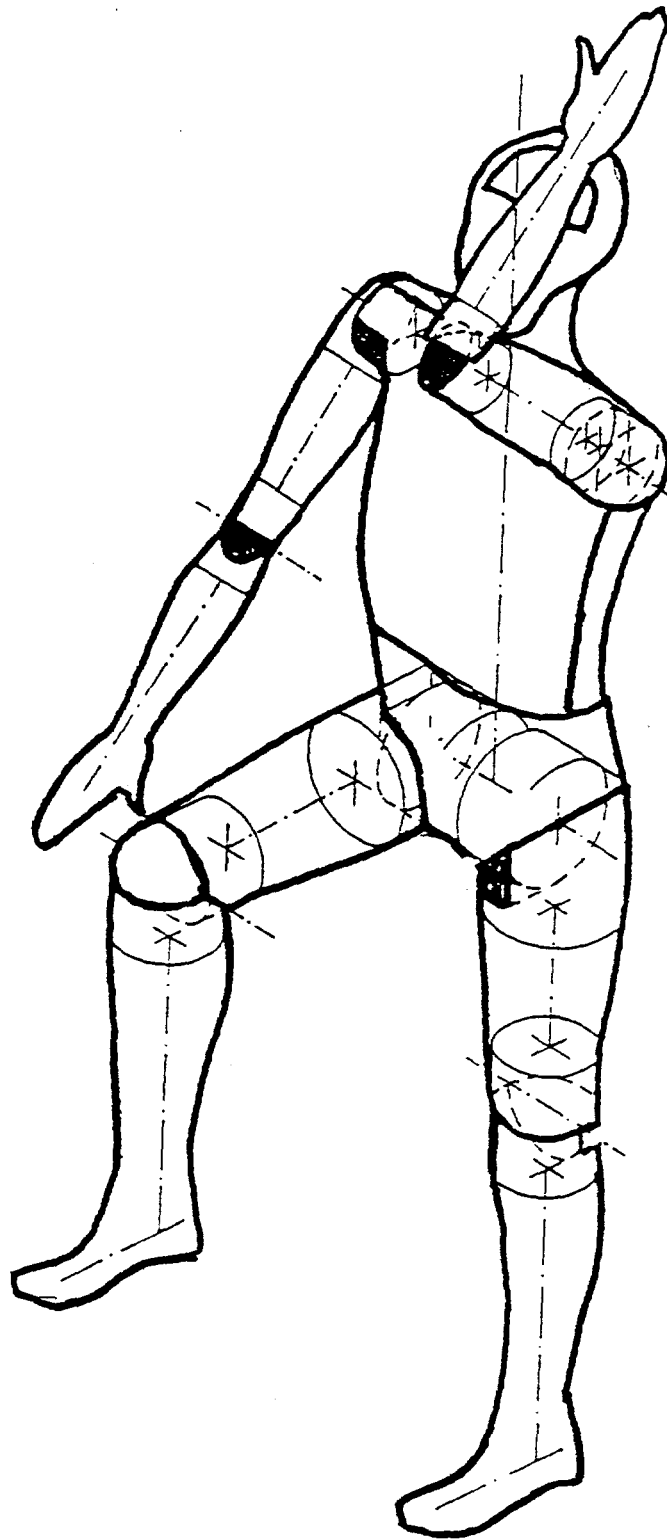


Fig. 12. Sculptural model of phantom body.

FINAL REPORT FOR MILESTONE 1.1.4 "ESTABLISH CONCEPTUAL AND MATHEMATICAL MODELS FOR SOURCES AND PATHWAYS OF EXPOSURE FOR THE MAYAK REGION POPULATION AT THE ST. PETERSBURG WORKSHOP"

This report describes the results of activities to establish a set of conceptual models that define the relationships, pathways, and parameters that will form the basis of the dose-reconstruction efforts. These conceptual models must be determined before any computational scheme can be developed. These models were developed and agreed upon by the contributing scientific organizations at a meeting in July 1995 in St. Petersburg, Russia.

Primary Sources and Pathways of Exposure

The reconstruction of radiation exposures to people living in the vicinity of the Mayak facility is potentially very complex. A graphical depiction of the primary sources of release, and the resulting primary ways the public was exposed from these releases, is shown in Fig. 13.

During the first decade of operation of the Mayak facility, gaseous and particulate radionuclides were released to the atmosphere in large quantities. Of potential public concern is the release of ^{239}Pu . Elevated levels of plutonium have been measured in the people living around the Mayak facility to distances of up to 100 km (Suslova et al. 1995). This plutonium would have been released through routine ventilation of the processing facility. The main pathway of exposure to plutonium is inhalation, both during passage of the released plumes and afterwards as a result of resuspension.

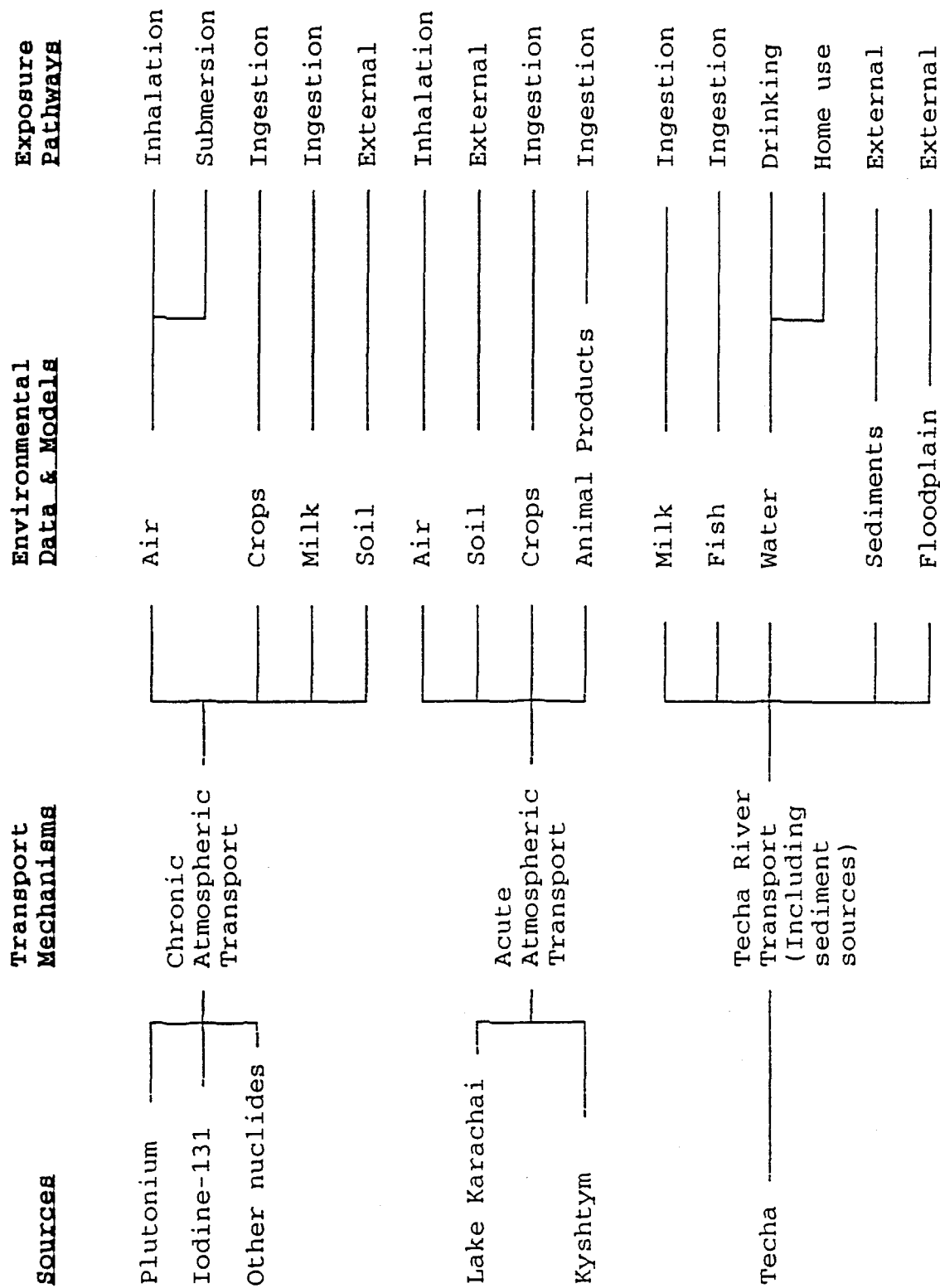
In a manner analogous to that at the Hanford Site in the United States (TSP 1994), ^{131}I was released to the atmosphere from routine processing operations (Khokhryakov et al. 1995). Iodine-131 is a reactive gas that deposits readily on vegetation and can be taken in by grazing cattle and transferred to milk. Production records and meteorological data are available for estimating the releases of ^{131}I and ^{239}Pu and their subsequent environmental distribution.

Other radionuclides were also emitted into the air during facility operations. Screening studies indicate that the doses resulting from these releases is relatively small. Documentation of the magnitudes of these releases will be prepared. It is likely that the primary exposure route for these other radionuclides will be external exposure.

Non-routine releases of radionuclides to the atmosphere also occurred. A small pond, Lake Karachai, that was used to receive contaminated liquids dried around the banks and provided a source for windblown resuspension during brief periods when the wind was high. About 600 Ci of longer-lived fission products were released to the air in this manner (Romanov 1995). The main exposure pathway is external exposure from materials deposited on the ground.

A chemical explosion in a high-level waste tank (the so-called Kyshtym Accident) resulted in the release of about 2×10^6 Ci to the atmosphere, primarily ^{90}Sr and ^{137}Cs , deposited in a footprint (the EURT) covering several thousand square kilometers. This area was extensively monitored during recovery efforts. Following the immediate deposition, the long-term pathways

Figure 13. Conceptual Model for JCCRRER Dose Reconstruction



leading to the greatest exposure have been external irradiation and ingestion of ^{90}Sr (Romanov 1995).

Between 1949 and 1956, liquid releases from the radiochemical plant and unmonitored overflow from cooling of the waste tanks resulted in release of about 3×10^6 Ci of mixed fission products to the Techa River, which traverses the Mayak site. Eventually, this resulted in external and ingestion exposures of 30,000 people living downstream along the river. Because of the long-term nature of the exposures, the primary radionuclide of concern from ingestion is ^{90}Sr . Other shorter-lived fission products contributed to the external and internal dose.

Major Pathways of Exposure

Certain groups were exposed to external irradiation from radionuclides in the Techa River and surrounding soils and sediments, as well as to internal doses from drinking the river water and milk and eating fish from the river. Some members of this group were subsequently evacuated to villages that were later contaminated by deposition from the 1957 Kyshtym explosion, resulting in additional external, inhalation, and food-crop-ingestion doses. Throughout this period, releases of gaseous and particulate effluents to the atmosphere from Mayak operations contributed yet another source of exposure. Each of these releases has associated with it different radionuclides and different pathways of exposure requiring evaluation of different sets of parameters to determine the exposure of individuals.

Because not all sources contributed significant doses to various groups through all pathways, it is most efficient to expend the most efforts on individual exposures leading to the higher doses, and to expend proportionately less on the pathways leading to smaller exposures. For the purposes of the dose reconstruction, a *major pathway* is defined as one resulting in a dose of greater than 10 rad to any organ in any exposed individual.

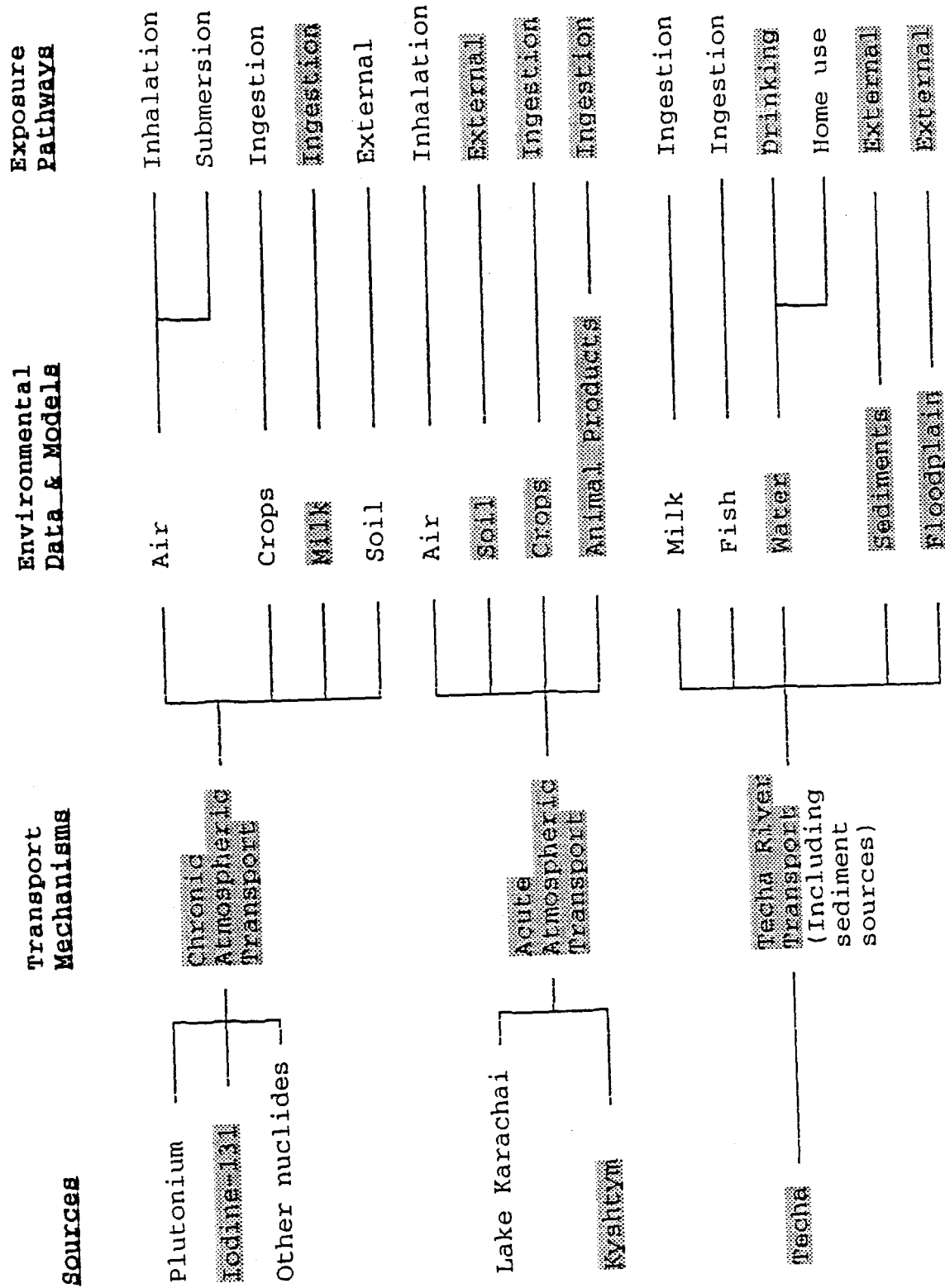
This definition has influence on the environmental data that must be reconstructed and ultimately on the sources that must be considered in detail. The major pathways are illustrated in Fig. 14.

Continuing releases of ^{131}I resulted in environmentally large concentrations in milk. This resulted in thyroid doses from ingestion of the milk in populations surrounding the Mayak site (Khokhryakov et al. 1995).

The Kyshtym explosion, which created the EURT, resulted in cumulative external doses to unevacuated populations reaching 4 to 50 rad (Romanov 1995).

The large releases to the Techa River created a number of significant exposure pathways. Radionuclide concentrations exceeded $100 \mu\text{Ci L}^{-1}$ in the early 1950s, with consequent concentrations in sediments as high as 10 mCi kg^{-1} and concentrations in garden soils also very high (Goloshchapov et al. 1995). The external dose rates were quite high (Burmistrov et al. 1995); cumulative doses as measured using environmental thermoluminescent dosimeters exceed 100 rad (Bougrov et al. 1995). The people living in villages downstream frequently had no other sources of drinking or sanitary water. Direct ingestion of drinking water is a straightforward

Figure 14. Major Pathways



Major pathways are those that result in doses of greater than about 10 rad to any organ

pathway. Consumption of milk from cows feeding the region lead to lower doses. Anecdotal evidence also indicates that fish from the river were frequently consumed.

It is apparent that there are several sources that should be followed, and that the timing, pathways, and magnitude depend on both the source and individual habits.

Minor Pathways of Exposure

Those pathways deemed minor are listed in Fig. 15. Initial calculations indicate that the routine releases of plutonium did not result in lung or bone doses to members of the public in excess of 10 rad. Similarly, the total release by resuspension from Lake Karachai beyond the boundaries of the Mayak facility were not sufficient to result in large depositions. (However, there is still some question about the inhalation doses resulting from this release.) Although numerous pathways can be postulated for use of Techa River water in the homes of local residents (e.g., washing clothes, washing floors), most will result in doses less than those from ingestion and direct external exposure. While scoping studies to refine the dose estimates for these various pathways should be performed, resources should be conserved to deal with the major pathways.

Bioassay Data Supporting Dose Reconstruction

The majority of the environmental exposures to short-lived radionuclides have not left currently-detectable signals in the exposed populations. However, some of the longer-lived radionuclides, with long biological residence times, still may be detected. Items for which data are available are shown in Fig. 16.

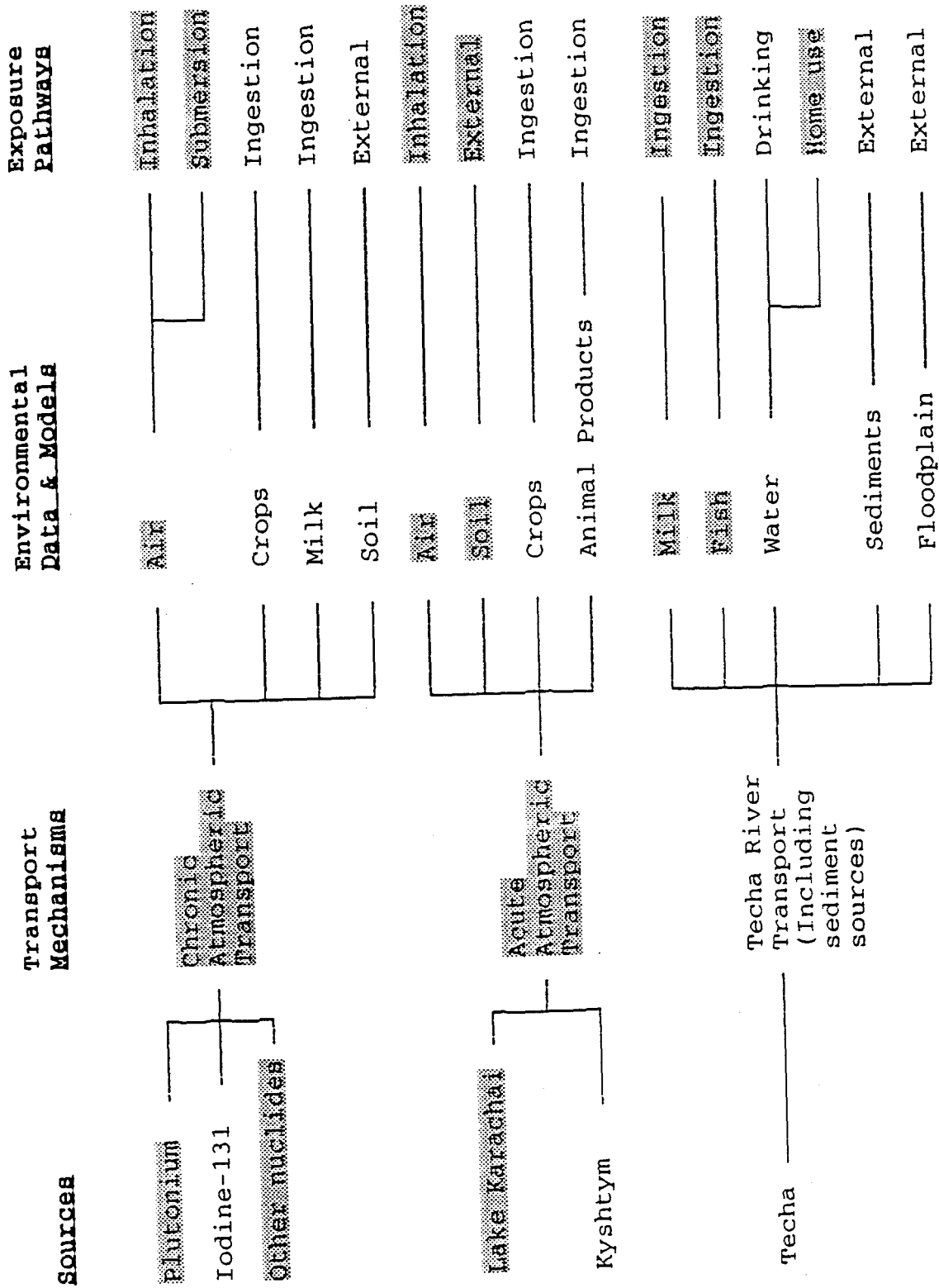
Human-body burdens of plutonium have been measured at levels above global background in the population out to distances of 100 km (Suslova et al. 1995).

A small amount of data is available for people (whole body counts) following the Kyshtym release. This is not a sufficient amount upon which to base dose estimates, but it may be used to validate release and uptake estimates.

Strontium-90 also has a long biological residence time in the body. The levels of environmental contamination are sufficient that $^{90}\text{Sr}/^{90}\text{Y}$ bremsstrahlung may be detected from outside the body. Measurements of individuals have been made for many years—over 15,000 people are enrolled in the registry with whole body measurements (Kozheurov 1995). Available instrumentation permits evaluation of minimum detectable activity in whole body in terms of ^{90}Sr at about 120–150 nCi. The ^{90}Sr content of the skeleton for about 80% of the living Techa River residents is presently less than 200 nCi. In order to continue the radiometric screening of the population, it is necessary to upgrade the whole body counter. A realistic goal of a minimum detectable activity of ^{90}Sr is 20 nCi, with an accuracy of about 10% above 200 nCi. Physical and mathematical phantoms are needed to calibrate the ^{90}Sr whole body counter.

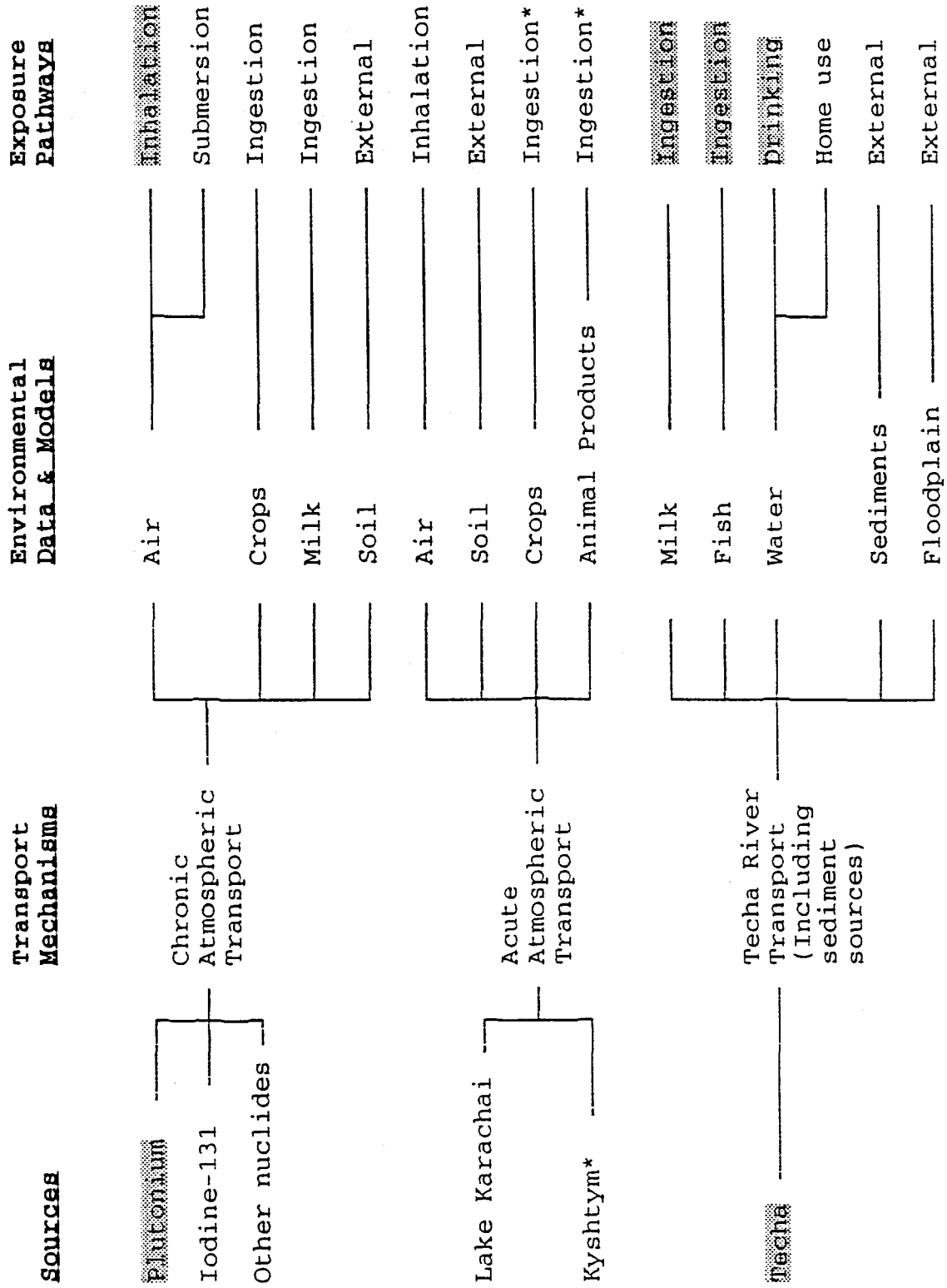
A very limited set of data has also been generated indicating that electron paramagnetic resonance (EPR) measurements of teeth samples can be used to estimate dose (Romanyukha et al.

Figure 15. Minor Pathways



Minor pathways are those that result in doses of less than about 10 rad to any organ

Figure 16. Bioassay Data Supporting Dose Reconstruction



Includes Sr-90 and Cs-137 whole body/bone/tooth counts, Pu-239 bioassay, and ESR

1995). This appears to be a promising technique. However, insufficient numbers of samples have been analyzed to date to provide a strong basis for dose reconstruction.

Additional techniques, such as the analysis of stable translocations in chromosomes by the fluorescent in-situ hybridization (FISH) assay, have been proposed. These techniques may be useful for research or validation of other dose estimates, but are not now sufficient for individual-dose reconstruction.

Environmental Data Supporting Dose Reconstruction

The bulk of the early atmospheric releases have decayed to undetectable levels (e.g., ^{131}I , ^{103}Ru , and ^{106}Ru). Those events and/or pathways for which some environmental data are available are shown in Fig. 17. Cesium-137 is readily detectable in soils from both the Kyshtym and Techa releases. This signal overwhelms the Lake Karachai ^{137}Cs trace in most locations. Strontium-90 is also readily detectable in soils and sediments near the Techa River, as well as in food crops and animal products in the EURT.

A small amount of information concerning ^{131}I in milk around the Mayak facility is available for a brief period in the 1960s. Detailed information on the environmental behavior of iodine was collected in the 1980s, using ^{129}I . A large amount of information is available from routine monitoring in Ozersk (Chelyabinsk-65) in the 1950s; however, this consists largely of gross-beta measurements of air, snow, soil, and vegetation at a limited number of locations.

Thermoluminescent analysis of environmental dosimeters (TLDs), such as quartz crystals in bricks, has proved useful (Bougrov et al. 1995).

Generic Dose Reconstruction

Because the number of significant sources or pathways is relatively small, it is possible to acquire adequate information for health-estimation purposes by performing fairly simple analyses for a large number of the potential exposure pathways. This approach allows the use of limited resources on the more important pathways, while not totally ignoring the contribution of the lesser pathways. The dose estimate for any one individual then consists of a detailed calculation for the individual's specific pathways and the sum of the (presumably smaller) contributions from the generic pathways.

For generic calculations, any specific individual is assigned the group-average dose for that particular source and pathway. Consideration is given to spatial variability based on the individual's residence location at the time of the event. Generic calculations have associated with them a relatively large uncertainty band, but this should contribute only a relatively small amount to the overall uncertainty to that associated with the doses from the specific pathways.

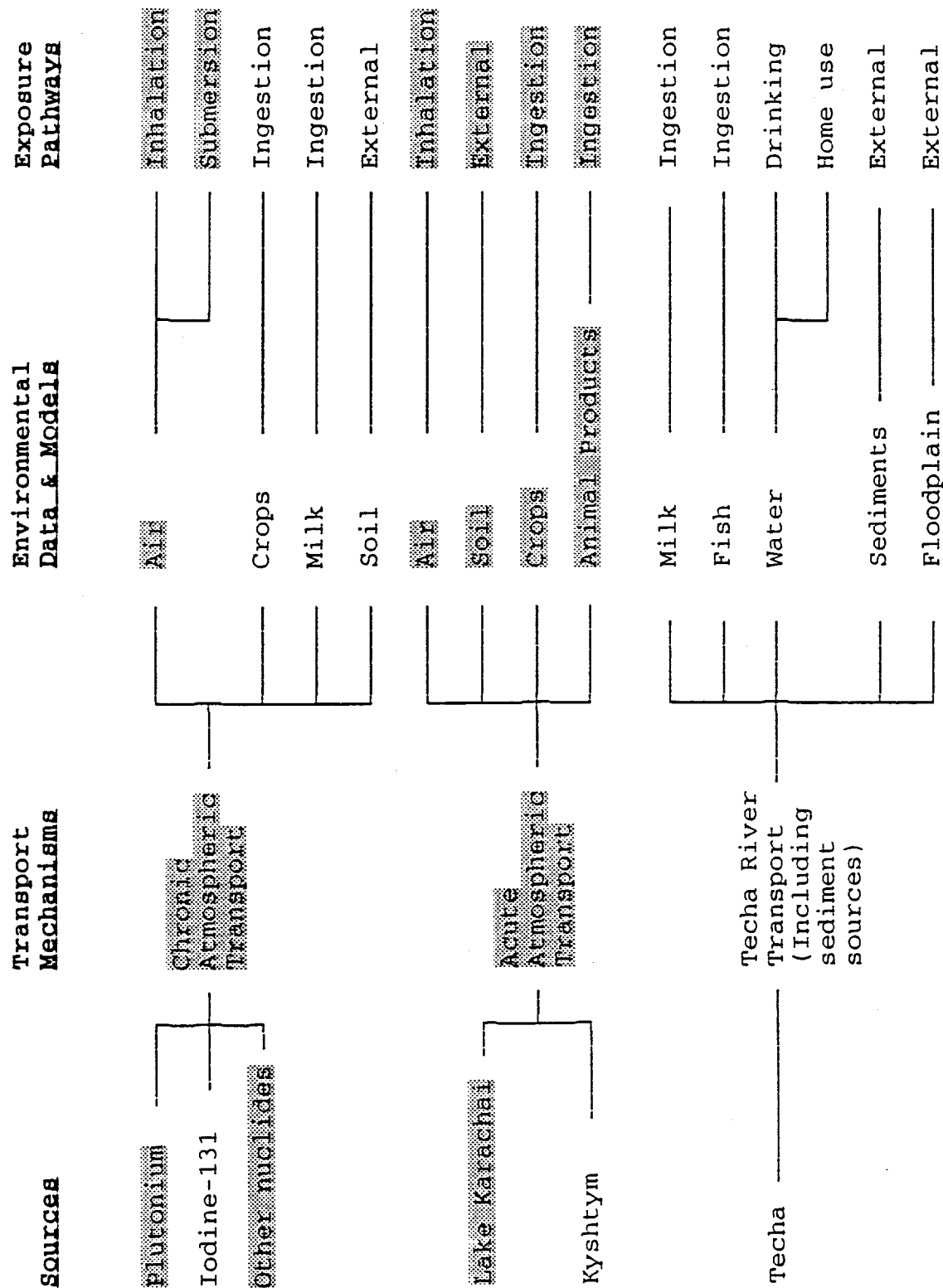
The sources and pathways for which generic calculations are appropriate are illustrated in Fig. 18.

Figure 17. Environmental Dose Rate Information Available for Dose Reconstruction

Sources	Transport Mechanisms	Environmental Data & Models	Exposure Pathways
Plutonium	Chronic Atmospheric Transport	Air	Inhalation
Iodine-131			Submersion
Other nuclides			Ingestion
		Crops	Ingestion*
		Milk	External
		Soil	Inhalation
Lake Karachai	Acute Atmospheric Transport	Air	External
			Ingestion
			Ingestion
Kyshtym		Crops	Ingestion
		Animal Products	Ingestion
		Milk	Ingestion
		Fish	Ingestion
		Water	Drinking
		Home use	Home use
		Sediments	External
		Floodplain	External

* Limited information available for the 1960s; additional information on I-129 behavior

Figure 18. Pathways Recommended for "Generic" Dose Reconstruction



"Generic" dose reconstruction is based on group average exposure, but includes spatial variability based on location at time of event. Models incorporate broad uncertainty.

Individual Specific Dose Reconstruction

Just as certain sources and pathways are adequately dealt with in generic terms, certain doses must be reconstructed specifically for the individual. This is because the doses are sufficiently large to be important, and because individual habits are sufficiently variable that a generic answer will not provide adequately detailed doses to support epidemiological studies.

The sources and pathways requiring individual specific dose reconstruction are illustrated in Fig. 19. These calculations require detailed histories of residence, food consumption, and personal lifestyles.

Dose reconstruction requires calculations based on models. However, in-vivo measurements and/or EPR and FISH techniques can provide powerful support and validation for the calculations.

Evaluation of the Feasibility of Dose Reconstruction

A large database of environmental measurements of radionuclide concentrations in soil and other media exists. This database is sufficient to provide the bulk of the required inputs for individual specific dose reconstruction for the pathways illustrated in Fig. 19.

Additional efforts are required to provide detailed time histories of the atmospheric releases of the dominant and subordinate radionuclides from Mayak stacks. Additional documentation of the releases from Lake Karachai is also needed. The generic dose calculations will remain incomplete without this supporting information.

It would be best if records from the production facility were available to support these activities. Such records would provide the best documentation and also provide the greatest public acceptability of the results.

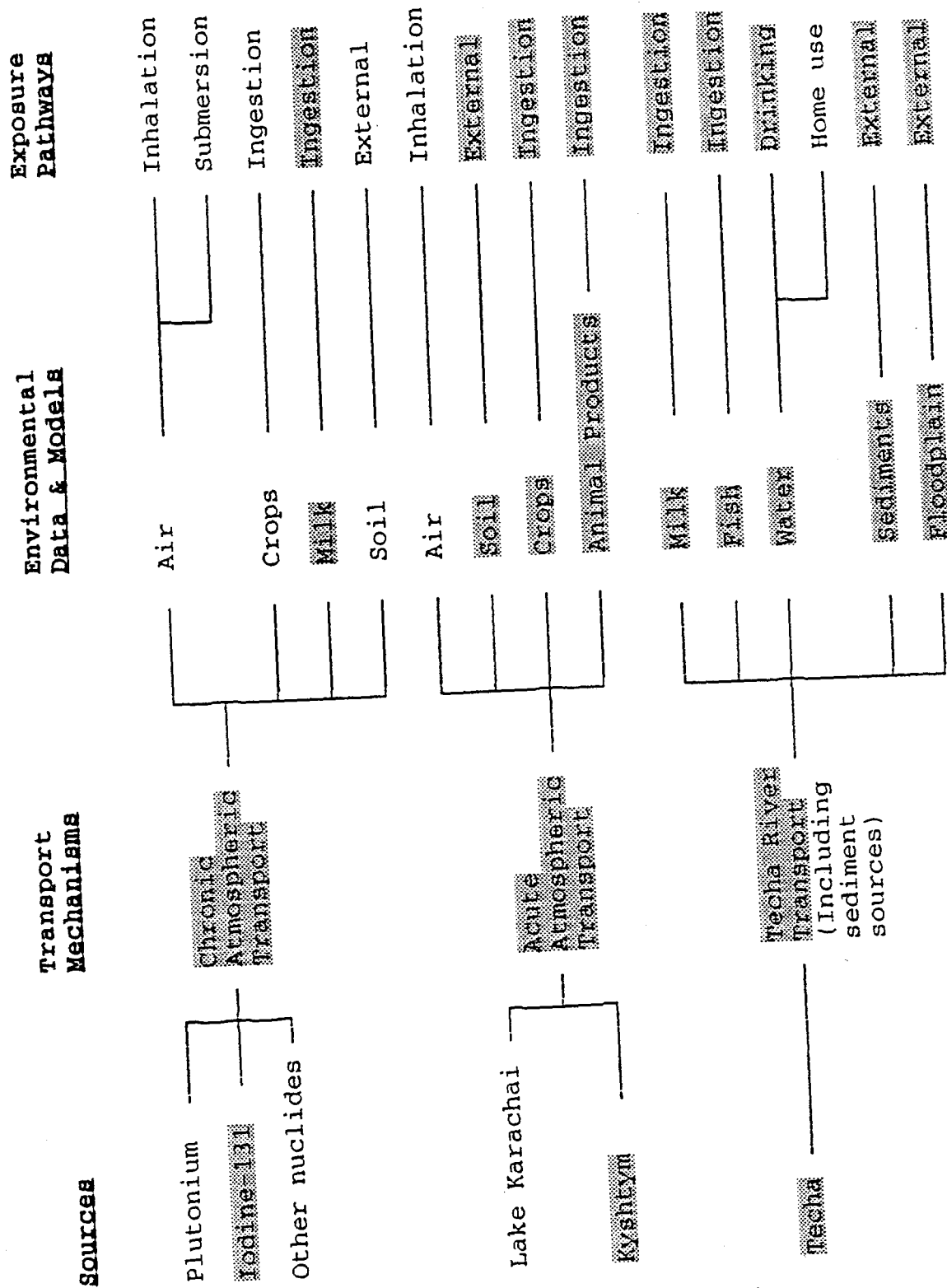
FINAL REPORT FOR MILESTONE 1.1.3 "PREPARE A REPORT THAT WILL INCLUDE THE METHODOLOGY FOR AND AN ASSESSMENT OF THE FEASIBILITY OF RECONSTRUCTING THE DOSES FOR PERSONS IN THE COHORT CONSIDERED IN PROJECT 1.2"

1. Introduction

The reconstruction of radiation exposures to people living in the vicinity of the Mayak facility is potentially very complex. A graphical depiction of the primary sources of release and the resulting primary ways in which the public was exposed from these releases is shown in Fig. 13.

During the first decade of operation of the Mayak facility, gaseous and particulate radionuclides were released to the atmosphere in large quantities. Of potential public concern is the release of ^{239}Pu . Elevated levels of plutonium have been measured in the people living

Figure 19. Pathways Recommended for "Individual Specific" Dose Reconstruction



Individual Specific calculations are based on detailed histories of residence, food consumption, and personal habits. In-vivo measurements provide support and validation.

around the Mayak facility to distances of up to 100 km (Suslova et al. 1995). This plutonium would have been released through routine ventilation of the processing facility. The main pathway of exposure to plutonium is inhalation, both during passage of the released plumes and afterwards as a result of resuspension.

In a manner analogous to that at the Hanford Site in the United States (TSP 1994), ^{131}I was also released to the atmosphere from routine processing operations (Khokhryakov et al. 1995). Iodine-131 is a reactive gas that deposits readily on vegetation and can be ingested by grazing cattle and transferred to milk. Production records and meteorological data are available for estimating the releases of ^{131}I and plutonium and their subsequent environmental distribution.

Other radionuclides were also emitted into the air during facility operations. Screening studies indicate that the doses resulting from these releases are relatively small. Documentation of the magnitudes of these releases will be prepared. It is likely that the primary exposure route for these other radionuclides will be external exposure.

Non-routine releases of radionuclides to the atmosphere also occurred. A small pond used to receive contaminated liquids, Lake Karachai, dried around the banks and provided a source for windblown resuspension during brief periods when the wind was high. About 600 Ci of longer-lived fission products were released to the air in this manner (Romanov 1995). The main exposure pathway is external exposure from materials deposited on the ground.

In 1957, a chemical explosion in a high-level waste tank (the so-called Kyshtym Accident) resulted in the release of about 2 million curies to the atmosphere, primarily ^{144}Ce , ^{95}Zr , ^{95}Nb and ^{90}Sr , deposited in a footprint called the East Urals Radioactive Trace (EURT) covering several thousand square kilometers. This area was extensively monitored for recovery efforts. Following the immediate deposition, the long-term pathways leading to the greatest exposure have been external irradiation and ingestion of ^{90}Sr (Romanov 1995).

Between 1949 and 1956, liquid releases from the radiochemical plant and unmonitored overflow from cooling of the waste tanks resulted in release of about 3 million curies of mixed fission products to the Techa River, which traverses the Mayak site. Eventually, this resulted in external and ingestion exposures of 30,000 people living downstream along the river. Because of the long-term nature of the exposures, the primary radionuclide of concern from ingestion is ^{90}Sr . Other shorter-lived fission products contributed to the external and internal dose.

Joint collaborations with epidemiologists working in Project 1.2 have identified three cohorts of people to be studied. In order of priority, these are 1) the people living along the banks of the Techa River, primarily exposed to the liquid effluents (the Techa River cohort), 2) the people exposed to the deposition from the East Urals Radioactive Trace (the EURT cohort), and 3) the residents of the city of Ozersk (Chelyabinsk-65), primarily exposed to the atmospheric releases of iodine, plutonium, and noble gases from routine Mayak operations (the Ozersk cohort). An epidemiological study of the Ozersk cohort is not yet certain; a pilot study to determine the possible statistical power of an epidemiology study is first proposed.

2. Dose Reconstruction Process

Radiation dose reconstructions are generally structured on a paradigm of release-transport-deposition-uptake/exposure-dose. The initial components are actually the most technically difficult; the individual dose calculation requires individual-specific information that must be obtained from the individual involved. Radioactive materials released to the environment generally are transported, deposited, and taken up in plants and animals in ways that are independent of individual humans. Individuals are exposed to time-varying "fields" of radiation and radioactive materials. Therefore, it is possible to reconstruct the time histories of the radiation fields and radionuclide concentrations without considering the activities of specific individuals. Once the time histories of the radionuclide fields throughout an area are known, it is possible to "introduce" the people into them and estimate the human's uptakes and resultant doses.

For many of the most significant exposures considered for these cohorts, historical information on the processes and releases is limited. However, measurements of radionuclides in specific people (^{90}Sr in bones or teeth, etc.) are available and may be used to estimate individual doses and, by implication, the fields to which others were exposed. Therefore, the dose reconstruction process planned is based extensively on measurements of radionuclide burden or exposure in humans, and the traditional paradigm is only used as a backup when other approaches have been exhausted. The types of information available are summarized in Table 5. Uses of each type of information is discussed below. The following discussion is structured on the basis of the primary cohorts and exposure pathways.

2.1 Techa River Residents - Internal Dose

The internal dose reconstruction approach for Techa River residents is described in Section 2.1.1. The tasks that derive from this approach are summarized in Section 2.1.2.

2.1.1 Techa Cohort Internal Dose Reconstruction Hierarchy

The hierarchy of information required for calculating internal radiation doses to people who lived along the Techa River during and after the largest releases is shown in Fig. 20. Internal dose is related to the time integral of the body burden. Information related to time is readily accessible through birthdates and residence histories. As shown in Table 5, a large number of individuals have had at least one whole body count; many have had several. These individual records are the preferred primary data for individual dose reconstruction. A smaller number of individual autopsy data are available; these are also preferred starting points. The last resort for estimating body burden histories for individuals is via analogy to family members or residents of the same location - if individual measurements are not available, it is preferable to estimate them via individual intake and metabolic models.

A sufficient number of sequential whole body counts for single individuals have been assembled so that detailed models of radionuclide uptake and retention can be prepared. Default metabolic models from the ICRP may also be employed.

Table 5. The types of information available for individual dose reconstruction

Cohort	Group/Number	Dominant Pathways	Type of data	Available Data	Number Available	Comments
A. Techa River Residents	A1. 4,500 subjects who lived in upper reaches in 1949-1952 and were evacuated later	External	Environmental	Historically measured dose rates Quartz TLD	250 5 locations	1951 - 1956 In Melino village
			Individual	EPR	5	Requires spectrometer
		Internal (water, milk, fish)	Environmental	Historically measured food stuffs	~100	1951 - 1956. Non computerized
			Individual	Whole body counts Tooth counts Sr-90 autopsy data Excreta counts Source of drinking water (well or river)	1,500 2,000 60 Many 2,500	Sr-90 and Cs-137 since 1974 Sr-90 since 1960 1951 - 1972 Mainly gross beta, non computerized Non computerized, could be extended via family data
			Environmental	Historically measured media (water, sediments, soils) Residence history	3,500 4,500	1951-1956, mainly gross beta Including house location for some of subjects
		Both external and internal	Individual	Residence history	4,500	Including house location for some of subjects
			Environmental	Historically measured dose rates Quartz TLD	>120 4 locations	1951-1956; later: non computerized In Muslyunovo village
		External	Individual	EPR	22	Requires spectrometer
			Environmental	Historically measured food stuffs	~1000	Non computerized
		Internal (water, milk, fish)	Individual	Whole body counts Tooth counts Sr-90 autopsy data Excreta counts Source of drinking water (well/river)	7,000 8,500 100 Many 8,000	Sr-90 and Cs-137 since 1974 Sr-90 since 1960 1955 - 1972 Mainly gross beta, non computerized Non computerized, could be extended via family data
			Both external and internal	Environmental	Historically measured media (water, sediments, soils) Residence history	7,000 22,000
			A2. 22,000 subjects who lived in lower reaches in 1949-1952			

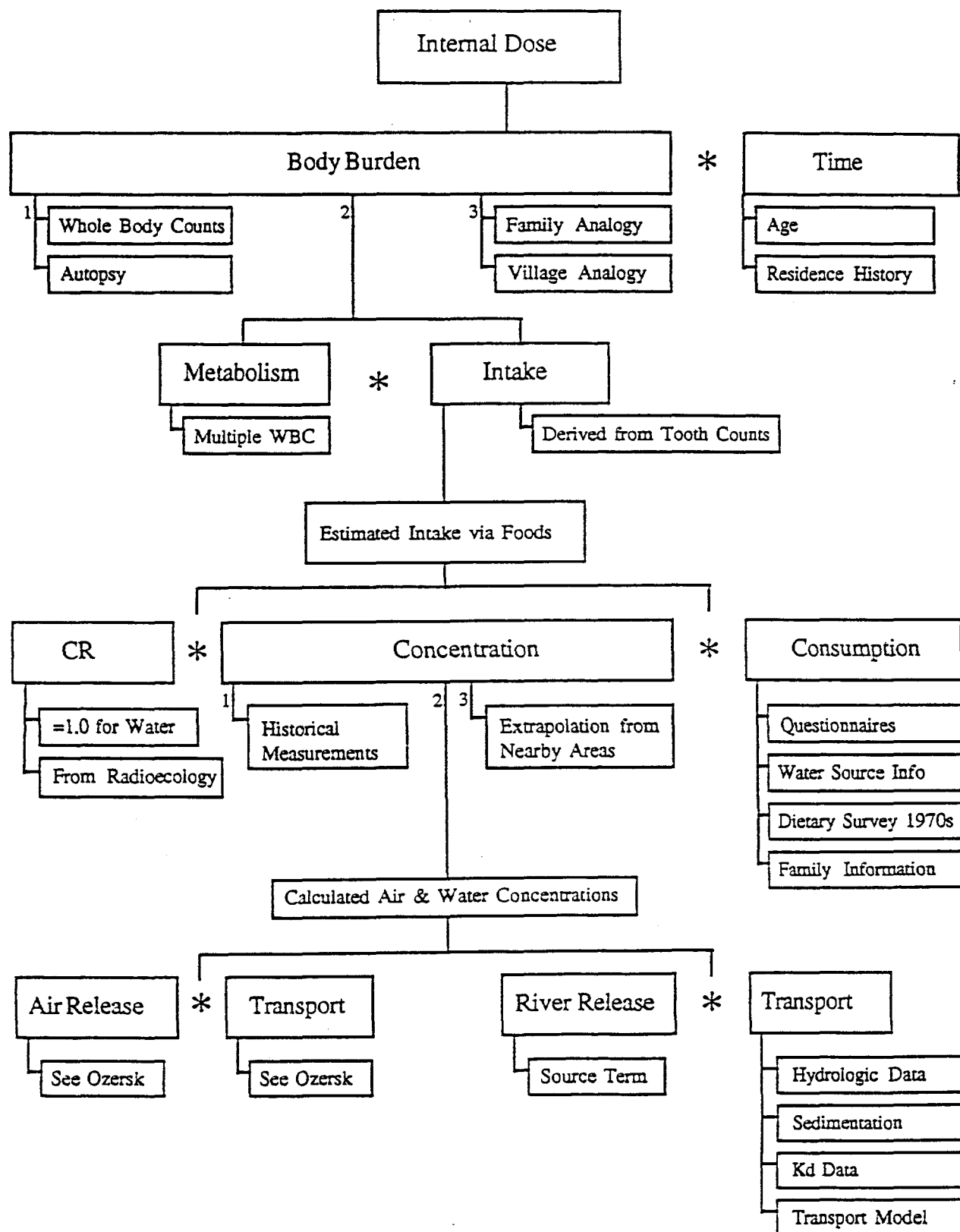
Table 5. (Continued)

Cohort	Group/Number	Dominant Pathways	Type of data	Available Data	Number Available	Comments
A. Techa River Residents	A3. 7,800 "late entrants" who moved in after 1952	External	Environmental	Historically measured dose rates Quartz TLD	120 4 locations	The same as for Cohort A2 but could be used since the date of entrance
		Internal (water, milk, fish)	Individual	EPR	7	Requires spectrometer
			Environmental	Historically measured food stuffs	~1000	Non computerized
			Individual	Whole body counts Tooth counts Sr-90 autopsy data Source of drinking water (well/river)	4,000 4,000 20 2,000	Sr-90 and Cs-137 since 1974 Sr-90 since 1960 1955 - 1972 Non computerized, could be extended via family data
B. EURT Residents	B1. 1,200 subjects evacuated early	Both external and internal	Environmental	Historically measured media (water, sediments, soils)	7,000	The same as for Cohort A2 but could be used since the date of entrance
			Individual	Residence history	7,800	Including house location for some of subjects
		External	Environmental	Historically measured dose rates	12	3 locations within 1 month after accident
			Individual	EPR	0	Requires spectrometer
		Internal (inhalation, bread, milk)	Environmental	Dietary investigations	7	Non computerized
			Individual	Whole body counts Tooth counts Sr-90 autopsy data	35 35 1	Sr-90 and Cs-137 Sr-90 1964
		Both external and internal	Environmental	Historically measured media	7	Non computerized
			Individual	Evacuation dates	1,200	Residence histories after evacuation non computerized
		External	Environmental	Historically measured dose rates	Many	Non computerized
			Individual	EPR	3	Requires spectrometer
		Internal (bread, milk)	Environmental	Dietary investigations	Many	Non computerized
			Individual	Whole body counts Tooth counts Excreta counts Sr-90 autopsy data	150 150 Many 45	Sr-90 and Cs-137 Sr-90 Gross beta, non computerized 1958 - 1972
		Both external and internal	Environmental	Historically measured media	Many	Non computerized
		Both external and internal	Individual	Residence history	14,000	Non computerized
			Individual	Residence history	14,000	Non computerized

Table 5. (Continued)

Cohort	Group/Number	Dominant Pathways	Type of data	Available Data	Number Available	Comments
C. Ozersk Residents	? (not established)	External	Environmental	Historically measured dose rates	?	Since 1964, non computerized
		Internal (milk, inhalation)	Individual	EPR	9	Requires spectrometer
			Environmental	Historically measured food stuffs	?	Sr-90 and Cs-137 since 1956, I-131 in milk in 1962-1964
				Radionuclide measurements in air	?	Beginning in 1960s
		Both external and internal	Individual	Cs-137 whole body counts	700	Since 1970, non computerized
				Sr-90 autopsy data	1000	Since 1963, non computerized
				Pu and Am autopsy data	450	Since 1975, non computerized
			Environmental	Approximate Source Term	?	Requires Mayak participation
		Climatological meteorology	?	Use of better information requires better source term		
		Individual	Residence history	?	Could be restored from Ozersk archives information	

Figure 20. Information Hierarchy for Estimating Internal Dose to Techa River Residents



There were a very large number of potential routes of ingestion of radionuclides. Drinking water, eating fish, and eating various contaminated garden crops and animal products could all lead to intake of radionuclides. A technique has been developed based on in-vivo measurements of ^{90}Sr in teeth that provides a reliable estimate of direct intake (Kozheurov and Degteva 1994). For individuals for whom examinations of radionuclide content in teeth have been made, this technique can be used to calculate ingestion rates of radionuclides. Also, as a backup for those individuals for whom tooth counts are not available, intake estimates for similar categories of people may be approximated using this technique. Alternatively, intakes may be approximated using food consumption rates and radionuclide concentrations in foods.

Consumption rates vary by age, sex, ethnicity, and perhaps by village. An extensive set of individual lifestyle and dietary questionnaires were administered to Techa River residents. A separate data set related to sources of drinking water (river or well) is also available in clinic outpatient records; this information is not yet available in digital form. In the 1970s, dietary surveys were made of people living in the EURT areas - this data could provide some default information if individual dietary preferences are not available. As a default, family or village food ingestion rates can be compiled.

Historically measured radionuclide concentrations in some selected environmental media (primarily river water and sediments) are available. However, it is likely that reconstruction of food contamination levels will be required. This can be done using extrapolation in a few instances, but generally concentrations must be calculated from common radioecological transfer factors and estimated river water concentrations. River water concentration must be estimated from released amounts and a river water transport model. The released amounts (source term) must be estimated from Mayak operating records and process descriptions.

Members of the Techa River cohort were primarily exposed to the effluents in the river, however, the atmospheric releases also affected this group - particularly those on the upper Techa near the Mayak facilities. The doses resulting from these atmospheric releases will be added to the doses calculated for this cohort according to the techniques described in Section 2.6 for the Ozersk cohort.

2.1.2 Techa River Cohort Internal Dose Activity Descriptions

The following activities are necessary to complete the full dose reconstruction illustrated in Fig. 20.

Evaluation of Bioassay Data This subtask will evaluate available whole body count data, excreta count data and autopsy data. This will provide body burden/intake estimates for individuals for whom measurements exist. This task will also assemble a database of whole body count derived body burdens for each family or village to be used as surrogates in case other approaches fail for unmeasured individuals.

Metabolic Models This subtask will use available sequential whole body count data to update radionuclide retention functions. This metabolic model would then be used to help evaluate all whole body counts to provide the integral exposures.

Tooth Count Analysis This subtask will extend the technique of Kozheurov and Degteva (1994) for dietary intake evaluation based on in vivo measurements of ^{90}Sr in teeth beyond the village of Muslymovo, where it was developed, to other sites along the Techa River.

Establish Food Consumption Rates This subtask will develop individual dietary intakes of various foods and water as functions of age, sex, ethnicity, and location. The efforts will use individual dietary information, results of local surveys, and information on the sources of drinking water.

Analysis of Historical and Current Monitoring Data This subtask will compile and evaluate available data on radionuclide concentrations in water, sediment, soil, and food. This information will serve as input to the radioecology and river transport subtasks.

Radioecology This subtask will review available data to determine the most appropriate transfer factors for radionuclides in fish, milk, and food crops. Sources of data may include site-specific measurements as well as generic sources such as the International Union of Radioecologists. This information will be used to develop estimates of radionuclide content in food crops.

Techa River Source Term Development This subtask will prepare estimates of the time history of radionuclide release to the Techa River. This will require review of historical Mayak documents regarding facility operating histories, technological processes involved, and any available measurements of releases. This task will develop estimated release fractions and prepare release estimates for use in transport modeling. This task may involve review of currently classified documents. Provisions will be made to declassify key documents supporting the release estimates. It is anticipated that staff from the Mayak Industrial Association will be key participants in this task.

Techa River Transport Modeling This subtask will accumulate data describing the historical Techa River hydrologic data, sediment loading, and dam construction history. This will be used as input to a numerical transport model to simulate the flow and contaminant loading of the Techa River from the Mayak facility to its confluence with the Iset River. The model will provide concentrations of radionuclides in water and sediment at specified locations along the river.

Techa River Cohort Internal Dose Estimation This task will provide management coordination and integration for the other subtasks involved with the Techa cohort. This task will assimilate the data and information prepared by the other tasks and make individual internal dose estimates based on the priority of the data hierarchy. This task will also collect a database of completed results to use as potential surrogates for use in estimating individual doses by analogy as a last resort. This task will also lead the evaluation of uncertainty in the individual dose estimates and use the collected information to attempt to validate the more numerically-intensive techniques against those with better measurements.

2.2 Techa River Residents - External Dose

The external dose reconstruction approach for Techa River residents is described in Section 2.2.1. The tasks that derive from this approach are summarized in Section 2.2.2.

2.2.1 Techa Cohort External Dose Reconstruction Hierarchy

The hierarchy of information required for calculating external radiation doses to people who lived along the Techa River during and after the largest releases is shown in Fig. 21. Measurements of tooth samples made with Electron Paramagnetic Resonance techniques have been shown to give very reliable and accurate indications of absorbed dose. This would be the highest priority technique for determining external exposure; however, from Table 5, it is apparent that very few individuals have been measured to date. A continuation of these studies is proposed. In addition, there is interest to evaluate whether biodosimetric techniques (e.g., fluorescent in-situ hybridization, T-Cell receptor, and others) can provide reliable estimates of external dose. Studies to date on these techniques have been inconclusive (Akleyev 1995), and pilot efforts to continue the research are proposed because the potential return on the investment is very high.

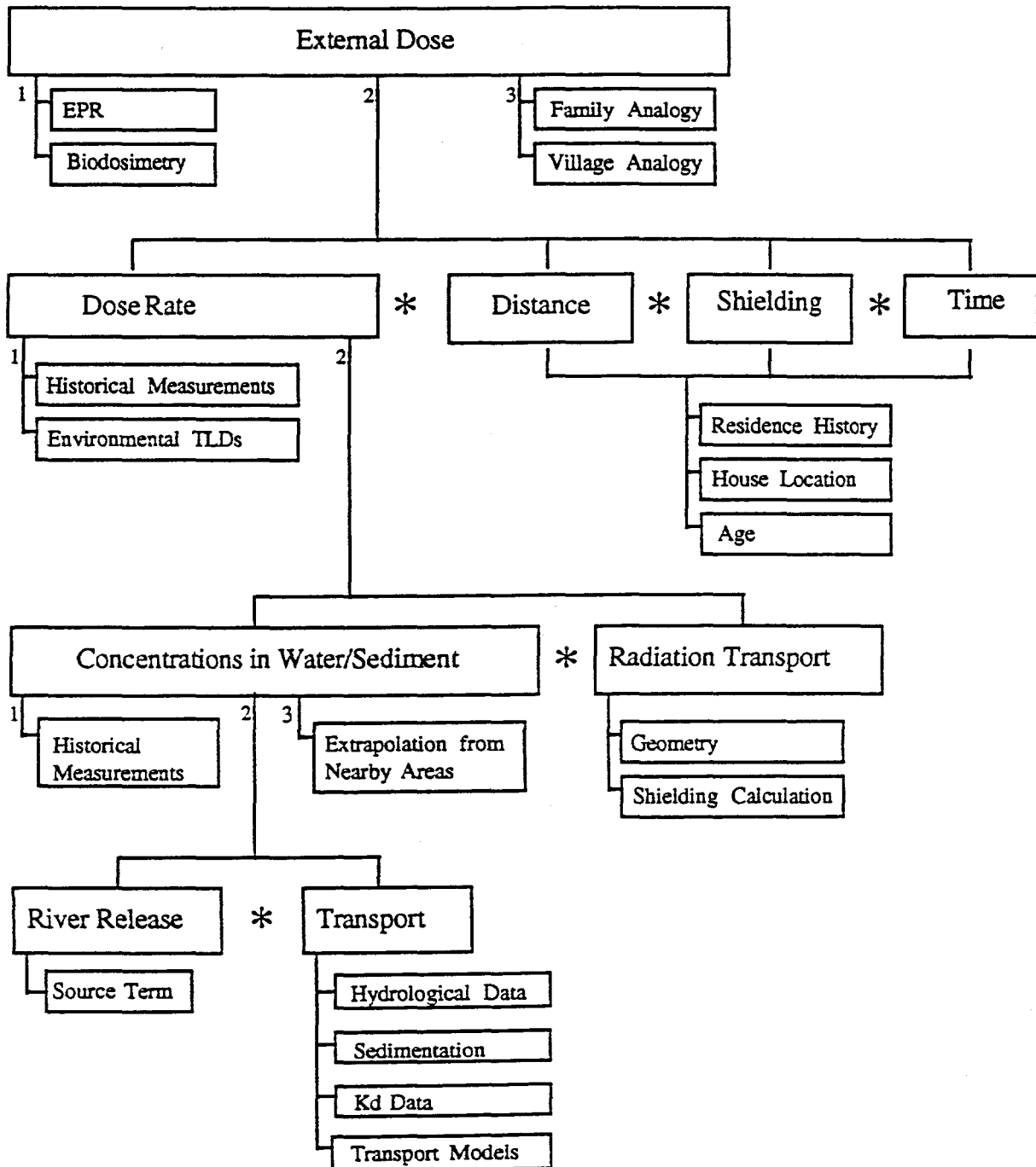
External dose is related to the time integral of the dose rate field to which individuals were exposed. Information related to time is readily accessible through birthdates and residence histories.

Some historical measurements of radiation dose rate were made in the vicinity of the Techa River. Most of these were made after the period of greatest release. Current environmental measurements can provide information about recent exposures; however, they lack any details of the contribution of short-lived radionuclides. A promising source of external dose rate data is the use of environmental thermoluminescent materials. This technique has been shown to be effective (Bougrov 1995), but as is indicated in Table 5, its use to date has been limited. Thus, it will be necessary to also approach the problem by investigating classical radiation shielding calculations.

Historically measured radionuclide concentrations in some selected environmental media (primarily river water and sediments) are available. However, it is likely that reconstruction of contamination levels will be required. This can be done using extrapolation in a few instances, but generally, concentrations must be calculated from released amounts and a river water transport model. The released amounts (source term) must be estimated from Mayak operating records and process descriptions.

Members of the Techa River cohort were primarily exposed to the effluents in the river, however, the atmospheric releases also effected this group - particularly those on the upper Techa near the Mayak facilities. The doses resulting from these atmospheric releases will be added to the doses calculated for this cohort according to the techniques described in Section 2.5 for the Ozersk cohort.

Figure 21. Information Hierarchy for Estimating External Dose to Techa River Residents



2.2.2 Techa River Cohort External Dose Activity Descriptions

The following activities are necessary to complete the dose reconstruction process illustrated in Fig. 21.

Electron Paramagnetic Resonance (EPR) This subtask will perform additional measurements as tooth samples become available through routine dental work and postmortems (no active recruitment of samples from exposed individuals is planned). These measurements will be used as the basis for external dose for the affected individuals and also placed into a database from which statistical regressions based on age and residence can be made to provide a source of analog information for persons without direct measurements. It is anticipated that this subtask would be performed by staff of the Metal Physics Institute in Ekaterinbourg. Procurement of an EPR spectrometer will simplify and greatly increase the number of samples that could be analyzed annually.

Environmental Thermoluminescent Dosimetry (TLD) This subtask will perform additional measurements in environmental samples collected at predetermined locations along the Techa River. A detailed sampling plan will be developed to optimize the number of samples required. The dose rates evaluated will be used to prepare a regression of dose rate for various distances away from the river at locations downstream of the release point. This will also serve to validate the radiation transport and shielding calculations.

Biodosimetry Pilot Study A feasibility study will be undertaken to evaluate the accuracy and reliability of measurements made with a suite of biodosimetric techniques, including fluorescent in-situ hybridization, T-cell receptor, and other techniques. If any of the techniques compare well with measurements made by other methods (EPR, etc.), further requests will be made to the JCCRER Executive Committee to incorporate the techniques into the ongoing dose reconstruction efforts.

Analysis of Historical and Current Monitoring Data This subtask will compile and evaluate available data on radionuclide concentrations in water and sediment. This information will serve as input to the river transport and radiation transport/ shielding subtasks.

Techa River Source Term Development This subtask will prepare estimates of the time history of radionuclide release to the Techa River. This will require review of historical Mayak documents regarding facility operating histories, technological processes involved, and any available measurements of releases. This task will develop estimated release fractions and prepare release estimates for use in transport modeling. This task may involve review of currently classified documents. Provisions will be made to declassify key documents supporting the release estimates. It is anticipated that staff from the Mayak Industrial Association will be key participants in this task.

Techa River Transport Modeling This subtask will accumulate data describing the historical Techa River hydrologic data, sediment loading, and dam construction history. This will be used as input to a numerical transport model to simulate the flow and contaminant loading of the Techa River from the Mayak facility to its confluence with the Iset River. The model will

provide concentrations of radionuclides in water and sediment at specified locations along the river.

Radiation Transport/Shielding Calculations This subtask will extend available measurements (from TLD and conventional sources) to provide dose rates as a function of location away from the Techa River. Inputs to the modeling will generally come from the Techa River source term and transport modeling activities.

Techa River Cohort External Dose Estimation This task will provide management coordination and integration for the other subtasks involved with the Techa cohort. This task will assimilate the data and information prepared by the other tasks and make individual external dose estimates based on the priority of the data hierarchy. This task will also collect a database of completed results to use as potential surrogates for use in estimating individual doses by analogy as a last resort. This task will also lead the evaluation of uncertainty in the individual dose estimates and use the collected information to attempt to validate the more numerically-intensive techniques against those with better measurements.

2.3 East Urals Radioactive Trace (EURT)—External Dose

The external dose reconstruction approach for residents exposed to the deposition forming the East Urals Radioactive Trace (EURT; also known as the "Kyshtym explosion") is described in Section 2.3.1. The tasks that derive from this approach are summarized in Section 2.3.2.

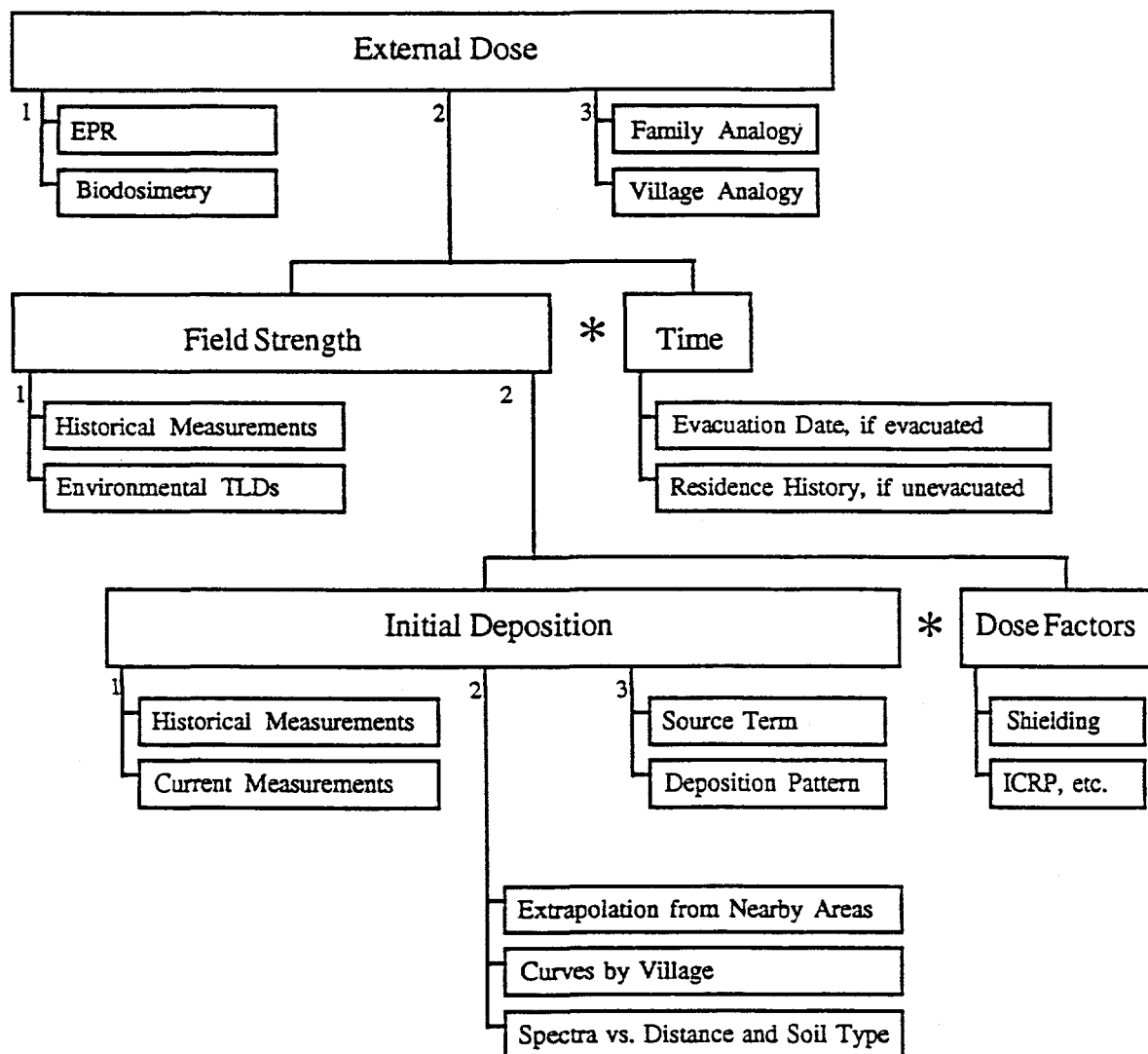
2.3.1 EURT External Dose Reconstruction Hierarchy

Residents of the area impacted by the EURT deposition may be divided into two groups (see Table 5) - those evacuated within the first days immediately following the release and those who were not evacuated. The general approach to external dose reconstruction is the same for both groups.

The hierarchy of information required for calculating external radiation doses to people who lived in the area effected by the EURT release is shown in Fig. 22. Measurements of tooth samples made with Electron Paramagnetic Resonance techniques have been shown to give very reliable and accurate indications of absorbed dose. This would be the highest priority technique for determining external exposure; however, from Table 5 it is apparent that very few individuals have been measured to date. A continuation of these studies is proposed. In addition, there is interest to evaluate whether biodosimetric techniques (e.g., florescent in-situ hybridization, T-Cell receptor, and others) can provide reliable estimates of external dose. Studies to date on these techniques have been inconclusive (Akleyev 1995), and pilot efforts to continue the research are proposed because the potential return on the investment is very high.

External dose is related to the time integral of the dose rate field to which individuals were exposed. Information related to time is readily accessible through birthdates and residence histories.

**Figure 22. Information Hierarchy for Estimating External Dose to EURT
Early Evacuated Residents (and Unevacuated Areas)**



Many historical measurements of radiation dose rate were made in the affected area immediately after the release and for many years afterward. These will provide the bulk of the necessary information. An additional promising source of external dose rate data is the use of environmental thermoluminescent materials. This technique has been shown to be effective (Bougrov 1995), but as is indicated in Table 5, it has not been used within the EURT zone. Some supporting information will also be provided by investigating classical radiation shielding calculations.

Historically measured radionuclide concentrations in many environmental media (including regional soils) are available. Curves of dose rate as a function of time are available for many villages, as are some radiation spectra. However, it is likely that reconstruction of contamination levels of some short-lived radionuclides will be required. This can be done using extrapolation in a few instances, but generally concentrations must be calculated from released amounts and the initial deposition pattern. The released amounts (source term) must be estimated from Mayak operating records and process descriptions. A parallel project at the Federal Nuclear Center in Snezhinsk (Chelyabinsk-70), managed by Dr. Evelina Kuropatenko, has a task to reconstruct the radionuclide release spectrum. Efforts will be coordinated with this group.

2.3.2 EURT Cohort External Dose Activity Descriptions

The following activities are necessary to complete the dose reconstruction process illustrated in Fig. 22.

Electron Paramagnetic Resonance (EPR) This subtask will perform additional measurements as tooth samples become available through routine dental work and postmortems (no active recruitment of samples from exposed individuals is planned). These measurements will be used as the basis for external dose for the affected individuals and also placed into a database from which statistical regressions based on age and residence can be made to provide a source of analog information for persons without direct measurements. It is anticipated that this subtask would be performed by staff of the Metal Physics Institute in Ekaterinbourg. Procurement of an EPR spectrometer will simplify and greatly increase the number of samples that could be analyzed annually.

Environmental Thermoluminescent Dosimetry (TLD) This subtask will perform initial measurements in environmental samples collected at predetermined locations within the EURT. A detailed sampling plan will be developed to optimize the number of samples required. The dose rates evaluated will be used to prepare a regression of dose rate for various locations. This will also serve to validate the radiation transport and shielding calculations.

Biodosimetry Pilot Study A feasibility study will be undertaken to evaluate the accuracy and reliability of measurements made with a suite of biodosimetric techniques, including fluorescent in-situ hybridization, T-cell receptor, and other techniques. If any of the techniques compare well with measurements made by other methods (EPR, etc.), further requests will be made to the JCCRER Executive Committee to incorporate the techniques into the ongoing dose reconstruction efforts.

Analysis of Historical and Current Monitoring Data This subtask will compile and evaluate available data on radionuclide concentrations in soils and associated dose rates. This information will serve as input to the individual dose calculations.

EURT Source Term Development This activity will prepare estimates of the radionuclide release to the air. This will require review of historical Mayak documents regarding facility operating histories, technological processes involved, and any available measurements of releases. This task may involve review of currently classified documents. Provisions will be made to declassify key documents supporting the release estimates. It is anticipated that staff from the Mayak Industrial Association will be key participants in this task, but that most efforts will be done by the staff of the Federal Nuclear Center in Snezhinsk.

EURT Cohort External Dose Estimation This task will provide management coordination and integration for the other subtasks involved with the EURT cohort. This task will assimilate the data and information prepared by the other tasks and make individual external dose estimates based on the priority of the data hierarchy. This task will also collect a database of completed results to use as potential surrogates for use in estimating individual doses by analogy as a last resort. This task will also lead the evaluation of uncertainty in the individual dose estimates and use the collected information to attempt to validate the more numerically-intensive techniques against those with better measurements.

2.4 East Urals Radioactive Trace (EURT)- Internal Dose

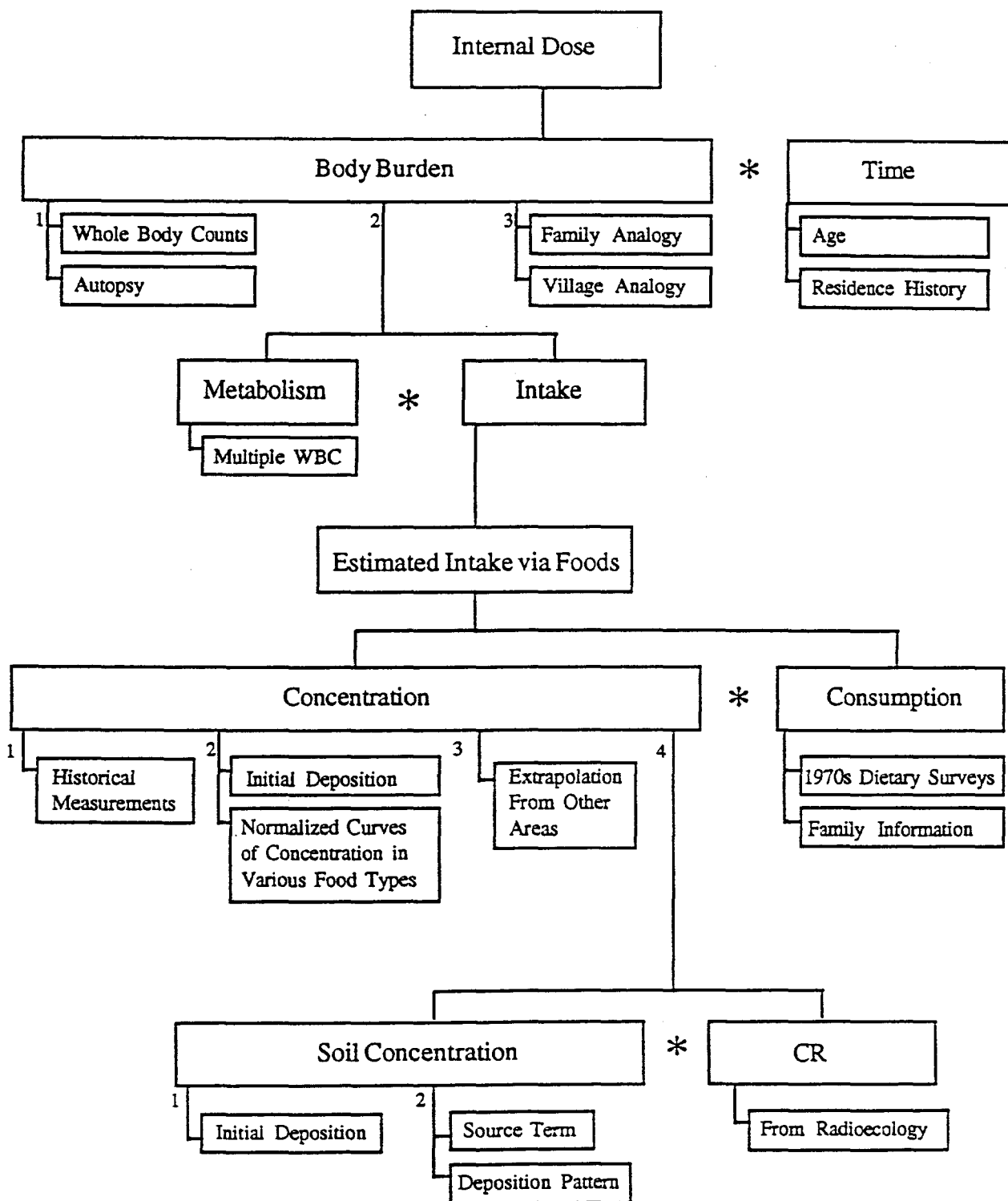
The internal dose reconstruction approach for residents exposed to the deposition forming the East Urals Radioactive Trace (EURT; also known as the "Kyshtym explosion") is described in Section 2.4.1. The tasks that derive from this approach are summarized in Section 2.4.2.

2.4.1 EURT Internal Dose Reconstruction Hierarchy

Residents of the area impacted by the EURT deposition may be divided into two groups (see Table 5)—those evacuated within the first days immediately following the release and those who were not evacuated. The general approach to internal dose reconstruction is generally used only for those who were not evacuated or who were only evacuated after a substantial time lapse.

The hierarchy of information required for calculating internal radiation doses to people who lived in the area impacted by the EURT release is shown in Fig. 23. Internal dose is related to the time integral of the body burden. Information related to time is readily accessible through birthdates and residence histories. As shown in Table 5, relatively few individuals have had whole body counts. These individual records are the preferred primary data for individual dose reconstruction, but will not support the bulk of the dose estimates for this cohort. A smaller number of individual autopsy data are available; these are also preferred starting points. The last resort for estimating body burden histories for individuals is via analogy to family members or residents of the same location - if individual measurements are not available, it is preferable to estimate them via individual intake and metabolic models.

Figure 23. Information Hierarchy for Estimating Internal Dose to EURT Late/Non-Evacuated Residents



There were a very large number of potential routes of ingestion of radionuclides. Eating various contaminated garden and field crops and animal products could all lead to intake of radionuclides. Consumption rates vary by age, sex, ethnic group, and perhaps by village. An extensive set of dietary questionnaires were administered to EURT residents in the 1970s. As a default, family or village food ingestion rates can be compiled.

Historically measured radionuclide concentrations in many selected environmental media (soil, crops, and animal products) are available. For many villages, there are time histories of the radionuclide concentration in multiple foods. These have been normalized into curves of concentration versus time for a unit initial deposition. These curves will provide the basic input for most individual dose reconstructions.

It is unlikely that reconstruction of food contamination levels will be required. This can be done using extrapolation in most instances. Concentrations could also be calculated from common radioecological transfer factors and estimated initial deposition. The released amounts (source term) must be estimated from Mayak operating records and process descriptions. This type of work is being undertaken by a parallel project at the Federal Nuclear Center in Snezhinsk (Chelyabinsk-70), managed by Dr. Evelina Kuropatenko, with a task to reconstruct the radionuclide release spectrum. Efforts will be coordinated with this group.

2.4.2 Techa River Cohort Internal Dose Activity Descriptions

The following activities are necessary to complete the full dose reconstruction illustrated in Fig. 23.

Evaluation of Bioassay Data This subtask will evaluate available whole body count data and autopsy data. This will provide body burden/intake estimates for individuals for whom measurements exist. This task will also assemble a database of whole body count derived body burdens for each family or village to be used as surrogates in case other approaches fail for unmeasured individuals.

Establish Food Consumption Rates This subtask will develop individual dietary intakes of various foods as functions of age, sex, ethnicity, and location. The efforts will use individual dietary information, and results of local surveys.

Analysis of Historical and Current Monitoring Data This subtask will compile and evaluate available data on radionuclide concentrations in soil and food. Curves of radionuclide content in foods versus time for a unit deposition will be verified and/or developed. This information will serve as the basis for most individual ingestion reconstruction.

EURT Source Term Development This activity will prepare estimates of the radionuclide release to the air. This will require review of historical Mayak documents regarding facility operating histories, technological processes involved, and any available measurements of releases. This task may involve review of currently classified documents. Provisions will be made to declassify key documents supporting the release estimates. It is anticipated that staff from the

Mayak Industrial Association will be key participants in this task, but that most efforts will be done by the staff of the Federal Nuclear Center in Snezhinsk.

EURT Cohort Internal Dose Estimation This task will provide management coordination and integration for the other subtasks involved with the Techa cohort. This task will assimilate the data and information prepared by the other tasks and make individual internal dose estimates based on the priority of the data hierarchy. This task will also collect a database of completed results to use as potential surrogates for use in estimating individual doses by analogy as a last resort. This task will also lead the evaluation of uncertainty in the individual dose estimates and use the collected information to attempt to validate the more numerically-intensive techniques against those with better measurements.

2.5 Ozersk Residents—External Dose

Use of the Ozersk cohort in an epidemiological study is not yet certain. A pilot study is first suggested to determine if there is sufficient statistical power to resolve health effects in the exposed population. However, because other residents near the Mayak facility were impacted by the gaseous and aerosol releases from the facility, most of the following activities will be required to complete the dose estimation for the Techa (and possibly EURT) cohorts.

The external dose reconstruction approach for residents of the city of Ozersk (Chelyabinsk-65) is described in Section 2.5.1. The tasks that derive from this approach are summarized in Section 2.5.2.

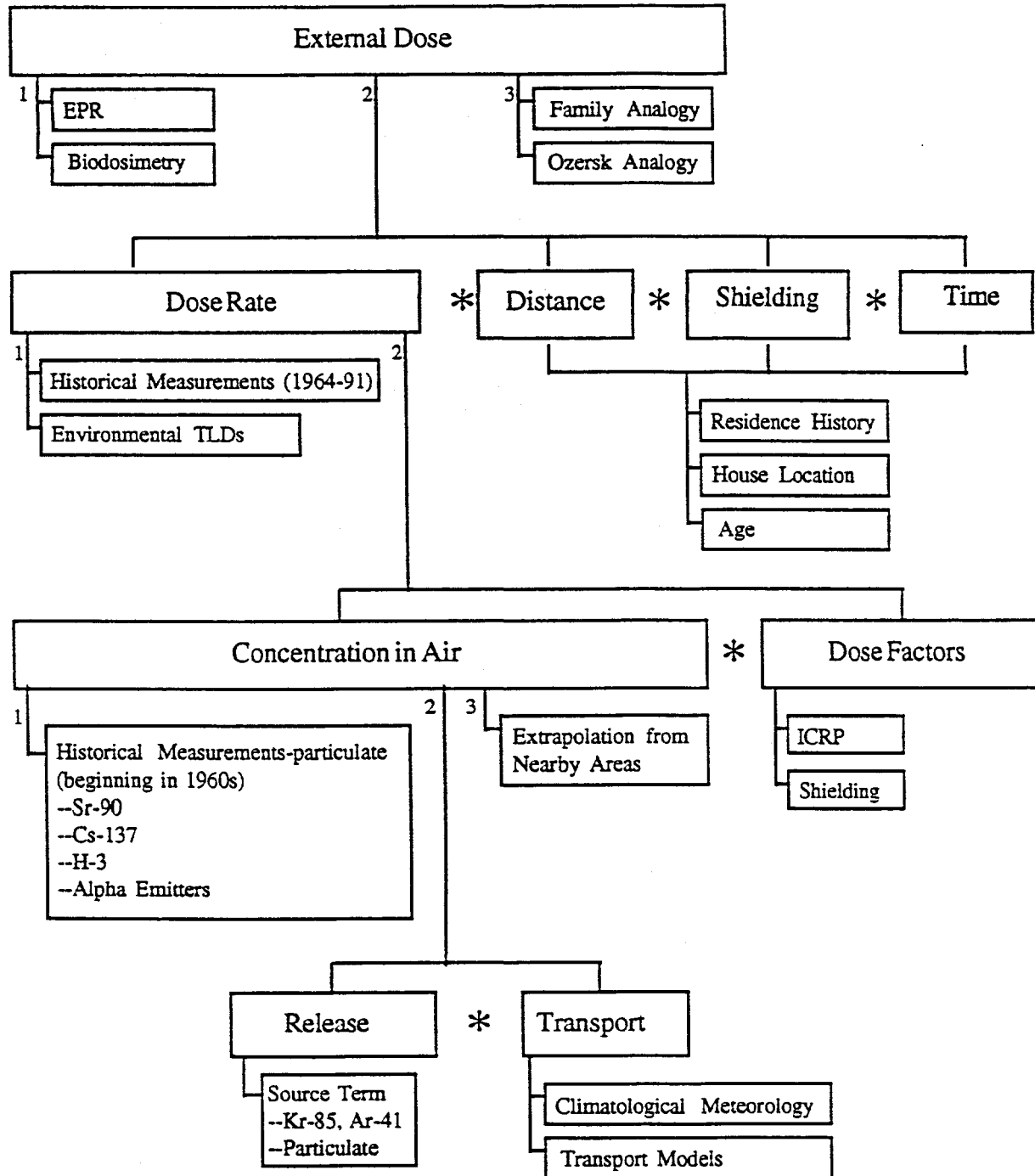
2.5.1 Ozersk Cohort External Dose Reconstruction Hierarchy

The hierarchy of information required for calculating external radiation doses to people who lived in Ozersk during the releases is shown in Fig. 24. Measurements of tooth samples made with Electron Paramagnetic Resonance techniques have been shown to give very reliable and accurate indications of absorbed dose. This would be the highest priority technique for determining external exposure; however, from Table 5 it is apparent that few individuals have been measured to date. Initiation of studies of this type is proposed. In addition, there is interest to evaluate whether biodosimetric techniques (e.g., fluorescent in-situ hybridization, T-Cell receptor, and others) can provide reliable estimates of external dose. Studies to date on these techniques have been inconclusive (Akleyev 1995), and pilot efforts to continue the research are proposed because the potential return on the investment is very high.

External dose is related to the time integral of the dose rate field to which individuals were exposed. Information related to time is readily accessible through birthdates and residence histories.

Some historical measurements of radiation dose rate were made in the vicinity of Ozersk. Most of these were made beginning in 1964, after the period of greatest release. Current environmental measurements can provide information about recent exposures; however, they lack any details of the earlier exposures. A promising source of external dose rate data is the use of environmental thermoluminescent materials. This technique has been shown to be effective

Figure 24. Information Hierarchy for Estimating External Dose to Ozersk Children



(Bougrov 1995), but as is indicated in Table 5, to date it has not been used in Ozersk. Thus, it will be necessary to also approach the problem by investigating classical radiation shielding calculations.

Historically measured concentrations of some selected radionuclides in air are available. However, the record only begins for these in the 1960s. Reconstruction of contamination levels will be required. This can be done using extrapolation in a few instances, but generally concentrations must be calculated from released amounts and an atmospheric transport model. The released amounts (source term) must be estimated from Mayak operating records and process descriptions. Atmospheric data available at this time are limited to climatological records - it is not yet known if hourly data (or equivalent) can be obtained.

2.5.2 Ozersk Cohort External Dose Activity Descriptions

The following activities are necessary to complete the dose reconstruction process illustrated in Fig. 24.

Epidemiological Feasibility Study This subtask will perform an initial evaluation of potential statistical power that an epidemiological study might have. Inputs will come from earlier studies performed by the Mayak Industrial Association. The results will be provided to the participants - it is anticipated that the decision to continue studies of the Ozersk cohort will be coordinated by the staff of FIB-1.

Electron Paramagnetic Resonance (EPR) This subtask will perform initial measurements as tooth samples become available through routine dental work and postmortems (no active recruitment of samples from exposed individuals is planned). These measurements will be used as the basis for external dose for the affected individuals and also placed into a database from which statistical regressions based on age and residence can be made to serve as a source of analog information for persons without direct measurements. It is anticipated that this subtask would be performed by staff of the Metal Physics Institute in Ekaterinbourg. Procurement of an EPR spectrometer will simplify and greatly increase the number of samples that could be analyzed annually.

Environmental Thermoluminescent Dosimetry (TLD) This subtask will perform initial measurements in environmental samples collected at predetermined locations within Ozersk. A detailed sampling plan will be developed to optimize the number of samples required. The dose rates evaluated will be used to prepare a regression of dose rate for various locations away from the Mayak facilities.

Biodosimetry Pilot Study A feasibility study will be undertaken to evaluate the accuracy and reliability of measurements made with a suite of biodosimetric techniques, including fluorescent in-situ hybridization, T-cell receptor, and other techniques. If any of the techniques compare well with measurements made by other methods (EPR, etc.), further requests will be made to the JCCRER Executive Committee to incorporate the techniques into the ongoing dose reconstruction efforts.

Analysis of Historical and Current Monitoring Data This subtask will compile and evaluate available data on radionuclide concentrations in air and soils. This information will serve as input to the source term and shielding subtasks.

Atmospheric Source Term Development This subtask will prepare estimates of the time history of radionuclide release to the atmosphere from Mayak activities. This will require review of historical Mayak documents regarding facility operating histories, technological processes involved, and any available measurements of releases. This task will develop estimated release fractions and prepare release estimates for use in atmospheric transport modeling. Radionuclides will include ^{131}I , ^{239}Pu , ^{137}Cs , ^{41}Ar , (^{85}Kr ?), and others. This task may involve review of currently classified documents. Provisions will be made to declassify key documents supporting the release estimates. It is anticipated that staff from the Mayak Industrial Association will be key participants in this task.

Atmospheric Transport Modeling This subtask will accumulate meteorological data describing the historical dispersion conditions. This will be used as input to a numerical transport model to simulate the advection, dispersion, and wet and dry deposition of radionuclides. The model will provide concentrations of radionuclides in the air and on the ground at specified locations throughout the Mayak region.

Ozersk Cohort External Dose Estimation This task will provide management coordination and integration for the other subtasks involved with the Ozersk cohort. This task will assimilate the data and information prepared by the other tasks and make individual external dose estimates based on the priority of the data hierarchy. This task will also collect a database of completed results to use as potential surrogates for use in estimating individual doses by analogy as a last resort. This task will also lead the evaluation of uncertainty in the individual dose estimates and use the collected information to attempt to validate the more numerically-intensive techniques against those with better measurements.

2.6 Ozersk Residents - Internal Dose

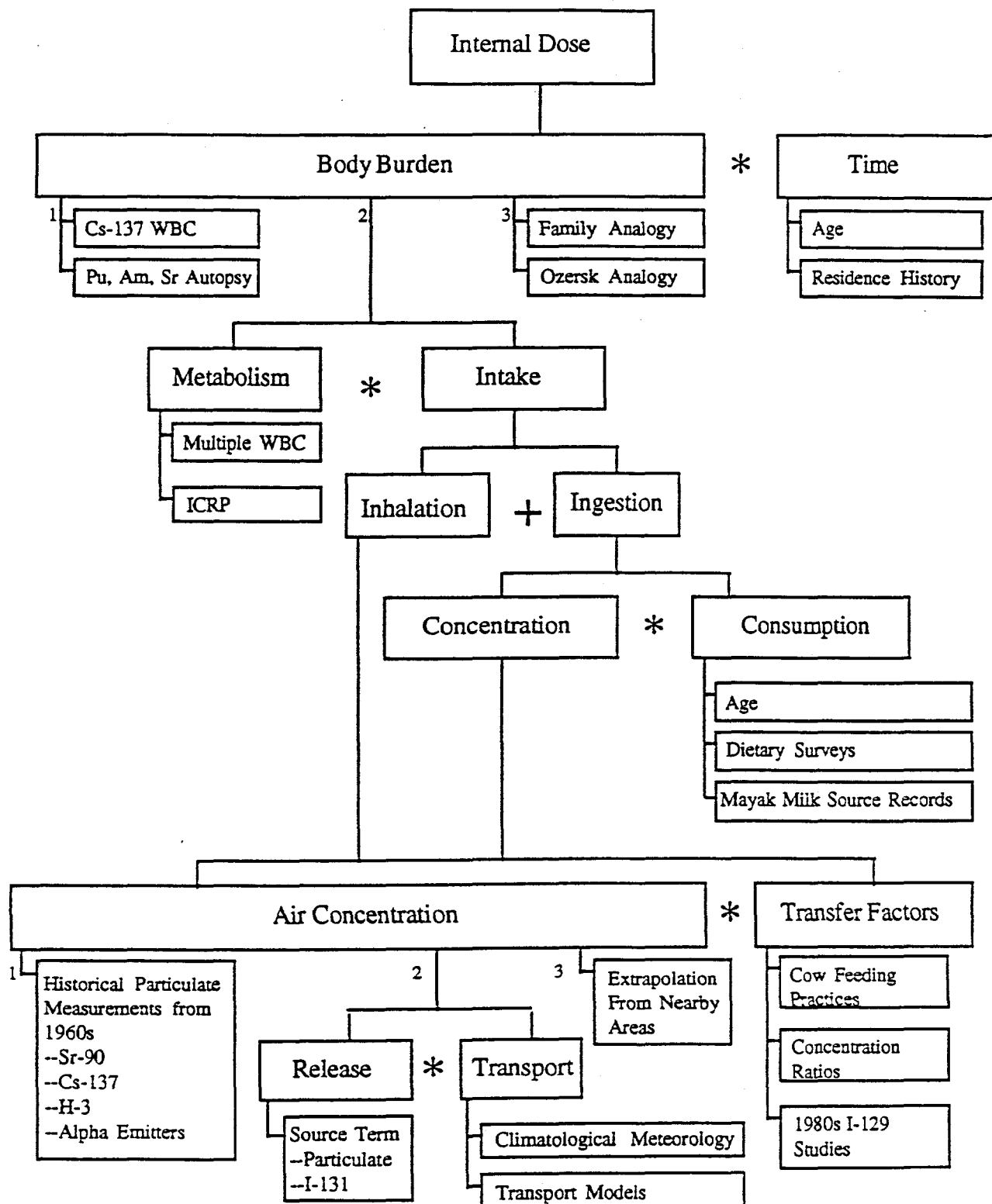
Use of the Ozersk cohort in an epidemiological study is not yet certain. A pilot study is first suggested to determine if there is sufficient statistical power to resolve health effects in the exposed population. However, because other residents near the Mayak facility were impacted by the gaseous and aerosol releases from the facility, most of the following activities will be required to complete the dose estimation for the Techa (and possibly EURT) cohorts. (Those activities required in either case are indicated in Section 4.3).

The internal dose reconstruction approach for residents of the City of Ozersk is described in Section 2.6.1. The tasks that derive from this approach are summarized in Section 2.6.2.

2.6.1 Ozersk Cohort Internal Dose Reconstruction Hierarchy

The hierarchy of information required for calculating internal radiation doses to people who lived in the vicinity of Ozersk during the releases is shown in Fig. 25. Internal dose is related to the time integral of the body burden. Information related to time is readily accessible through

Figure 25. Information Hierarchy for Estimating Internal Dose to Ozersk Children



birthdates and residence histories. As shown in Table 5, a number of individuals have had at least one whole body count; however, these did not begin until relatively late in the release period and consider only the readily-assessed gamma-emitting radionuclides. Individual autopsy records are also available for ^{137}Cs , plutonium, and ^{241}Am beginning in about 1975. These individual records are the preferred primary data for individual dose reconstruction, but none of these sources address what is potentially the key radionuclide— ^{131}I . The last resort for estimating body burden histories for individuals is via analogy to family members or residents of the same location - if individual measurements are not available, it is preferable to estimate them via individual intake and metabolic models.

There were a very large number of potential routes of ingestion of radionuclides. Drinking milk probably lead to the largest exposures of ^{131}I in the early years, but inhalation is the leading pathway for doses from plutonium.

Consumption rates vary by age and sex. In the 1970s, dietary surveys were made of people living in the EURT areas - this data could provide some default information if individual dietary preferences are not available. Some information has been compiled by Mayak staff regarding sources of milk and other foods consumed in Ozersk. Collective farms in the area have provided milk to the Ozersk population and their production records are available. Additionally, studies were made in the 1980s of emission rates and environmental concentrations of ^{129}I ; these could provide valuable information applicable to ^{131}I transfer in the region.

Historically measured radionuclide concentrations in some selected environmental media (^{137}Cs and ^{90}Sr in foods between 1956-1989, and ^{131}I in milk between 1962-1964) are available. Measurements of particulate radionuclides and tritium in air are available from the 1960s onwards. However, reconstruction of food-contamination levels will be required. This can be done using extrapolation in a few instances, but generally concentrations must be calculated from common radioecological transfer factors and estimated atmospheric concentrations. Air concentration must be estimated from released amounts and an atmospheric transport model. The released amounts (source term) must be estimated from Mayak operating records and process descriptions.

2.6.2 Ozersk Cohort Internal Dose Activity Descriptions

The following activities are necessary to complete the full dose reconstruction illustrated in Fig. 25.

Epidemiological Feasibility Study This subtask will perform an initial evaluation of potential statistical power that an epidemiological study might have. Inputs will come from earlier studies performed by the Mayak Industrial Association. The results will be provided to the participants—it is anticipated that the decision to continue studies of the Ozersk cohort will be coordinated by the staff of FIB-1.

Evaluation of Bioassay Data This subtask will evaluate available whole body count data and autopsy data. This will provide body burden/intake estimates for individuals for whom measurements exist. This task will also assemble a database of whole body count derived body

burdens for each family or village to be used as surrogates in case other approaches fail for unmeasured individuals.

Establish Food-Consumption Rates This subtask will develop individual dietary intakes of various foods and water as functions of age, sex, ethnicity, and location. The efforts will use individual dietary information, results of local surveys, and information on the sources of drinking water.

Analysis of Historical and Current Monitoring Data This subtask will compile and evaluate available data on radionuclide concentrations in air, soil, and food. This information will serve as input to the radioecology and atmospheric transport subtasks.

Radioecology This subtask will review available data to determine the most appropriate transfer factors for radionuclides in milk and food crops. Sources of data may include site-specific measurements as well as generic sources such as the International Union of Radioecologists. This information will be used to develop estimates of radionuclide content in food crops. Additionally, information will be developed concerning the feeding practices for dairy cattle and distribution systems for milk and other foods produced in the area.

Atmospheric Source-Term Development This subtask will prepare estimates of the time history of radionuclide release to the atmosphere. This will require review of historical Mayak documents regarding facility operating histories, technological processes involved, and any available measurements of releases. This task will develop estimated release fractions and prepare release estimates for use in transport modeling. This task may involve review of currently classified documents. Provisions will be made to declassify key documents supporting the release estimates. It is anticipated that staff from the Mayak Industrial Association will be key participants in this task.

Atmospheric Transport Modeling This subtask will accumulate meteorological data describing the historical dispersion conditions. This will be used as input to a numerical transport model to simulate the advection, dispersion, and wet and dry deposition of radionuclides. The model will provide concentrations of radionuclides in the air and on the ground at specified locations throughout the Mayak region.

Ozersk Cohort Internal Dose Estimation This task will provide management coordination and integration for the other subtasks involved with the Ozersk cohort. This task will assimilate the data and information prepared by the other tasks and make individual internal dose estimates based on the priority of the data hierarchy. This task will also collect a database of completed results to use as potential surrogates for use in estimating individual doses by analogy as a last resort. This task will also lead the evaluation of uncertainty in the individual dose estimates and use the collected information to attempt to validate the more numerically-intensive techniques against those with better measurements.

3. Project 1.1 Project Organization

The activities described in Section 2 are often parallel, and frequently one activity can support dose reconstruction for more than one cohort. It is therefore best to combine many of the activities into related tasks so that they may be better coordinated and managed.

3.1 Task 1: Project Management/Task Integration

(Project 1.1 Principal Investigators: M. Degteva, E. Drozhko, L. Anspaugh, B. Napier)

This task will provide overall direction and project management. This will include scheduling, financial control, meeting attendance, quality assurance, and peer review.

3.2 Task 2: Electron Paramagnetic Resonance Studies

(Metal Physics Institute: A. Romanyukha)

This task will coordinate and perform measurements as tooth samples become available through routine dental work and postmortems (no active recruitment of samples from exposed individuals is planned). Samples will be evaluated from each of the Techa River, EURT, and Ozersk cohorts. These measurements will be used as the basis for external dose for the effected individuals and also placed into a database from which statistical regressions based on age and residence can be made to serve as a source of analog information for persons without direct measurements. Procurement of an EPR spectrometer will simplify and greatly increase the number of samples that could be analyzed annually.

3.3 Task 3: Biodosimetry Pilot Studies

(Urals Research Center for Radiation Medicine: A. Akleyev)

A feasibility study will be undertaken to evaluate the accuracy and reliability of measurements made with a suite of biodosimetric techniques, including fluorescent in-situ hybridization, T-cell receptor, and other techniques. If any of the techniques compare well with measurements made by other methods (EPR, etc.), further requests will be made to the JCCRER Executive Committee to incorporate the techniques into the ongoing dose reconstruction efforts.

3.4 Task 4: Thermoluminescent Dosimetry Studies

(Urals Research Center for Radiation Medicine: N. Bougrov)

This task will perform initial measurements of environmental samples collected at predetermined locations along the Techa River, within the EURT, and within Ozersk. Detailed sampling plans will be developed to optimize the number of samples required. The dose rates evaluated will be used to prepare a regression of dose rate for various locations away from the Mayak facilities.

3.5 Task 5: Analysis of Historical Monitoring Data

(Urals Research Center for Radiation Medicine: M. Vorobiova)

This task will collect and interpret historical measurements of dose rate and radionuclide concentration in water, sediment, soil, fish, air, crops, and animal products. Specific data sets will be prepared for the Techa River between the Mayak release point and the confluence with the Iset River, the East Urals Radioactive Trace for inhabited areas with initial depositions greater than 0.01 Ci km^{-2} , and regions within 50 kilometers of the Mayak facility in which food crops or animal products were produced. These data sets will indicate the time histories of contamination where possible.

3.6 Task 6: Analysis of Bioassay Data

(Urals Research Center for Radiation Medicine: V. Kozheurov; FIB-1: K. Suslova)

This task is subdivided into four subtasks.

Subtask 6A: Evaluation of Available Data

(URCRM: V. Kozheurov; FIB-1: K. Suslova)

This subtask will collect and analyze existing whole body count and autopsy data. Databases will be prepared for the Techa River, EURT, and Ozersk cohorts. This will provide body burden/intake estimates for individuals for whom measurements exist. This task will also assemble a database of whole body count derived body burdens for each family or village to be used as surrogates in case other approaches fail for unmeasured individuals.

Subtask 6B: Calibration of SICH-9.1 Whole Body Counter

(URCRM: V. Kozheurov; Institute of Marine Transport Hygiene, St. Petersburg: A. Kovtun)

This subtask will continue the work begun in the feasibility stage of Project 1.1 in calibrating the URCRM whole body counter. A physical phantom has been designed and is being constructed to aid in this calibration; a mathematical phantom will also be prepared. This calibration is necessary to provide continuity and verification of the thousands of whole body counts available at URCRM.

Subtask 6C: Continued WBC Acquisition

(URCRM: V. Kozheurov)

This subtask supports continued data gathering and counting of the various cohorts. This is important for all aspects of the dose reconstruction as well as supporting the public outreach efforts of URCRM in the impacted populations. In order to most expeditiously continue this work, new detectors and electronics are required for the SICH-9.1 whole body counter. This subtask supports purchase and installation of this new equipment.

Subtask 6D: Metabolism Studies

(URCRM: V. Kozheurov, E. Tolstykh)

This subtask will use available sequential whole body count data to update radionuclide retention functions. This metabolic model would then be used to help evaluate all whole body counts to provide the integral exposures.

Subtask 6E: Tooth Count Analysis
(URCRM: V. Kozheurov)

This subtask will extend the technique of Kozheurov and Degteva (1994) for dietary intake evaluation based on in vivo measurements of strontium-90 in teeth beyond the village of Muslymovo, where it was developed, to other sites along the Techa River.

3.7 Task 7: Individual Definition/Epidemiological Interface
(URCRM: M. Degteva)

This task will coordinate the development of individual dietary intakes of various foods and water as functions of age, sex, ethnicity, and location. The efforts will use individual dietary information, results of local surveys, and information on the sources of drinking water. This task will also support the continued validation of individual residence histories for members of each cohort. This task will coordinate the assignment of family or village analogs, where required, to individuals under assessment.

3.8 Task 8: Radioecology/Transfer Factors
(URCRM: M. Vorobiova; MIA: G. Romanov)

This task will review available data to determine the most appropriate transfer factors for radionuclides in fish, milk, and food crops. Sources of data may include site-specific measurements as well as generic sources such as the International Union of Radioecologists. This information will be used to develop estimates of radionuclide content in food crops. This effort will be coordinated with the available monitoring data collected in Task 5.

3.9 Task 9: Techa River Source Term Development
(MIA: Yu. Mokrov)

This task will prepare estimates of the time history of radionuclide release to the Techa River. This will require review of historical Mayak documents regarding facility operating histories, technological processes involved, and any available measurements of releases. This task will develop estimated release fractions and prepare release estimates for use in transport modeling. This task may involve review of currently classified documents. Provisions will be made to declassify key documents supporting the release estimates.

3.10 Task 10: Atmospheric Source Term Development
(MIA: V.V. Khokhryakov; Federal Nuclear Center: E. Kuropatenko)

This task will prepare estimates of the time history of radionuclide release to the atmosphere from Mayak activities. This will require review of historical Mayak documents regarding facility operating histories, technological processes involved, and any available measurements of releases. This task will develop estimated release fractions and prepare release estimates for use in atmospheric transport modeling. Radionuclides will include ^{131}I , ^{239}Pu ,

^{137}Cs , ^{41}Ar , (^{85}Kr ?), and others. This task may involve review of currently classified documents. Provisions will be made to declassify key documents supporting the release estimates.

Reasonably complete information is available for the atmospheric release from the explosion that formed the East Urals Radioactive Trace. However, work is being undertaken by a parallel project at the Federal Nuclear Center in Snezhinsk (Chelyabinsk-70), managed by Dr. Evelina Kuropatenko, under a task to reconstruct the radionuclide release spectrum. Efforts will be coordinated with this group.

3.11 Task 11: Techa River Radionuclide Transport Modeling (URCRM: D. Burmistrov)

This task has two subtasks.

Subtask 11.A: Radionuclide Transport Modeling (URCRM: D. Burmistrov, M. Vorobiova)

This subtask will accumulate data describing the historical Techa River hydrologic data, sediment loading, and dam construction history. This will be used as input to a numerical transport model to simulate the flow and contaminant loading of the Techa River from the Mayak facility to its confluence with the Iset River. The model will provide concentrations of radionuclides in water and sediment at specified locations along the river.

Subtask 11B: Radiation Transport/Shielding (URCRM: D. Burmistrov)

This subtask will also use the modeled river concentrations to extend available measurements (from TLD and conventional sources) to provide dose rates as a function of location away from the Techa River. Inputs to the modeling will generally come from the Techa River source term and transport modeling activities. Additional calculations may be performed to estimate external doses from noble gases released to the atmosphere.

3.12 Task 12: Atmospheric Transport Modeling (MLA: V.V. Khokhryakov)

This task will accumulate meteorological data describing the historical dispersion conditions. This will be used as input to a numerical transport model to simulate the advection, dispersion, and wet and dry deposition of radionuclides. The model will provide concentrations of radionuclides in the air and on the ground at specified locations throughout the Mayak region.

3.13 Task 13: Dose Estimation for Techa Cohort (Project 1.1 Principal Investigators: M. Degteva, E. Drozhko, L. Anspaugh, B. Napier)

This task will provide management coordination and integration for the other subtasks involved with the Techa cohort. This task will assimilate the data and information prepared by the other tasks and make individual internal and external dose estimates based on the priority of the

data hierarchy. This task will also collect a database of completed Techa River cohort results to use as potential surrogates for use in estimating individual doses by analogy as a last resort. This task will also lead the evaluation of uncertainty in the Techa River cohort individual dose estimates and use the collected information to attempt to validate the more numerically-intensive techniques against those with better measurements.

3.14 Task 14: Dose Estimation for EURT Cohort

(Project 1.1 Principal Investigators: M. Degteva, E. Drozhko, L. Anspaugh, B. Napier)

This task will provide management coordination and integration for the other subtasks involved with the EURT cohort. This task will assimilate the data and information prepared by the other tasks and make individual internal and external dose estimates based on the priority of the data hierarchy. This task will also collect a database of completed EURT cohort results to use as potential surrogates for use in estimating individual doses by analogy as a last resort. This task will also lead the evaluation of uncertainty in the EURT cohort individual dose estimates and use the collected information to attempt to validate the more numerically-intensive techniques against those with better measurements.

3.15 Task 15: Dose Estimation for Ozersk Cohort

(Project 1.1 Principal Investigators: M. Degteva, E. Drozhko, L. Anspaugh, B. Napier;
FIB-1: K. Suslova)

This task will provide management coordination and integration for the other subtasks involved with the Ozersk cohort. Following the epidemiology feasibility study, this task will assimilate the data and information prepared by the other tasks and make individual internal and external dose estimates based on the priority of the data hierarchy. This task will also collect a database of completed Ozersk cohort results to use as potential surrogates for use in estimating individual doses by analogy as a last resort. This task will also lead the evaluation of uncertainty in the Ozersk cohort individual dose estimates and use the collected information to attempt to validate the more numerically-intensive techniques against those with better measurements.

4. Cohort Summary Schedules

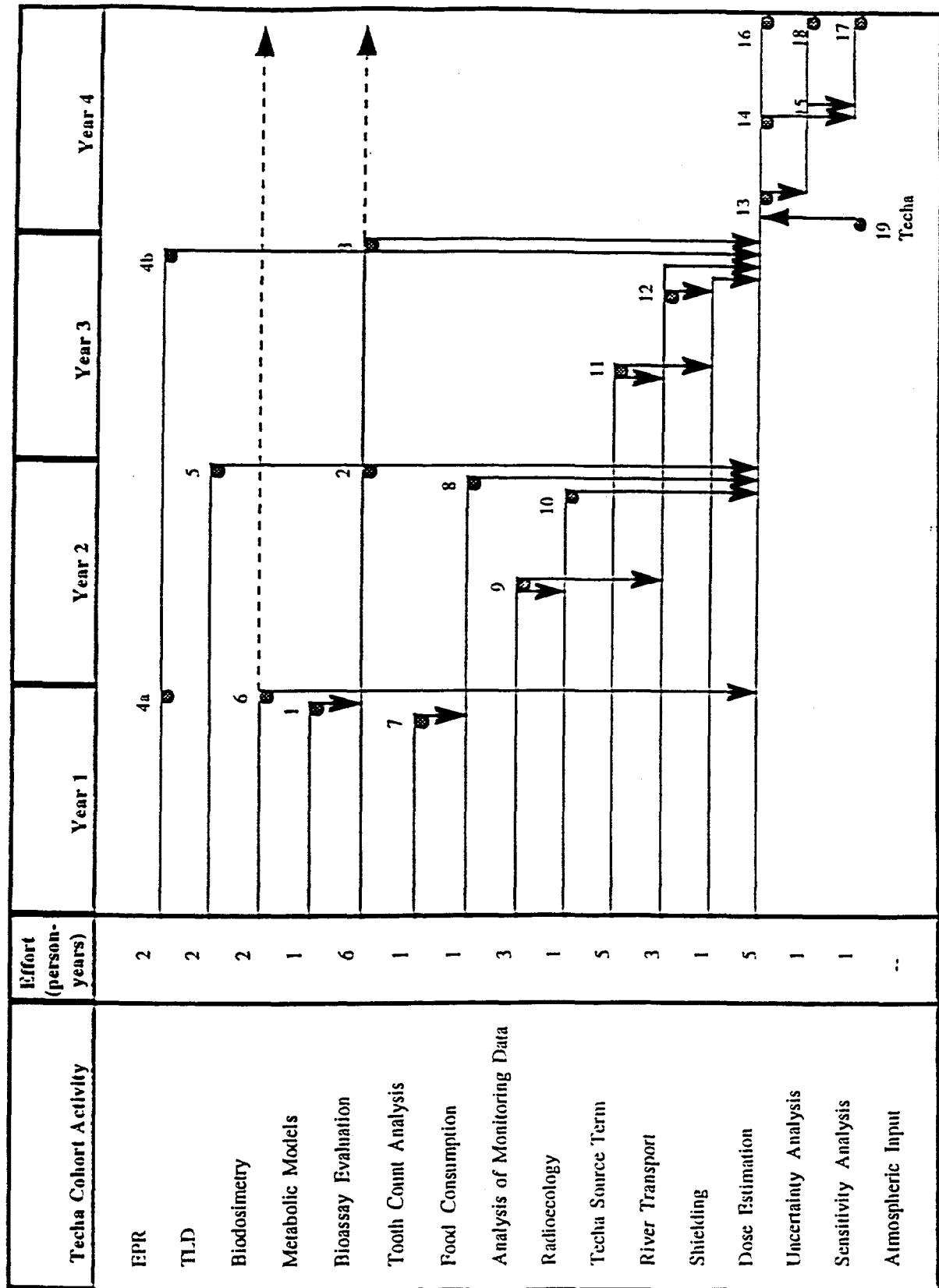
A summary schedule, showing estimated staffing requirements, time lines, task interdependencies, and milestones, is provided for each of the three dose-reconstruction cohorts.

4.1 Techa River Cohort Summary Schedule

Fig. 26 illustrates the summary schedule for the Techa River cohort. The activities listed are described in Sections 2.1.2 and 2.2.2. The connections illustrated generally represent the last date on which data are exchanged between the activities; it is anticipated that the staff would be in continual communication and the important information would be shared as it is developed. The individual milestones, which may be published as separate reports by the participating authors, are:

1. Description of radionuclide metabolic models to assist in evaluation of bioassay data.

Figure 26. Schedule, Dependencies, and Milestones for Techa Cohorts

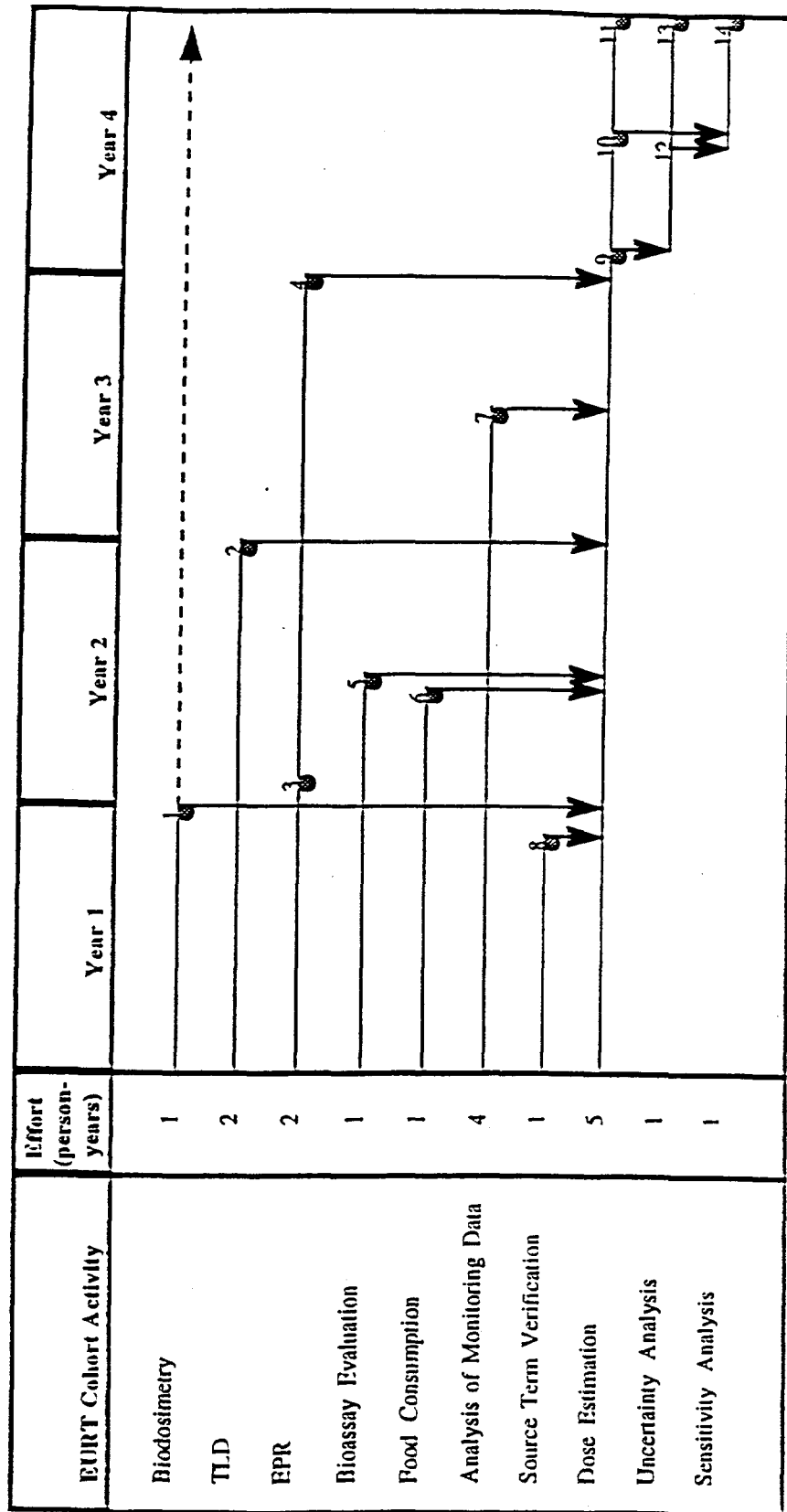


2. Completion of updating and calibration of the SICH-9.1 whole body counter.
3. Final report on individual body burden histories and resulting doses evaluated for Techa River cohort.
- 4a. Completion of procurement, installation, and calibration of EPR spectrometer.
- 4b. Final report on individual external doses measured for specific individuals using EPR, and description of methodology for extrapolating to other individuals in the Techa River cohort.
5. Final report on environmental thermoluminescent dosimetry measurements and description of methodology for extrapolating to other individuals in the Techa River cohort.
6. Final report of feasibility study on use of biodosimetric techniques. If selected techniques are deemed to be useful, additional measurements would be proposed to the executive committee.
7. Final report of the dietary intake evaluation and dosimetric modeling for the Techa River residents based on in-vivo measurements of radionuclides in teeth, to be used as input to the development of individual dietary information.
8. Final report on development of individual dietary information.
9. Final report on historically measured dose rates, radionuclide concentrations in water, sediment, soils, and foods.
10. Final report on default transfer factors for use in estimating radionuclide concentrations in fish, crops, and animal products, including references and derivations.
11. Final report on derivation of the radionuclide release rates from Mayak facilities to the Techa River. Includes time histories of individual radionuclides.
12. Final report of modeled concentrations of radionuclides in Techa River water and sediments at specified locations over time. Includes description of hydrologic data and model(s) employed.
13. Initial individual dose models and estimates for specific individuals for uncertainty analysis.
14. Refined individual dose estimates for use in sensitivity analysis.
15. Description of uncertainty in individual dose estimates for use in sensitivity analysis.
16. Final report to epidemiological study on radiation doses to individuals within the Techa River cohort.
17. Final report on parameters resulting in uncertainty in the individual doses.
18. Final report on uncertainties associated with radiation doses for individuals within the Techa River cohort.
19. Placeholder milestone to indicate connection with analyses for the Ozersk cohort for atmospheric pathways. Data regarding dose from atmospheric releases is input here (Section 4.3, Milestone 14).

4.2 EURT Cohort Summary Schedule

Fig. 27 illustrates the summary schedule for the EURT cohort. The activities listed are described in Sections 2.3.2 and 2.4.2. The connections illustrated generally represent the last date on which data are exchanged between the activities; it is anticipated that the staff would be in continual communication and the important information would be shared as it is developed. The individual milestones, which may be published as separate reports by the participating authors, are:

Figure 27. Schedule, Dependencies, and Milestones for EURT Cohorts



1. Final report of feasibility study on use of biodosimetric techniques. If selected techniques are deemed to be useful, additional measurements would be proposed to the executive committee.
2. Final report on environmental thermoluminescent dosimetry measurements and description of methodology for extrapolating to other individuals in the EURT cohort.
3. Completion of procurement, installation, and calibration of EPR spectrometer.
4. Final report on individual external doses measured for specific individuals using EPR, and description of methodology for extrapolating to other individuals in the EURT cohort.
5. Final report on individual body burden histories and resulting doses evaluated for the EURT cohort.
6. Final report on development of individual dietary information.
7. Final report on historically measured dose rates, radionuclide concentrations in water, sediment, soils, and foods. Includes default transfer factors for use in estimating radionuclide concentrations crops and animal products, including references and derivations.
8. Final report on derivation of the radionuclide release from the Kyshtym explosion to the atmosphere. It is anticipated that this report will be prepared by a parallel project.
9. Initial individual dose models and estimates for specific individuals for uncertainty analysis.
10. Refined individual dose estimates for use in sensitivity analysis.
11. Final report to epidemiological study on radiation doses to individuals within the EURT cohort.
12. Description of uncertainty in individual dose estimates for use in sensitivity analysis.
13. Final report on uncertainties associated with radiation doses for individuals within the EURT cohort.
14. Final report on sensitive parameters resulting in uncertainty in the individual doses for the EURT cohort.

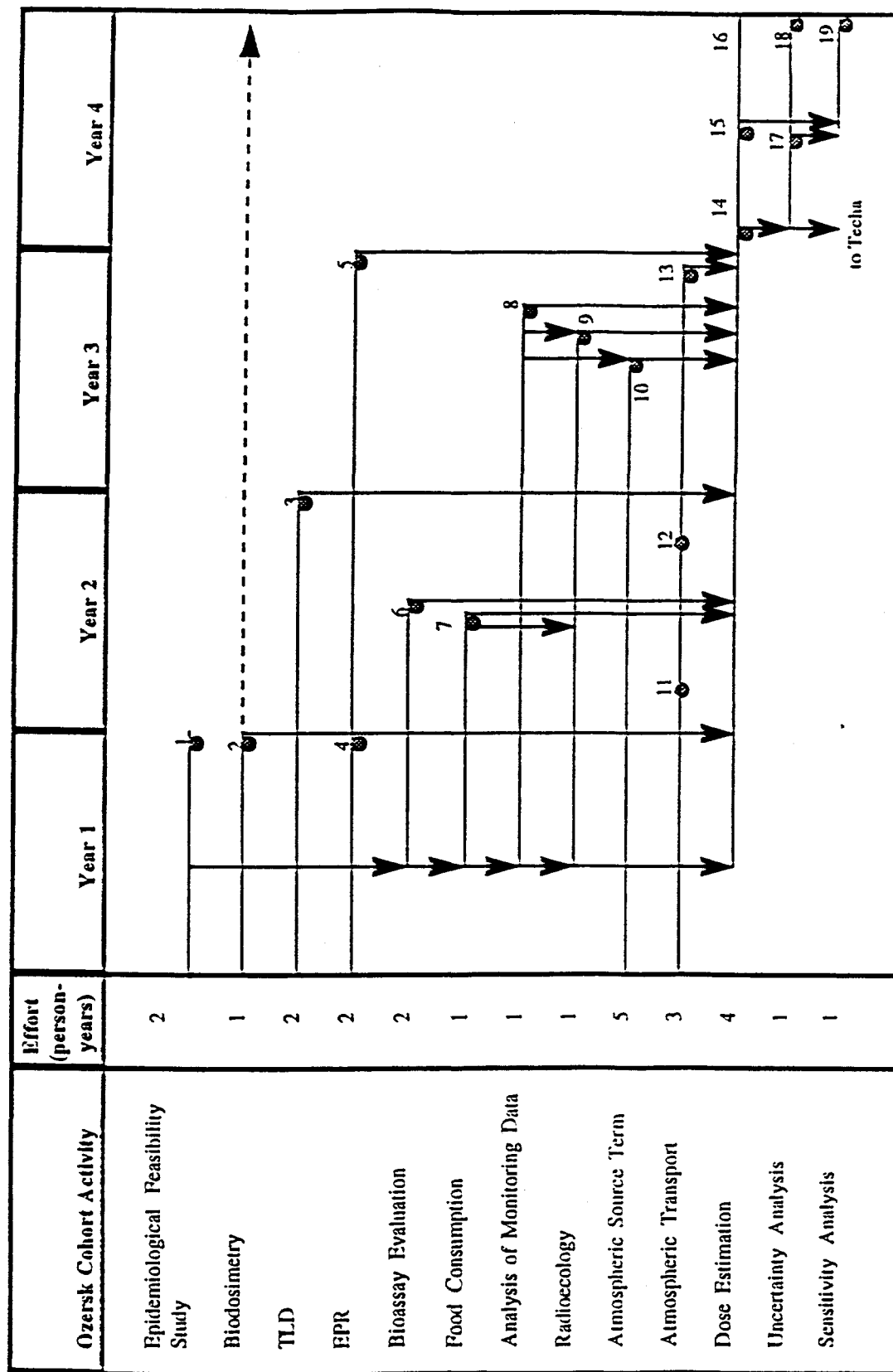
4.3 Ozersk Cohort Summary Schedule

Fig. 28 illustrates the summary schedule for the Ozersk cohort. The activities listed are described in Sections 2.5.2 and 2.6.2. This set of activities begins with a one-year feasibility study to determine if the efforts are required - however, several of the tasks will be performed in conjunction with studies for the Techa River and EURT cohorts. Thus, while some of the activities do not begin until after the completion of the feasibility study, others are required whether or not the Ozersk cohort is studied. These are assumed to begin at the same time as the other efforts.

The connections illustrated generally represent the last date on which data are exchanged between the activities; it is anticipated that the staff would be in continual communication and the important information would be shared as it is developed. The individual milestones, which may be published as separate reports by the participating authors, are:

1. Final report on the feasibility study evaluating the statistical power of an epidemiological study of the Ozersk cohort. A decision should be reached prior to the publication of this report - a positive determination would result in work beginning on subsequent tasks prior to the report's final release.

Figure 28. Schedule, Dependencies, and Milestones for Ozersk Cohorts



2. Final report of feasibility study on use of biodosimetric techniques. If selected techniques are deemed to be useful, additional measurements would be proposed to the executive committee.
3. Final report on environmental thermoluminescent dosimetry measurements and description of methodology for extrapolating to other individuals in the Ozersk cohort.
4. Completion of procurement, installation, and calibration of EPR spectrometer.
5. Final report on individual external doses measured for specific individuals using EPR, and description of methodology for extrapolating to other individuals in the Ozersk cohort.
6. Final report on individual body burden histories and resulting doses evaluated for the Ozersk cohort.
7. Final report on development of individual dietary information.
8. Final report on historically measured dose rates, radionuclide concentrations in air, soils, and foods.
9. Final report on default transfer factors for use in estimating radionuclide concentrations in crops and animal products, including references and derivations.
10. Final report on derivation of the radionuclide release rates from Mayak facilities to the atmosphere. Includes time histories of individual radionuclides - noble gases, reactive gases, and iodines.
11. Evaluation of meteorological data availability and selection of modeling approach.
12. Final development of atmospheric dispersion model.
13. Final report of modeled concentrations of radionuclides in air and deposited on the ground at specified locations over time. Includes description of meteorological data and model(s) employed.
14. Initial individual dose models and estimates for specific individuals for uncertainty analysis. This information is also provided for the Techa River cohort at this time.
15. Refined individual dose estimates for use in sensitivity analysis.
16. Final report to epidemiological study on radiation doses to individuals within the Ozersk cohort.
17. Description of uncertainty in individual dose estimates for use in sensitivity analysis.
18. Final report on parameters resulting in uncertainty in the individual doses.
19. Final report on uncertainties associated with radiation doses for individuals within the Ozersk cohort.

FUNDING

From the Russian Side

The Russian side agreed to "...provide up to six senior investigators and scientists on a full-time basis" (JCCRER 1995a). Further internal agreements were that this commitment would be funded by the Federal Department of the Ministry of Health and Medical Industry and by the Ministry for Civil Defense Affairs, Emergencies and Elimination of Consequences of Natural Disasters (EMERCOM). The funding of 422,000,000 rubles was received for the research connected with population dose and risk assessments from the Federal Agency of Medical and Extreme Problems. This funding included 100,000,000 rubles for the work of the Institute of Marine Transport Hygiene for work on the new phantom for the URCRM whole-body counter;

the remaining 322,000,000 rubles was provided for all tasks related to Direction 1 at the URCRM. Only 75,000,000 rubles of the expected 218,000,000 rubles was received from EMERCOM; no funds were received during the last half of the calendar (and Russian fiscal) year.

From the American Side

The American side agreed to "...provide collaborating scientists up to five in number and individual participation, in general, will not exceed 20%" (JCCRER 1995a). Drs. Lynn Anspaugh, Bruce Napier, André Bouville, Charles Miller, and James Smith have participated in the project. Drs. Anspaugh and Napier have received funding specifically for their participation in the project; the other U.S. team members are federal employees.

Money Provided by the American Side to the Russian Side

The EC agreed that the American Side would provide \$150,000 to the URCRM for the first year's work on Direction 1 (JCCRER 1995a). The actual agreement to transfer this money was delayed (JCCRER 1995b) until August or September 1995. Further guidelines were that up to 20% of the funds may be allocated for direct project-related travel; up to 40% of funds may be allocated for capital equipment costs associated to the research; and up to 40% of the funds may be allocated for institutional support activities (indirect costs). At this date only half of the \$150,000 has been received by the URCRM. Of the \$75,000 received half has been given to Project 1.1 and half to Project 1.2.

Of the \$37,500 received by the URCRM from the American Side, disbursements have been approximately as follows:

Travel	\$7,500	20%
Equipment	12,500	33
Salaries for direct participants	2,500	7
Taxes	4,000	11
Institutional support	<u>11,000</u>	<u>29</u>
Total	\$37,500	100%

The main expense of travel was for four scientists (two each from the URCRM and the MIA) to travel to the Hanford Works, WA, and to Washington, DC, to pursue studies related to fulfilling Milestone 1. A person from the Institute of Metal Physics traveled to the U.S. to confer with personnel at two laboratories conducting EPR research. Travel within Russia has also been funded.

The equipment purchased has included two Pentium-style computers for use in fulfilling the goals detailed in Milestone 1. A copier has also been purchased.

RUSSIAN-AMERICAN INTERACTIONS

Successes

Scientists from the Russian Federation and the United States have met together on several occasions to pursue the goals of Project 1.1. These interactions have included a visit of three American scientists to Chelyabinsk in January 1995; a visit of the Russian Principal Investigator (and the Russian Principal Investigator for Project 1.2) to Livermore in March 1995 and an opportunity during the following week to interact with other American scientists during the annual meeting of the American National Council on Radiation Protection and Measurements in Washington, DC. Nearly all participants in the project met in St. Petersburg, Russia, in July 1996 during a JCCRER Workshop in order to accomplish specific milestone work. Four scientists from the URCRM and the MIA spent two weeks in Hanford, WA, and Washington, DC, where they met many scientists who had worked on the Hanford Environmental Dose Reconstruction Study and other pertinent studies; they concluded their travel with a workshop that other American scientists working on Projects 1.1 and 1.2 attended. The Russian Principal Investigator met during November 1995 in Bad Honnef, Germany (as part of a workshop on dose reconstruction) with one of the American scientists and with Drs. Tore Straume and Edwin Haskell, who will likely participate in future work. Dr. Alex Romanyukha of the Institute of Metal Physics traveled to the University of Utah to discuss the analysis of dose by the technique of electron paramagnetic resonance. Drs. Anspaugh and Napier spent two weeks in Chelyabinsk during January 1996 in order to prepare the final report and to plan future work. During this time they were able to consult with both Russian and American members of the research team for closely related Project 1.2. An important result of these interactions is that the American and Russian scientists have been able to establish effective working relationships with each other, and they have derived confidence that they can work together effectively on a long-term project.

Problems and Suggested Resolutions

Several problems have arisen during the course of the work that could be addressed by the Executive Committee. We specify these problems below and provide our suggestions for resolution.

1. Confusion has arisen due to the fact that Project 1.2a on Data Inventory and Preservation was included only in Project 1.2; this has tended to obscure the need to preserve data pertinent to dosimetry. Such data exists in archives present at both the URCRM and at the MIA. It would be desirable to create a Data Preservation Project as a separate activity that would serve the needs of both dosimetry and epidemiology. However, such data-preservation activities must be thought out very carefully, as attempts to preserve, duplicate, and computerize data can balloon out of proportion, if left unchecked. Thus, it is important to maintain a close liaison among the three projects of data preservation, dosimetry, and epidemiology.
2. The Mayak Industrial Association (MIA) holds data and expertise crucial to the success of dose-reconstruction efforts for the Techa River, East Urals Radioactive Trace, and Ozersk cohorts. It is unfortunate that the MIA was not recognized as an official participant in either

JCCRER (1995a) or JCCRER (1995b), even though the need for their participation was indicated in JCCRER (1994). This created some misunderstanding among the MIA team; one result has been the preparation of a separate proposal (see Appendix 6) for submission to the EC. As can be seen from a comparison of Appendix 6 and our Final Report for Milestone 1.1.2 (see pages 39-75), the work proposed by the Mayak team is taken into account in the Milestone 1.1.3 Report. The problems caused by the omission of the MIA as a participant should be corrected by the Executive Committee (EC). In addition, other institutes have been playing key roles in the work for Project 1.1, and we anticipate that others will participate in the future. Thus, we propose that the following collaborating institutes be recognized formally as participants in Project 1.1:

Urals Research Center for Radiation Medicine, Chelyabinsk, Main Coordination
Mayak Industrial Association, Ozersk
Institute of Marine Transport Hygiene, St. Petersburg
Institute of Metal Physics, Ekaterinoburg
Branch Number 1, Institute of Biophysics (FIB-1), Ozersk
Federal Nuclear Center, Snezhinsk

The work on phantom construction and calibration of the URCRM whole-body counter is being conducted by scientists from the Institute of Marine Transport Hygiene. Important work on electron paramagnetic resonance analysis of teeth for dosimetric purposes is being conducted by Dr. Romanyukha from the Institute of Metal Physics. Dr. Evelina Kuropatenko of the Federal Nuclear Center (Chelyabinsk-70) has major activities that are closely related to those being conducted for Projects 1.1 and 1.2. We believe that both projects can benefit from collaboration in dose-reconstruction activities; in addition there is potential for duplication of effort without careful coordination of activities. Depending upon the exact selection of cohorts to be studied, FIB-1 scientists may be able to provide valuable information on doses received. They have conducted many studies of autopsy materials for the content of ^{239}Pu and ^{90}Sr .

3. There are problems relating to the release and/or declassification of data pertaining to the past releases from the MIA. Even though it is possible for uninvolved scientists to derive reasonable estimates of releases, scientists from the MIA feel that they cannot even discuss such estimates. It would be very helpful to the project, if such data would be freely available to at least the Russian participants in the project. There is no need for American scientists to view classified or sensitive data, but the Russian participants clearly need such access and some mechanism to provide declassified summaries of some data.
4. There tends to be an artificial barrier (and resulting competition) between the work of the URCRM and the FIB-1. This arises from the provision of U.S. money to the URCRM for population studies and to the FIB-1 for worker studies. Depending upon the cohorts ultimately selected for inclusion in studies, there may be needed a much closer association between the scientists and the studies being performed by the URCRM and the FIB-1. If the Ozersk children's cohort is to be included in any studies, this epidemiologic study should be performed by the FIB-1; any supporting dose-reconstruction work should be performed

mainly by scientists from the MIA with participation from scientists at the FIB-1. Any future allocations of money should be based upon need and upon defined work to be done.

5. There is confusion about the tax status of the money being sent by the American side to the Russian side. At the URCRM the 20% Value Added Tax of the Russian Federation has been avoided; this is consistent with the terms of the agreement stated in JCCRER (1995b). However, the future status of customs taxes and other taxes for equipment to be provided to or purchased by the Russian side with American money is clouded. We believe that this issue should be addressed explicitly by the Executive Committee.

ACKNOWLEDGEMENTS

This work was performed under the sponsorship of the U.S.-Russia Joint Coordinating Committee on Radiation Effects Research. Russian participants received funding or support from the Federal Department of the Ministry of Health and Medical Industry; the Ministry for Civil Defense Affairs, Emergencies and Elimination of the Consequences of Natural Disasters; the Mayak Industrial Association (Ministry of Atomic Industry); and the Office of International Health Programs, U.S. Department of Energy. American participants received funding or support from the Office of International Health Programs of the Assistant Secretary for Environment, Health and Safety, U.S. Department of Energy; the National Cancer Institute; and the Centers for Disease Control and Prevention. Portions of this work were performed at the Lawrence Livermore National Laboratory under the auspices of the U.S. Department of Energy under contract number W.7405-Eng-48.

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С О Г Л А Ш Е Н И Е

между Правительством
Российской Федерации
и

Правительством Соединенных
Штатов Америки
о

СОТРУДНИЧЕСТВЕ В ОБЛАСТИ ИЗУЧЕНИЯ
РАДИАЦИОННЫХ ВОЗДЕЙСТВИЙ С ЦЕЛЬЮ
МИНИМИЗАЦИИ ВЛИЯНИЯ ПОСЛЕДСТВИЙ
РАДИОАКТИВНОГО ЗАГРЯЗНЕНИЯ НА
ЗДОРОВЬЕ ЧЕЛОВЕКА И
ОКРУЖАЮЩУЮ СРЕДУ

A G R E E M E N T

between the Government of the
United States of America
and
the Government of the
Russian Federation
on

COOPERATION IN RESEARCH ON
RADIATION EFFECTS FOR THE
PURPOSE OF MINIMIZATION OF
CONSEQUENCES OF RADIOACTIVE
CONTAMINATION ON HEALTH
AND THE ENVIRONMENT

Direction 1

MEDICAL ASPECTS OF RADIATION EXPOSURE EFFECTS ON POPULATION

PROJECT 1.1

Dose Reconstruction for the Population Subjected to Radiation

Moscow

1994

Dose Reconstruction for the Population Subjected to Radiation

1 Background

Technological dumps of the radioactive materials into the atmosphere, waste dumps into Techa river, occurred in 1949-1956, emergency situations in 1957 and 1961 resulted in high exposure levels of the population in the region of the river Techa and the Eastern Ural radioactive trace. The information on the radioactive contamination of the environment, source characteristics, and dosimetry studies requires systematization and estimation.

Since 1986 large scale dosimetric studies of the population subjected to radiation after the Chernobyl accident are performed.

The aim of the project is the improving of the reconstruction methods of the internal and external population exposure doses, and the dose reconstruction itself for the population with the maximum exposure rate.

2 Directions of work

Analysis and systematization of all archive information on Ural district including:

- measurements of the radioactivity in the environment objects, which started from 1951;
- personalized data on migration for 90.000 people — residents of the most contaminated territories;
- life-time measurements of the radionuclide content of the whole body (12 thousand persons), separate organs (15 thousand persons), autopsy data (since 1951).

System analysis of the archive information on regions contaminated by radionuclides after the Chernobyl accident includes:

- measurements of radioactivity in the environment, which started from 1986;
- dosimetric data on external and internal irradiation.

Continuation of the dosimetry investigations using whole body counting, electron spin resonance, thermo-luminescent dosimetry methods.

Development of the data reconstruction models of the external (under conditions of the radioactive contamination of the local site and the atmosphere) and internal exposure from long-living plutonium, strontium-90, cesium-137, tritium, short-living iodine-131, and other radionuclides with account for the local conditions.

Improving of the databases and software for the exposure dose reconstruction.

Reconstruction of the personal exposure doses and estimate of the reliability of the obtained data.

3 First-year works of the project

- proofing of the project:
- detailed formulation of the aims and tasks of the project:
- choice of partners:
- collecting and preliminary estimate of the accumulated data on the radioactive contamination of the environment and results of the dosimetry measurements:
- determination of the sources and amount of funding;
- detailed planning of the joint work.

4 Assumed Russian participants of the project

- Ural Research Center for Radiation Medicine;
- St.Petersburg Radiation Hygiene Institute;
- The First Branch of the Biophysics Institute of the Russian Ministry of Health;
- Industrial Association "MAYAK".

С О Г Л А Ш Е Н И Е

между Правительством
Российской Федерации
и

Правительством Соединенных
Штатов Америки
о

СОТРУДНИЧЕСТВЕ В ОБЛАСТИ ИЗУЧЕНИЯ
РАДИАЦИОННЫХ ВОЗДЕЙСТВИЙ С ЦЕЛЬЮ
МИНИМИЗАЦИИ ВЛИЯНИЯ ПОСЛЕДСТВИЙ
РАДИОАКТИВНОГО ЗАГРЯЗНЕНИЯ НА
ЗДОРОВЬЕ ЧЕЛОВЕКА И
ОКРУЖАЮЩУЮ СРЕДУ

A G R E E M E N T

between the Government of the
United States of America
and

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COOPERATION IN RESEARCH ON
RADIATION EFFECTS FOR THE
PURPOSE OF MINIMIZATION OF
CONSEQUENCES OF RADIOACTIVE
CONTAMINATION ON HEALTH
AND THE ENVIRONMENT

Direction 1

MEDICAL ASPECTS OF RADIATION EXPOSURE EFFECTS ON POPULATION

PROJECT 1.2

Risk Estimation for the Deterministic and
Stochastic Exposure Effects and the Results
of Actual Observations of the Population
Health in the Region of the Industrial
Association "MAYAK"

Moscow

1994

PROJECT 1.2

Risk Estimation for the Deterministic and Stochastic Exposure Effects and the Results of Actual Observations of the Population Health in the Region of the Industrial Association "MAYAK"

1 Background

Sufficiently high population exposure levels in the region of Techa river and the Eastern Ural radioactive trace, which would be determined more accurately in the framework of the project "Reconstruction of the internal and external exposure doses for the population of the Ural region", allow the estimate the possible deterministic and stochastic effects with the use of the already existing models and those under development. Long demographic, epidemiologic, and direct clinical observations of the health of the exposed population and specially chosen control groups were performed in the region. More than 40-year time period after the start of the exposure seems to be long enough to obtain the reliable estimates of the possible harmful impact of the radiation on the human health.

The aim of the project is the comparison of the risk estimates for the deterministic and stochastic effects of radiation with the results of actual health observations of the residents of the "MAYAK" site.

2 Directions of work

Analysis, systematization, and estimate of the archive information on demographic, epidemiologic, and direct clinical observations of the health of the exposed population and specially chosen control groups.

Development of the models, estimating the radiation risk, with account for the demographic (including ethnic) specific features of the exposed population.

Formation of the risk groups according to the estimated doses of the external and internal exposure of the population.

Estimate of the possible deterministic and stochastic effects with account for various models and ambiguities in the data on the exposure doses and in the risk coefficients for the appearance of the oncologic diseases and death rates from cancer of various localization.

Comparison of the results of the risk estimates with the actual observation data in time dynamics after the start of the human exposure.

3 First-year works of the project

- proofing of the project;
- detailed formulation of the aims and tasks of the project;
- choice of partners;

- collecting and preliminary estimate of the accumulated observation data on the population health;
- determination of the sources and amount of funding;
- detailed planning of the joint work.

4 Assumed Russian participants of the project

- Ural Research Center for Radiation Medicine;
- Experimental Research Station of the Industrial Association "MAYAK";
- Biophysics Institute of the Russian Ministry of Health;
- Nuclear Safety Institute of the Russian Academy of Sciences (IBRAE).

PROPOSALS FOR THE RUSSIAN-US COLLABORATIVE PROJECT ON DOSE
RECONSTRUCTION FOR THE URALS POPULATION
PROJECT 1.1

Principal Investigators:

For Russia: Marina O. Degteva and Evgenii Drozhko

For the United States: Lynn R. Anspaugh, Bruce A. Napier, André C. Bouville,
Charles W. Miller, and James M. Smith

Background

Population exposure in the Urals occurred as a result of failures in the technological processes at the Mayak plutonium facility in the 1950's. The major sources of radioactive contamination were the discharges of 2.7×10^6 Ci of liquid wastes into the Techa River (1949-1956); an explosion in the radioactive waste storage facility in 1957 (the so-called Kyshtym Accident) that formed the East Urals Radioactive Trace (EURT) due to dispersion of 2×10^6 Ci in the atmosphere; and gaseous aerosol releases (about 560,000 Ci of ^{131}I in total) within the first decades of the facility's operation (1949-1966). The significant portion of activity for the Techa River and EURT consists of long-lived radionuclides, mainly ^{90}Sr .

Systematic measurements of radioactive contamination in and near the Techa river started in the summer of 1951. The contamination of the river water, bottom sediments, flood-plain soils, vegetation, fish, milk, and other food stuffs, and external γ -exposure rates were measured. In 1957 the monitoring was expanded to include the area covered by the EURT. The results of these measurements are kept in archives of Mayak and URCRM mainly on paper media (maps, working notebooks, technical reports, etc.).

The population of the contaminated territories was exposed to external and chronic internal irradiation. Medical checkups of the Techa riverside communities had been started by 1951. In addition to medical examinations, individual data on the conditions of contact with the contaminated river (the distance of the house from the water's edge, the source of drinking water, fishing, etc.) were collected. Also, radiometric measurements of bioassay and autopsy samples were performed. Medical checkups of the population of the most contaminated area of the EURT were started in autumn 1957. Later, a Registry numbering 90,000 subjects in the accidentally exposed population (the residents of the Techa riverside communities and the residents of the area covered by the EURT) was established at the URCRM. All places and terms of residence inside the contaminated area were collected for the members of this registry for the purposes of individual-dose reconstruction. Also, extensive measurements of ^{90}Sr content in teeth were performed beginning in 1960, in forehead bone (since 1976) and whole-body counting (since 1974).

Now this information is contained in the computer data base (so-called Data Base MAN)(Figure 1), which contains personal data on 62,190 subjects exposed on the Techa River and their children, 26,023 subjects from the EURT, and 1847 subjects

exposed in both situations. Whole body counter measurements were performed for 14,400 persons, teeth measurements for 15,440 persons, forehead bone measurements for 12,788 persons, and radiochemical measurements of urine for 1564 persons. Autopsy data are available for about 1500 subjects, but they are not yet entered into the computer database and matched to the registry.

It is necessary to develop a set of dosimetric models, validated on the whole available data set, and special software for individual-dose reconstruction. The development of the separate models (for instance, age-dependent strontium metabolic model, dietary intake models, radionuclide-transport model for the Techa River, etc.) has begun at the URCRM. Last year, pilot studies on electron spin resonance (ESR) dosimetry of teeth and thermoluminescent (TL) dosimetry of brick samples were also carried out for the purposes of dose reconstruction.

Goal and Specific Aims

The goal of the first-year's collaborative research project is the study of feasibility of individual-dose reconstruction for the Urals population. Specific aims are discussed below.

Report Data Base with Annotated Bibliography

The first major, critical goal is to create a searchable data base of the available archived information that would be essential and useful to perform individual and collective dose calculations for the populations effected by the routine and accidental releases from the Mayak Production Association (PA). Such information would include the data needed to determine the releases to the environment via all pathways, with emphasis on the releases to the Techa River, from the Kyshtym tank explosion, and routine and accidental airborne releases; all environmental monitoring data; all bioassay data; and all previous estimates of releases and doses. It is especially important that this information include working notebooks from the Mayak PA, as well as contamination maps and technical reports. Such bibliographic information will be entered into a data base that would include the author(s), title, and summary with key words.

It is not possible to accomplish this large task during the feasibility phase. Rather, the first proposed effort is to establish the optimum conditions for the conduct of this task. It is recognized that this task could become very consumptive of manpower, if not controlled and limited. The feasibility phase would be limited to the design of the hardware and software systems needed to accomplish the larger overall task. First steps would be a visit of a few staff members from the URCRM/Mayak PA to the United States in order to visit similar systems that have already been successfully demonstrated for the purpose of collecting information for dose-reconstruction. The first priority for visit is the Pacific Northwest Laboratory (PNL), which is the best US analog of the Mayak PA and which has just completed a similar bibliographic data base and dose-reconstruction project. A second priority

for visit will be an as yet unspecified site where another dose-reconstruction project is now underway.

After these visits are accomplished, US and Russian experts will consult and determine the optimum hardware and software requirements to implement such a system. It is anticipated that this system will operate on a PC platform and will use commercially available software. Two sets of software and hardware, with appropriate backup storage and protection, will be purchased during the early phases so that work can proceed promptly on the implementation of this process.

One of the early goals of this process will be to identify all data sets that will be useful during the dose-reconstruction phases and to identify some unique data sets that might be saved for use in model-validation studies.

Establish Conceptual Models for Sources and Pathways of Exposure of the Urals Population

The reconstruction of radiation exposures to people living in the vicinity of the Mayak facility is potentially very complex. For example, certain groups were exposed to external irradiation from radionuclides in the Techa River and surrounding soils and sediments, as well as internal doses from drinking the river water and eating the fish from the river. Some members of this group were subsequently evacuated to villages that were later contaminated by deposition from the 1957 Kyshtym explosion, resulting in additional external, inhalation, and food-crop-ingestion doses. Throughout this period, releases of gaseous and particulate effluents to the atmosphere from Mayak operations contributed yet another source of exposure.

Each of these releases has associated with it different radionuclides and different pathways of exposure requiring evaluation of different sets of parameters to determine the exposure of individuals. The objective of this activity is to establish a set of conceptual models that define the relationships, pathways, and parameters that will form the basis of the dose-reconstruction efforts. These conceptual models must be determined before any computational scheme can be developed.

It is proposed to hold a one-week workshop in Chelyabinsk with the URCRM participants and invitees from other organizations who are familiar with dose reconstruction. Also included will be participants from Mayak who understand the operating history and types of releases that occurred. US participants would include scientists from the dose reconstructions at Nevada, Hanford, Fernald, and Oak Ridge sites. The product of this workshop will be a report that will act as the focal point for further model development. If the workshop were opened to the local public, additional valuable input might be obtained. The report will detail the pathways to be considered, the parameters to be evaluated, and the interrelationships that will be preserved.

Provide positive calibration for the URCRM Whole Body Counter

The URCRM whole body counter has been used since 1974 to measure ^{90}Sr and other radionuclides in people exposed to the effluent released to the Techa River. The whole body counter was calibrated with a special anthropomorphic phantom (FAUST) when it was built and check sources have been counted periodically since that time.

This data base of measurements is critical to the success of efforts to provide individual doses. There are plans to update this whole body counter with modern detectors and electronics. However, it is highly desirable to ensure that the old measurement system is once again calibrated in depth on the basis of measurements of a special anthropomorphic phantom. Also, the measurements of the special phantom with the new system will ensure the comparability of the results with the old and the new systems.

The data of concern are of major interest to the reconstruction of dose to the active bone marrow of the members of the Techa River cohort and to the completion of the major study of Sr metabolism that is being undertaken at URCRM. The whole body counter will be used in the future for continuing measurements for these purposes, and it is important to note also that the whole body counter is now an integral part of the public outreach program for the local residents.

During the first year, it is proposed that the phantom will be designed and procured from a Russian source and that the existing components in the whole body counter will be recalibrated with the phantom.

Improvement of Individual Exposure Database

The URCRM has established a database of the parameters associated with the exposures of individual people. This database includes information about residence history, housing type, food sources, and other parameters related to the lifestyles of the exposed individuals. It also has components related to incidence of illness, causes of death, and measured radionuclide content of many individuals. The structure of the current database is shown in Figure 2. The number of individuals in all categories approaches 90,000, as illustrated in Figure 1. The information in the database is needed for both dose reconstruction and epidemiological purposes.

This task will allow continuation of interviews with exposed individuals and provide for additional staff to continue data entry to the database.

Feasibility of Mathematical Modeling for Dose Reconstruction

This task involves the initial stages of development of a system for individual and collective dose reconstruction. Both the US and Russian scientists have had extensive experience in the reconstruction of radiation dose to exposed populations.

An early goal for the joint studies will be the design of a dose-reconstruction mathematical system for the calculation of individual and collective doses from all routes of exposure. Such a system must include not only calculation of dose but also an expression of uncertainty. This subproject will follow the conclusion of the above project on conceptual model development.

It is proposed that Russian scientists from Mayak and URCRM visit with appropriate specialists in the US. The form of the visit will be a brief workshop in which the participants from each side will explain the nature of the problems they have dealt with and the mathematical approaches that they have used. This will be followed with individual visits by the Russian participants at the home laboratories of the US participants. Topics of discussion will include source-term development, atmospheric and surface-water transport, food-chain evaluation, individual-dose-calculation techniques, and techniques for calculation of uncertainty. It is probable that the workshop would take up to a week, and visits at two US sites afterwards would take one week each.

The product of the discussions will be a flow diagram of the proposed mathematical models that will show the interconnections of the overall pathways. The techniques selected to deal with the uncertainty calculations will be explicitly outlined.

It is anticipated that the approaches to be taken will be computationally intensive. In order to establish the computational capability for the Russian participants, it is proposed to proceed with procurement of two computer systems, with appropriate backup systems; one each for the Mayak and URCRM participants. The necessary operating systems and compilers will be determined in the course of the discussions.

Pilot Studies on the Feasibility of ESR, TLD and Biodosimetry Methods for Dose Reconstruction

It is recognized that the pathways of exposure to the Techa River and other cohorts were complex. Therefore mathematical modeling will be very difficult and subject to many sources of uncertainty. In recent years many methods of physical and biological dosimetry have been developed, but they have not been used in many situations due to a lack of sufficient sensitivity.

Many members of the Techa River cohort were exposed to doses sufficiently high that some techniques of biological dosimetry should be useful and can be expected to provide extremely valuable results. The method of choice in biological dosimetry is the analysis of stable chromosome translocations using the fluorescence in situ hybridization test (FISHT). This method has proven to be reliable in inferring the bone-marrow dose received by individuals even decades after exposure. The disadvantage of this technique is that it is time consuming and not very many analyses can be done per man year of effort.

The analysis of doses by electron spin resonance (ESR) has also been found to be very useful in situations where individuals have received higher doses either from external exposure or from the incorporation of some radionuclides, particularly ^{90}Sr . The disadvantages of the technique are that the tooth to be analyzed must be extracted, and some disease processes have been observed to effect the dosimetry signal. Also, methods of sample preparation are not uniform at this time.

A pilot scale project is proposed to demonstrate the usefulness of the FISH and ESR techniques for this study, especially for the purpose of model validation. After obtaining the necessary clearances from the appropriate Institutional Review Boards, approximately ten individuals will be selected for whom reliable dose estimates are available and for whom tooth samples are already available. Samples of blood will be drawn for the purposes of analysis of dose by FISHT and the teeth will be analyzed for dose by ESR. Results of the three analyses will be compared and conclusions drawn for future work on the project. A review of sample preparation methods and calibration with appropriate spectra will be performed.

Within only the last few years, a new technology has developed that allows the measurement of very low levels of isotopic concentrations. It is proposed that this technology be evaluated for determining exposures to short-lived radionuclides. Samples of teeth are available from exposed and unexposed individuals. It is proposed that a pilot study of a few teeth be attempted to analyze the concentrations of the stable daughter products of radionuclides such as ^{90}Sr , ^{95}Zr , ^{144}Ce and others. Several teeth from the unexposed cohort will first be evaluated by US laboratories to determine background levels of these elements, and then one or two teeth from relatively highly exposed individuals will be checked. The pilot study will show whether additional efforts in this direction are warranted.

To support both the ESR and stable daughter evaluations, a review of available literature on the rates of deposition of calcium in tooth enamel is proposed. The incremental rate of constant tooth-enamel formation is a required input in order to estimate on the basis of ESR and stable daughter-product measurements the intake of ^{90}Sr in 1950 and the dose. Researchers from the US and Russia will evaluate information available from their own respective sources and compile a joint report.

Thermoluminescent dosimetry (TLD) techniques have been successfully used in the US for retrospective doses from external penetrating radiation. The technique provides integrated doses from materials such as brick, porcelain, and ceramics. A few samples of bricks from buildings on the Techa River are available. It is proposed that a Russian scientist accompany the samples and observe the analysis and estimation of dose at an American laboratory.

There are already collaborative agreements on the subjects of ESR, TLD, and biodosimetry between Russia and organizations in Germany and Japan. The studies proposed here will be conducted in such a way that there is no interference or duplication of existing prior agreements.

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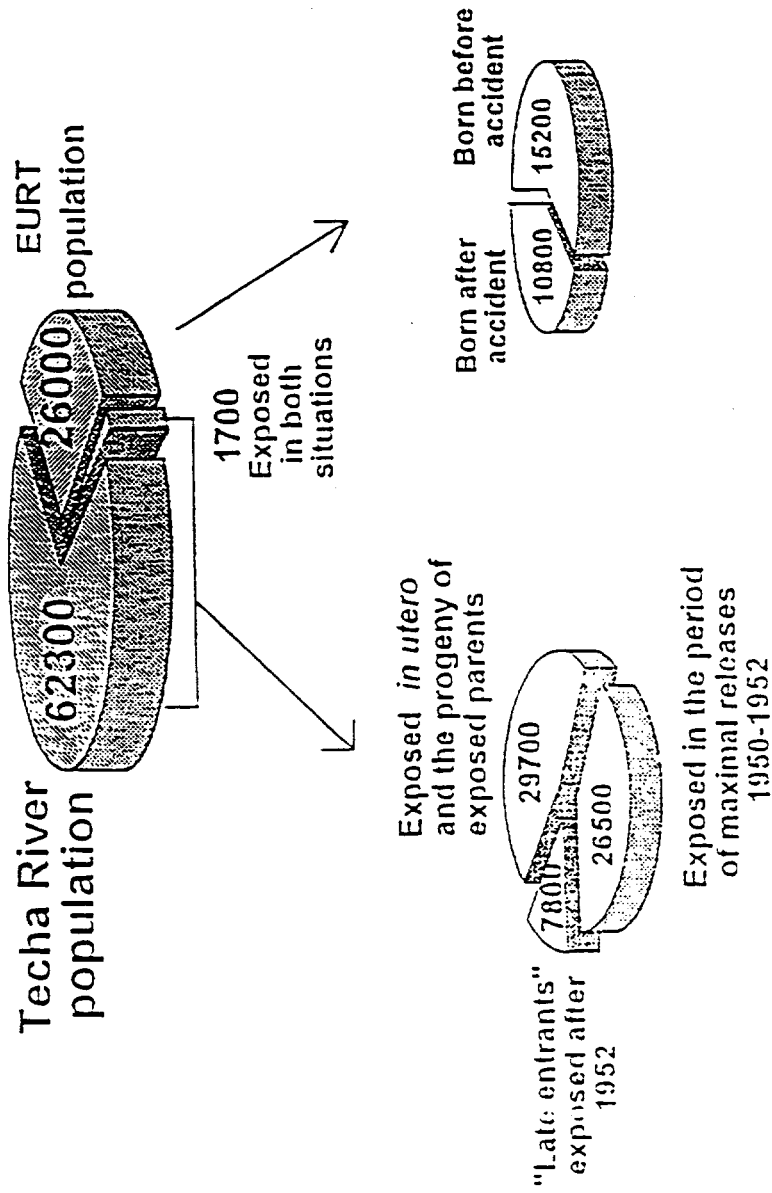


Fig. 1.

Data Base MAN

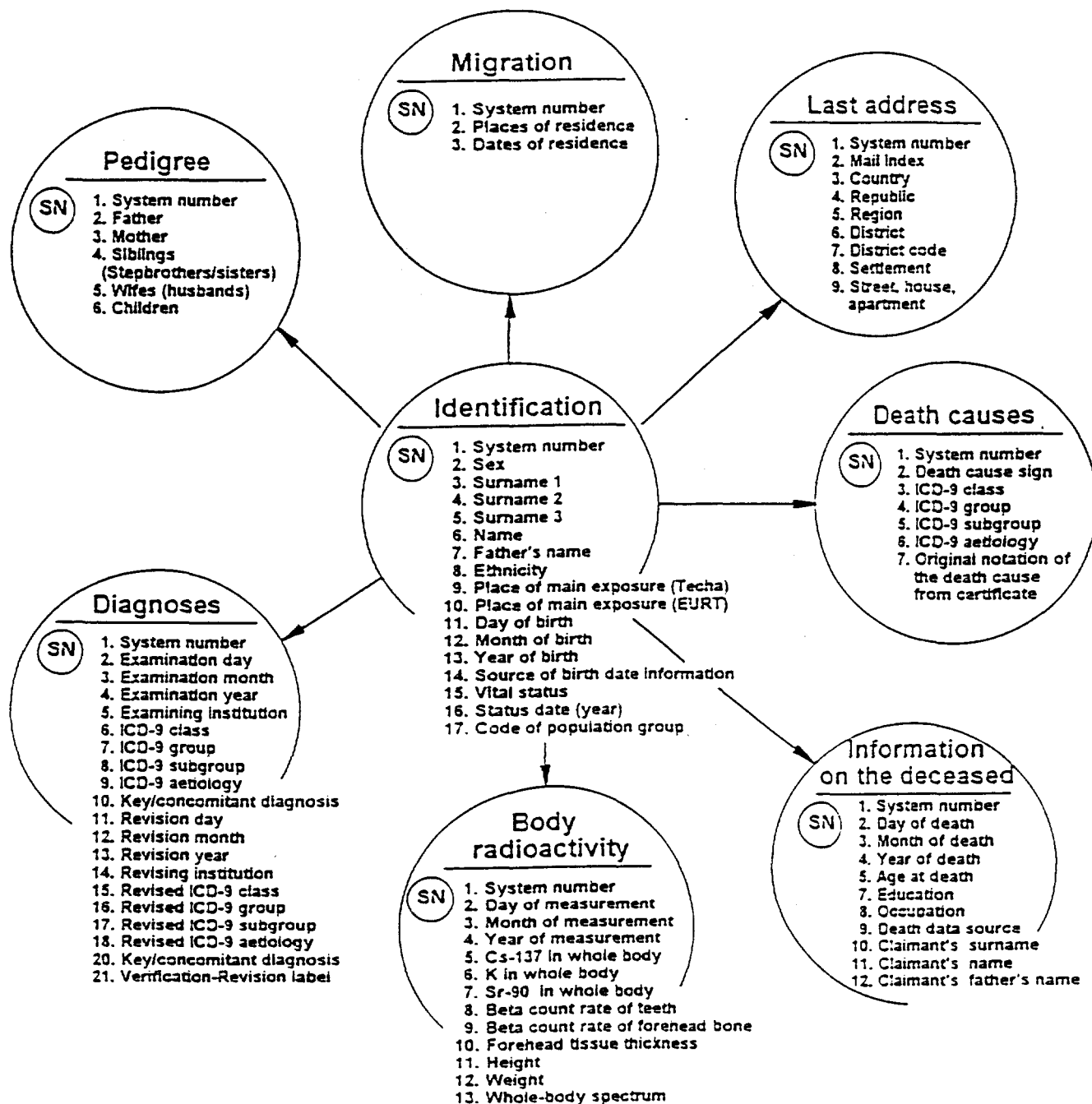


Fig. 2.

С О Г Л А Ш Е Н И Е

между Правительством
Российской Федерации

и

Правительством Соединенных
Штатов Америки

о

СОТРУДНИЧЕСТВЕ В ОБЛАСТИ ИЗУЧЕНИЯ
РАДИАЦИОННЫХ ВОЗДЕЙСТВИЙ С ЦЕЛЬЮ
МИНИМИЗАЦИИ ВЛИЯНИЯ ПОСЛЕДСТВИЙ
РАДИОАКТИВНОГО ЗАГРЯЗНЕНИЯ НА
ЗДОРОВЬЕ ЧЕЛОВЕКА И
ОКРУЖАЮЩУЮ СРЕДУ

A G R E E M E N T

between the Government of the
United States of America

and

the Government of the
Russian Federation

on

COOPERATION IN RESEARCH ON
RADIATION EFFECTS FOR THE
PURPOSE OF MINIMIZATION OF
CONSEQUENCES OF RADIOACTIVE
CONTAMINATION ON HEALTH
AND THE ENVIRONMENT

Direction 1

MEDICAL ASPECTS OF RADIATION EXPOSURE EFFECTS
ON POPULATION

PROJECT 1.1

Dose Reconstruction for the Urals Population

PROJECT 1.1

Dose Reconstruction for the Urals Population

Summary:

The purpose of the first-year's collaborative research project is to study the feasibility of reconstructing individual doses for the exposed Urals population, especially those persons in the cohort to be considered in Project 1.2.

Milestones:

- (1) Preserve and verify the existing database and design a searchable database structure, including software and hardware needed. Include the available archived information related to dose reconstruction. Prepare a report describing the data base design by December 31, 1995.
- (2) Begin calibration of the URCRM whole body counter. Construct a phantom, begin calibration of the counter with the phantom, and prepare a progress report on this milestone by February 29, 1996.
- (3) Prepare a report that will include the methodology for and an assessment of the feasibility of reconstructing the doses for persons in the cohort considered in Project 1.2 by February 29, 1996.
- (4) Establish conceptual and mathematical models for sources and pathways of exposure for the Mayak Region population at the St. Petersburg Workshop (June 1995).

(All feasibility project final reports shall be submitted according the Guidelines for Conducting Scientific Research Projects under the Agreement on Cooperation in Research on Radiation Effects, adopted by the JCC RER and revised by the EC 02/16/95).

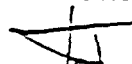
Resources:

The Russian side will provide up to six senior investigators and scientists on a full-time basis. The American side will provide collaborating scientists up to five in number and individual participation, in general, will not exceed 20%.

APPROVAL:

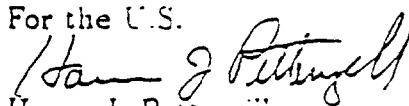
The Executive Committee for the JCCRER has reviewed and approved the implementation of Project 1.1 in accordance with the milestones and resources stipulated above.

For the Russian Federation


Leonid A. Bolshov
Co-chairman EC

February 16, 1995

For the U.S.


Harry J. Pettengill
Co-chairman EC

СОГЛАШЕНИЕ

между Правительством
Российской Федерации

и

Правительством Соединенных
Штатов Америки

о

СОТРУДНИЧЕСТВЕ В ОБЛАСТИ ИЗУЧЕНИЯ
РАДИАЦИОННЫХ ВОЗДЕЙСТВИЙ С ЦЕЛЬЮ
МИНИМИЗАЦИИ ВЛИЯНИЯ ПОСЛЕДСТВИЙ
РАДИОАКТИВНОГО ЗАГРЯЗНЕНИЯ НА
ЗДОРОВЬЕ ЧЕЛОВЕКА И
ОКРУЖАЮЩУЮ СРЕДУ

AGREEMENT

between the Government of the
United States of America

and

the Government of the
Russian Federation

on

COOPERATION IN RESEARCH ON
RADIATION EFFECTS FOR THE
PURPOSE OF MINIMIZATION OF
CONSEQUENCES OF RADIOACTIVE
CONTAMINATION ON HEALTH
AND THE ENVIRONMENT

Direction 1

MEDICAL ASPECTS OF RADIATION EXPOSURE EFFECTS ON POPULATION

PROJECT 1.2

Risk Estimation for the Deterministic and Stochastic
Exposure Effects and the Results of Actual Observations
of the Population Health in the Region of the Industrial
Association "Mayak"

PROJECT 1.2

Risk Estimation for the Deterministic and Stochastic Exposure Effects and the Results of Actual Observations of the Population Health in the Region of the Industrial Association "Mayak"

Summary:

The objective of this project is to develop a long-term Russian-American collaboration for studying the stochastic effects of chronic environmental radiation exposure. In developing this project, three major objectives have been identified. These will be implemented as separate sub-projects: (a) physical preservation of existing data; (b) evaluation of cancer mortality in relation to radiation exposure among persons living in the vicinity of the Techa River; (c) development of a long-term Russian-American collaborative epidemiologic program for studying the stochastic effects of environmental radiation exposure in populations living near the Mayak Industrial Association.

Milestones:

Project 1.2a

- (1) Complete inventory of accumulated material on exposed populations. Prepare written documentation describing types of documents, information contained therein, and current storage methods by December 31, 1995.
- (2) Analyze the quality of the records and prepare a written report including recommendations for systematic preservation by December 31, 1995.

Project 1.2b

- (1) Develop methods and procedures for determining vital status (alive or dead) of the Techa River population through the calendar year for which the most recent information is available. Prepare written documentation of the procedures by September 30, 1995.
- (2) Develop procedures for incorporating more precise estimates of dose from Project 1.1 into the Techa River population database. Prepare written documentation of these procedures by February 29, 1996.
- (3) Develop methods and procedures for identifying a suitable comparison group for the exposed Techa River population. Prepare written documentation of the procedures by October 31, 1995.

Project 1.2c

- (1) Develop a bibliographic database of population studies for a comprehensive systematic critical review. The data base should be completed by December 31, 1995.
- (2) Develop a summary of results of past epidemiologic studies of relevance to the Techa River basin populations. Prepare a written report by February 29, 1996.

(All feasibility project final reports shall be submitted according the Guidelines for Conducting Scientific Research Projects under the Agreement on Cooperation in Research on Radiation Effects, adopted by the JCC RER and revised by the EC 02/16/05)

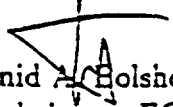
Resources:

The Russian side will provide up to six senior investigators and scientists on a full-time basis. The American side will provide collaborating scientists up to five in number and individual participation, in general, will not exceed 20%.

APPROVAL:

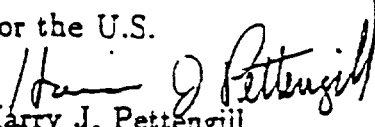
The Executive Committee for the JCCRER has reviewed and approved the implementation of Project 1.2 in accordance with the milestones and resources stipulated above.

For the Russian Federation


Leonid A. Bolshov
Co-chairman EC

February 16, 1995

For the U.S.


Harry J. Pettengill
Co-chairman EC

September 9-30 Trip Summary

**Joint Coordinating Committee on Radiation Effects Research
Project 1.1: Dose Reconstruction for the Urals Population**

Russian scientists from the *Mayak* Production Association and the Urals Research Center for Radiation Medicine met with American collaborators on the JCCRER Project 1.1 from September 9 through 30, 1995. This report summarizes discussions held and conclusions and recommendations reached by the various contributors. This summary is structured following the logic of environmental dose reconstruction; the itinerary of the trip is attached.

Background

Project 1.1 involves the calculational reconstruction of radiation doses to the population living around the Mayak nuclear materials production facility in the southern Ural Mountains of Russia. The general outline of activities for the first year of JCCRER Project 1.1 has been approved by the JCCRER and includes milestones related to establishing a database of information, establishing conceptual models of the sources and pathways of exposure, and establishing the feasibility of and methodology for reconstructing the radiation doses.

The reconstruction of radiation exposures to people living in the vicinity of the Mayak facility is potentially very complex. For example, certain groups were exposed to external irradiation from radionuclides in the Techa River and surrounding soils and sediments, as well as internal doses from drinking the river water, drinking milk from the local area, and other pathways such as eating locally-produced vegetables, meat, and the fish from the river. Some members of this group were subsequently evacuated to villages that were later contaminated by deposition from the 1957 Kyshtym explosion, resulting in additional external, inhalation, and food crop ingestion doses. Throughout this period, releases of gaseous and particulate effluents to the atmosphere from Mayak operations contributed yet another source of exposure. Each of these releases has associated with

it different radionuclides and different pathways of exposure requiring evaluation of different sets of parameters to determine the exposure of individuals. The objective of this activity is to establish a set of conceptual models that define the relationships, pathways, and parameters that will form the basis of the dose reconstruction efforts. These conceptual models must be determined before any computational scheme can be developed. A meeting was held in July 1995, in St. Petersburg, Russia, to address this activity; a conceptual model has been prepared and routed to the JCCRER participants.

The next major goal of Project 1.1 is to create a searchable data base of the available archived information essential for performing individual and collective dose calculations for the populations effected by the routine and accidental releases from the Mayak Production Association. Such information will include the data needed to determine the releases to the environment via all pathways, with emphasis on the releases to the Techa River, from the tank explosion, and routine and accidental airborne releases; all environmental monitoring data; all bioassay data; and all previous estimates of releases and doses. It is especially important that this information include working notebooks from the Mayak PA, as well as contamination maps and technical reports. Such bibliographic information will be entered into a data base that would include the author(s), title, and summary with key words. It is not possible to accomplish this large task during the feasibility phase. Rather, the first is to establish the optimum conditions for the conduct of this task. The feasibility phase is limited to the design of the hardware and software systems needed to accomplish the larger overall task.

The third task for the first year involves the initial stages of development of a system for individual and collective dose reconstruction. Both the US and Russian scientists have had extensive experience in the reconstruction of radiation dose to exposed populations. An early goal for the joint studies is the design of a dose-reconstruction mathematical system for the calculation of individual and collective doses from all routes of exposure. Such a system must include not only calculation of dose but also an expression of uncertainty.

The latter two tasks were addressed during the three weeks of discussions

associated with this visit.

Project Management Issues

Bruce Napier discussed the organization and history of the Hanford Environmental Dose Reconstruction Project (HEDR) performed at Battelle Pacific Northwest Laboratories under the direction of an independent Technical Steering panel for the U.S. Centers for Disease Control and Prevention (CDC). The discussion included required staffing, preparation and updating of project management plans, and task work plans. Critical topics included the early use of "scoping" calculations to define the size of the analysis domain, the temporal and spatial resolution requirements, and the dominant radionuclides and exposure pathways. The presentation of this information in a "Project Summary Schedule" was discussed.

John Zimbrick and Evan Douple, National Academy of Sciences (NAS), provided copies of the NAS report "Dose Reconstruction for Epidemiological Purposes." This NAS report was written as part of a review of the HEDR project for CDC by NAS. This report also stresses the importance of early scoping and definition of dose reconstruction objectives.

Data Searching/Source Term Development

Shirley Gydesen described the Hanford efforts to search massive collections of historical records. The HEDR data search involved review of over 90,000 numbered documents and an additional 46,000 boxes stored in various archive locations. The HEDR project performed a "directed search" using a search tree approach, as well as selected oral histories from veteran employees. Much material was repetitive, with laboratory reports, weekly reports, monthly reports, and annual summaries often containing the same (but summarized) information.

Ms. Gydesen provided a summary of various relational databases that may be used for organizing library-type information. These include *askSam*, *Isys*, and *Zyindex*. The HEDR project prepared a bibliographic database using *askSam* library database software.

The PC-based *askSam Version 2.0 for Windows* software was recommended because it is easy to use, does not require fixed-width fields, and supports use of key words. Searches may be made using boolean operators on commands, as well as employing truncation of keywords, titles, etc.

When the Hanford dose reconstruction began in 1986, many of the early reports were still considered to be "classified," i.e., secret and unavailable for the public. Great efforts were expended to make broad categories unclassified. However, although now all information regarding plutonium production activities at Hanford are now no longer classified, the actual declassification of reports is still a lengthy process, because each individual report must be reviewed before it can be released. This process takes a great deal of time and resources, and must be planned for.

Surface Water Transport

The models used for estimating radionuclide transport in rivers were discussed by Lyle Hibler and Marshall Richmond. The model that was used for HEDR, and is currently being used for simulations of the Techa River, is called CHARIMA. This model is written in FORTRAN and may be run on PC computers. It is one-dimensional, but will simulate multiple (braided) channels. It is based on equations of physics, using the geometry of the river cross-sections and historical flow-rate information. It handles the changes resulting from dam construction easily. It will allow estimation of contaminant transport via sediment using multiple size fractions, each with an independent sorption coefficient (K_d). However, the problems involved with modeling the Techa River historically are different than those today; the historical efforts must use the existing contamination as initial conditions and work backward to the historical conditions. Thus, direct application of CHARIMA or models like it is not advised. This program was originally written by Forest Holley at the University of Iowa; the Marine Sciences Laboratory (PNL/MSL) staff are looking into its general availability.

The surface water transport models can generate very large numerical data sets as output. They also require fairly comprehensive data sets as input. The PNL/MSL staff do

not use relational databases to handle this information. Data are generally stored as large flat files to aid data transportability between computer types. The primary data format is called NETCDF. NETCDF is a binary (compressed) method. This format is common to plotting and statistical analysis packages such as PLOT-PLUS, PSI-PLOT, MATLAB, and EPS. The MSL staff tend to use PLOT-PLUS and EPS, in part because the developer, Don Denbow, works at MSL.

The MSL laboratory routinely handles large computed output data sets; data visualization was demonstrated. Data visualization requires fairly large, fast computers.

Atmospheric Transport

Van Ramsdell provided information about the current state of model development useful for dose reconstruction. The models used should be fit to the amounts of information available. The "best" modeling requires detail on release rates of the effluents of interest, as well as details of the historical meteorology at numerous locations near the release point. If highly detailed historical information is not available, then progressively simpler modeling approaches are warranted.

For HEDR, atmospheric diffusion coefficients were modeled as functions of atmospheric stability class, wind speed, and surface roughness (as defined with a Monin-Obukov length). Wet and dry deposition were also modeled as functions of stability, wind speed, and surface roughness. Washout was based on precipitation rates as characterized as light/moderate/heavy rain/snow. Wind fields were interpolated from available measurements using a $1/r^2$ scheme. Chemical speciation of iodine-131 was handled in HEDR calculations using partitioning between reactive gases (I_2), particles, and organic forms (principally CH_3I). This speciation was based on limited available data from experiments at Hanford, experiments at Idaho Falls, natural stable iodine, and the results following the Chernobyl accident. Resuspension processes were discussed; a review article by George Sehmel was provided.

Like the output from the surface water models, output from atmospheric transport models can be very numerically intensive. The input meteorological data approached 1

megabyte in size. This data is stored as an ASCII flat file. Data were input from old paper or microfiche records. The data from 1944 through 1949 required keypunch input totalling nearly 2 person-years. The data were checked for errors using mechanical techniques (for gross errors) and with statistically-based data quality objectives for minor errors.

Monitoring Data

The current Hanford environmental surveillance project was discussed by Roger Dirkes and his staff. It was pointed out that the objectives and techniques of environmental monitoring vary over time. Historical data are often found repeatedly in laboratory records, weekly, bi-weekly, monthly, quarterly, and annual reports. It is necessary to track measurements back as closely as possible to the laboratory records, since averaging, errors, or subjective adjustments may be added.

The historical measurement techniques evolved over many years. The HEDR project evaluated the conversion of historical counting rates to measured concentrations. It was determined that the historically-used conversion factors frequently held biases which required adjustment. This is particularly true for gross beta and gross alpha measurements, some of which are simply labelled as "iodine" or other dominant radionuclides. Sample handling records are also required, to determine if volatile radionuclides may have been lost in the sample preparation.

The large Hanford Environmental Information System (HEIS) database was partially demonstrated. The HEIS system holds results of measurements up to 20 years old. The HEIS system makes data available to users on and off the Hanford Site, including to members of the general public. Not demonstrated with HEIS was its mapping capabilities - HEIS contains a sophisticated Geographical Information System and associated plotting routines.

Environmental Accumulation and Dose

Paul Eslinger and Bruce Napier described the development of the HEDR computer codes for estimating the environmental contamination levels and human exposure. The

process for development of the computer codes began with early scoping studies to define the spatial and temporal resolution, the dominant radionuclides and exposure pathways, and the size and complexity of intermediate databases. These lead to the writing of Software Requirements Specifications to define the minimum acceptable operations for the codes. The software development plans were based on the requirements; these included requirements for testing by both the code developers and outside individuals. Coding implementation was performed by as many as 5 computer programmers simultaneously, so a Software Code Configuration System was employed to maintain control over the source code. A system of problem reports and change requests was implemented to provide records of the code development.

A key consideration in the development of the HEDR codes was the incorporation of uncertainty in all parts of the calculations. The HEDR codes used both simple random sampling (Monte Carlo) techniques, as well as Latin Hypercube sampling for selected critical parameters.

The HEDR codes were written in FORTRAN and C++ languages. Although the main codes were written for a SUN 6/690 computer with parallel processing capability and over 30 gigabytes of on-line storage, they were initially developed on PC machines. In fact, the progression of computer power has moved so quickly that the main codes will now run on Pentium-chip PC computers at nearly the same speed as developed for the much larger mainframes. The codes can be compiled with extended-memory FORTRAN (HEDR uses Lahey FORTRAN 90 extended-memory compiler). The executable code for the environmental transport code is 75 megabytes, and data inputs to the code exceed 300 megabytes per year of execution. Computers to perform this type of calculation may now be purchased for \$5-9,000.

A geographical information system (GIS) was used to prepare the HEDR "public information" output for distribution. The GIS used was ARC/INFO. Both the surface water scientists at MSL and those at PNL agree that GIS technology is probably inappropriate for most dose reconstruction uses. Very "regular" information, such as comes out of most calculational programs, is better used in flat files, so that the user does not pay a huge

price in overhead and speed. Database managers in general add to code complexity in most applications.

Epidemiology

Staff at the Fred Hutchinson Cancer Research Center in Seattle described the process and status of the Hanford Thyroid Disease Study (HTDS). The HTDS study uses the modeling results of the HEDR project to estimate radiation doses to real people who lived in the vicinity of Hanford in the 1940s. The HTDS staff have worked to locate individuals, obtain life history information to use in the dose reconstruction models, , and check for the health status of the individuals.

The HTDS is a cohort study; the cohort consists of about 4700 individuals who were born in the Hanford vicinity between 1943 and 1948. About 3400 of these individuals have been located, about 1300 have been intensively interviewed, and about 1500 clinical examinations have been performed to date.

The individuals life histories are obtained through a computer-aided telephone interview (CATI). A paper copy of the flow chart of questions was obtained; in written form, this questionnaire is over 100 pages. A discussion resulted concerning the possibility of respondent bias to the questionnaire; the HTDS staff are not applying any "corrections" to the responses they receive. The individual data acquired so far are similar to the generic default data provided by the HEDR project.

A suggestion was made that the results of the CATI could be calibrated using autopsy data of strontium-90 in bones. This approach could work with the *Mayak* data, but was considered infeasible with the US data.

The HTDS individual data are stored from the CATI in ORACLE or FoxPro software. Generally, they use Pentium PC computers. The overall HTDS database will be about 2-3 megabytes in total. The outputs from the dose models are much larger than the inputs from the CATI; generally these are reduced to statistical summaries of the voluminous output. The HTDS staff will not be using the EPICURE software, in part because of the nature of the uncertainty analysis - the doses are actually correlated between individuals.

The group assembled at the closing workshop in Washington, D.C., emphasized

the importance of defining the exposed cohorts early in the dose reconstruction, so that efforts could be focused. The Techa cohort is currently defined as those who lived along the Techa for at least one month between 1 January 1950 and 31 December 1952. It was pointed out that the ideal case would result in individual doses, annually and cumulatively. As a secondary position, doses by groups could be used, as long as the groups were as small as possible and stratified by age. The least desirable option would be village-level dose estimates.

Notes on Databases

Devin Smith provided information on how data were handled in two large projects unrelated to dose reconstruction. The Programmatic Environmental Impact Statement (PEIS) and the Hanford Integrated Risk Assessment Project (IRAP). These projects used large databases of information on numerous waste sites, numerous potential contaminants, various environmental settings, with variable supporting data. The data had different degrees of "goodness," and was given in different units and dimensions. The database had to convert units, standardize dimensions, and provide genealogy for each piece of information. It had to be available to many users simultaneously.

The database manager used for both of these large projects was FoxPro, with additional programming in C language. FoxPro uses dBase format (.dbf) files. FoxPro was used because it has the fastest PC index implementation of any database manager. It is sufficiently flexible to interact with programs written in other languages as well, and it has a good programming language. FoxPro will read files in ASCII, dBase, or EXCEL format. FoxPro has access to Windows libraries, and can thus communicate with other Windows-based programs using Windows environment variables, or to/from C programs through application protocol interface (API).

Other possible databases were discussed. MicroSoft Access is a competitor, but is slower. Clipper is also slower; an advantage of Clipper is that it may be compiled to make data storage smaller. Paradox is similar and slightly slower. Visual FoxPro is a recent release; it is a Windows 95 product.

Staff at Mayak already use and are familiar with FoxPro. Staff at URCRM use a

database manager specifically designed for use with the Chelyabinsk environmental and human data. URCRM wishes to continue to use and enhance this system.

Summary and Recommendations

The primary objective of the discussions was the development of a list of hardware and software requirements. The minimum requirements were determined to be easily obtained; large computers or expensive commercial software were determined to be generally unnecessary. Hardware and software required for the start of the project include:

Hardware

1. DELL OPTIPLEX XMT 5120 (example) (2)
120MHz, PENTIUM PROCESSOR
32MB RAM/1GB HDD
2MB Video Memory
512KB Cache
17 Monitor (17" CRT,.26mm)
3 Year Extended Warranty
CD ROM
Back Up System (>=1GB)
UPS System

- 2.486DX2/66 Motherboard,Coprocessor (4)

- 3.500MB HDD (5)

- 4.32MB RAM (4x8Mb)

- 5.HP ScanJet IIIci (2)

Software

6. Basic Software for Pentium Computer: DOS,Windows 3.x (2)

7. Lahey Fortran 90 with additional tools: (2)

8. C++ for Pentium (2)

9. STATGRAPHICS, Statistical pa

ckage, the last edition (2)

10. FoxPro for MS-DOS and Windows 3.x, last edition (2)

11. ArcView for PC (2)

(The points 2,3,4 are required by URCRM only.

The points 1,5-11 are required by MAYAK and URCRM.)

In addition, the following general recommendations were developed:

- The dose reconstruction efforts at Hanford and *Mayak* have similarities and differences. The differences must be emphasized.
- The United States has great experience in dose reconstruction. The following items are of great interest to the Russian investigators:
 - Planning and management of the project,
 - Organization of information support, especially treatment of original documents concerning site operations,
 - Methods of modeling radionuclide migration, particularly the atmospheric pathways,
 - Optimization and validation of models,
 - Uncertainty and sensitivity analysis techniques, and
 - Techniques for epidemiological study for dose reconstruction, with emphasis on the iodine-131 releases.
- Direct use of the HEDR models for the Urals population is impossible without adaptation for local conditions in the Urals region. It will be interesting to investigate the adaptation of the models and evaluation of differences for evaluating Russian models.
- It is important for dose reconstruction to exactly define the population cohorts. It is recommended to add the population of the City of Ozersk to the domain.
- Dose reconstruction requires treatment and storage of a huge amount of information. It is necessary to have high-powered computers such as IBM Pentium-based machines. Software programs that will be useful include FORTRAN and C

language compilers, SAS statistical analysis, FoxPro database manager, and Arc/Info geographic information system. Note that URCRM uses a self-developed database manager; its expansion should be supported.

- It is important to have the opportunity to request additional software during the life of the project. All potential uses and problems cannot be foreseen at this time, and the ability to obtain other programs is vital.
- All participants must be included in discussions of the planning and results of the project. JCCRER Executive Committee members are not capable of defining the overall requirements and direction without significant inputs from the working staff.
- The "final" report of the feasibility phase should be a detailed work plan including goals, required steps and resources, and timing. This should be prepared during a working meeting in Chelyabinsk in January 1996.

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Itinerary for JCCRER Visit

<u>Date</u>	<u>Location</u>	<u>Topic</u>	<u>Contacts</u>
9. Sat	Seattle	Arrive	Bruce Napier
10. Sun	Seattle	Visit Seattle area	Bruce Napier
11. Mon	Sequim	Marine Sciences Lab	Ann Drum Peter Becker Lyle Hibler
12. Tues	Sequim	River Modeling Techa River	Terri Paluszkiwcz Peter Becker Lyle Hibler
13. Wed	Seattle	Hanford Thyroid Disease Study	Ken Kopecky Scott Davis Mark Saporito Peggy Adams-Meyers
14. Thurs	en Route	Mt. Rainier	Bruce Napier
15. Fri	Richland	Battelle Badging Russian Presentation	Bill Farris HEDR Team
16. Sat	Richland	Sausage Fest	Bruce Napier
17. Sun	Richland	Boating	Bruce Napier
18. Mon	Richland	Data Searching Source Term River modeling	Shirley Gydesen Marshall Richmond
19. Tues	Hanford	Site Tour PNL/Russian Programs JCCER (Wastes)	Bruce Napier Laurin Dodd, Bryan Gore Don Bradley, Mike Foley
20. Wed	Richland	Atmospheric transport Databases	J. Van Ramsdell, Jr. Devin Smith

21. Thurs	Richland	Monitoring/databases HEIS Database	Roger Dirkes Ted Poston Bill Hanf Lynn Bisping
22. Fri	Richland	Dose Reconstruction Models & Platforms	Bruce Napier Paul Eslinger
23. Sat	Richland	Hockey	Bruce Napier
24. Sun	Richland	Weekend	--
25. Mon	Richland	Prepare conclusions to present at workshop	Bruce Napier
26. Tues	en route	Travel to D.C.	Bruce Napier
27. Wed	Washington	a.m. Visit D.C. Academy of Sciences p.m. DOE Intl. Health	Bruce Napier John Zimbrick, Evan Douple Frank Hawkins, Elaine Gallin Mohandas Bhat, Maria Pavlova
28. Thur	Washington	Workshop	JCCRER Pls,
29. Fri	Washington	Workshop	JCCRER Pls,
30. Sat	Washington	Depart	

Workshop attendees: Lynn Anspaugh, Larisa Anspaugh, Terri Thomas, Andre Bouville,
Mona Dreicer, Valeri Khrouch, Viktor Minenko, Dan Hoffman (9/29), Elaine Ron (9/29)

DATA MANAGEMENT SYSTEM FOR THE FOLLOW-UP OF EXPOSED POPULATION IN THE URALS

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Abstract -The paper presents the description of the data management system MAN (DMS MAN) for the support of long-term follow-up of population exposed as a result of radioactive releases by plutonium production facility Mayak and environmental contamination in the Urals. The subjects of DMS are 90,000 persons exposed in the 1950's in the vicinity of the Techa river and/or as a result of Kyshtym Accident. DMS MAN contains personal data, places of residence within catchment area and last address, pedigrees, individual dosimetric and medical examination data, the causes of death for the deceased. DMS MAN is based on IBM PC/AT local area network (LAN) and fits the information sources (patients and documents) and data processing realized in the Urals Research Center for Radiation Medicine (URCRM), Chelyabinsk, Russia.

INTRODUCTION

Radiation exposure of population in the Urals occurred as a result of fallibility in technological processes at the Mayak plutonium facility in the 1950's. The major sources of radioactive contamination were the discharges of liquid wastes into the Techa River (1949-1956); an explosion in the storage facility of radioactive wastes (so called Kyshtym Accident) which formed East Urals Radioactive Trace (EURT) in 1957; and gaseous aerosole releases within the first decade of the facility's operation (1949-1957). The series of radioactive releases which occurred in the same region in different years and the intensive migration of population within contaminated area have become the specific features of the Urals situation. It determined the following approach to epidemiologic follow-up: selecting of fixed cohort of people and tracing all places of residence after the beginning of radioactive contamination for each subject of this cohort (Degteva et al 1995). Such cohort numbering 90,000 subjects of accidentally exposed population (the residents of the Techa riverside communities and the residents of the area covered by EURT) was established at the Urals Research Center for Radiation Medicine (URCRM), Chelyabinsk. The data for identification of exposed persons and their children are kept in MAIN registry. The formation of this registry has been almost completed but the personal data are continuously updated and corrected. The structure of MAIN registry is shown in Fig.1: 62,300 persons were registered in connection with the exposure situation on the banks of the Techa river; 26,000 persons were registered in connection with EURT; and 1,700 persons were exposed in both situations. The Techa population is subdivided into three cohorts of subjects: 26,500 persons exposed in the period of maximal releases between 1950-1952 who were born before the onset of exposure (1949 year of birth and older); 7,800 persons of the same ages but who settled in the Techa communities after 1952; and 29,700 children of exposed parents. The data resulted from long-term observation of exposed people have been collected in Clinical Department of URCRM (the head is Dr. M. Kossenko), recorded on paper media, and a part of them in computer data bases. This information has formed

appropriate basis for population risk analysis under conditions of continuous exposure. The follow-up is being continued and the special software has been developed to manage available data.

PURPOSES OF THE DATA MANAGEMENT SYSTEM

The goal of data management system MAN (DMS MAN) development is software and hardware support of long-term observation of exposed population for individual dose evaluation and risk assessment. The purposes of DMS MAN are: to arrange initial data; to verify the information by means of comparison of data taken from different sources; to support processing of available information and error-free supplementing by new information. So, the goal is to transfer available information into forms (structures) yielding to risk analysis, and to develop the basis for further long-term observation of exposed population (including offsprings).

DMS MAN is oriented to the registration documents and medical examinations flow charts (paper media), which are used at the URCRM clinics. They are: registration journals; the copies of rural property registration books (economy taxation books); small-cards; out-patient's cards (OPC); in-patient's case reports (IPCR); death certificate (DC) copies; birth certificate (BC) copies. Fig. 2 shows the information on the subjects of MAIN registry collected from 1950's and arranged in the MAN data base. The central circle in Fig. 2 is the data for identification of a person. Each registered person has a special system number (SN) which is the key to other personal information on the dates and the places of residence within the catchment area, postal address, the pedigree, the results of medical and dosimetric examinations, and causes of death for the deceased. The management of these data fits to the information sources (both verbal data received from patients and official documents) and data processing used in the URCRM for many years.

INFORMATION SOURCES AND DATA PROCESSING

The typical scheme of routine work with patients is the following. The patient's system number is checked at URCRM clinics registry according to registration journal. The latter contains SNs, first, middle and last names of patients for each settlement. Knowing the SN a registering clerk finds out-patient's card. The registering clerk inquires the patient about passport data, the places and terms of residence in contaminated and control territories, the current address, education, employment, unhealthy work conditions, risk factors, family history (that is information on parents, brothers, sisters, children, wives/husbands). After interview patient passes through whole-body counting (WBC) and medical examination. All data are recorded in OPC. In case of patient's hospitalization, the diagnosis is written from IPCR down into OPC by the doctor in charge at the in-patient unit. Every day after doctor's examination or patient's discharge OPCs are passed to statistics section where the small-card index information is verified. The family history is specified more precisely: in case the patient has got children or grandchildren, who have not been included in small-card index before, these latter are assigned SNs and they get their own OPCs; in case of some relative's death the small-card and OPC are notified: "dead according to someone's words". In case of the first visit of unregistered person, who really lived on contaminated territory the documents listed above are filled in for him and his relatives. Doctor encodes patient's diagnosis. Only after that OPCs are passed to information center, where the computer data base is updated.

Two or three times a year the clinic employees go to settlements belong to the catchment area (five districts of Chelyabinsk region and Kurgan region). Besides the medical observation the patients' inquiry aimed at precise specification of passport

data and family histories is carried out. Back in clinic the obtained information is verified by means of comparison with small-cards (the work as with OPCs), diagnoses are encoded. New patients are registered, given SNs, small-cards and OPCs. These new documents and updated information on the registered patients are passed to information center.

Periodically the statistics and clinical sections employees make copies of DCs and BCs for the residents of catchment area in Bureaus of Civic Status registration archives. These data are matched with the roster of exposed people (MAIN registry). Then the small-card index information is verified. The deceased are marked, the newborn are registered. Information on the newborn and the deceased is passed to computer data base. Currently there is no mechanism for routine collection of DCs for people known to have left the catchment area (only from relatives' words).

SYSTEM HARDWARE AND SOFTWARE

DMS MAN is based on IBM PC/AT local area network (LAN) which consists now of the following hardware: the main file server; additional file server for coping all crucial data from the main server; 15 workstations of various types; one "drifting" tape drive, which is usually connected to data base administrator's workstation (the copies of database are being made daily); the LAN media is 10 Mbit "thin Ethernet". The URCRM LAN runs Novell Netware v.3.11 software.

DMS MAN is based on the relational data base system RDB (C) originally developed by A. Kozyrev for work on IBM/PC compatibles under DOS. Any RDB relation consists of corteges (records) of the same length. Each cortege is a sequence of domains (columns). Thus a relation may be thought of as an ordinary rectangular table. The data in relations is stored as internal binary computer formats. While maximum number of columns is limited by the size of available dynamic memory, maximum number of corteges is limited by the capacity of the disk used. RDB has a set of general-purpose utilities, which may be grouped in the following way: relational algebra, mathematics and statistics, general service, import and export utilities. The utilities implementing relational algebra can benefit in the case of sorted relations-operands, dramatically decreasing the operation time. The brief description of RDB is given in Appendix. RDB is compact, flexible and polifunctional system. It supports the entry, storage and initial processing of data and compatible with standard statistics and graphic software. But for the optimization of routine work with patients and other information sources as well as generalized updating of information from all main relations from the data base special problem-oriented tasks have been developed.

PROBLEM ORIENTED TASKS

The problem oriented task is a shell for the call of special task and for the exchange of information between different registries. These tasks are installed on LAN workstations in specific sites of URCRM where routine work with the sources of information is performed (clinics registry, statistics section, whole-body counter unit, information centre). All the tasks which compose DMS MAN (Identification, MAIN registry, Pedigrees editor, Diagnoses editor, etc.) are specific editors which maintain the data base in updated condition. The changes are not immediately put into the main data base, they find themselves in the temporary buffers. There is a special set of administering tasks which are activated according to a predefined schedule. The administering tasks change the main data base, taking information from the temporary buffers.

Identification Task

Identification is the key task which supports access to each registered person. It must be started (as a child process) from other problem-oriented task, which compose DMS MAN (MAIN registry, Pedigrees editor, Diagnoses editor, In vivo radioactivity measuring). An example of screen layout for Identification task is shown on Fig. 3. The main window at the left serves for search prescription input (with the label! "") and search results visualization. The right window serves for incremental search of fitting texts while text data is entered, and for visualization of all the system numbers which meet the search prescription. Because the text data is stored as numerical codes in the identification registry, special RDB relations-coders are used to get the appropriate codes for the texts entered. The process of incremental search in the coders is displayed in the right window, while the text is being entered letter by letter. A text without code cannot serve as a search prescription parameter (except for the case when only the first letter of name and father's name is checked). Similarly, when a patient is found and his data is displayed in the main window, the relations-decoders are used. Checks for consistency include date tests and logical tests performed as input field filters. Test for inadmissible void fields is also performed.

Main Registry Task

MAIN registry task is the key task which supports consistency of identification, migration, last address data and data on the deceased. The task's flow chart is shown on Fig. 4. The data input is started as a quest of a real patient and/or reading his medical card records (Fig. 4, left). To gain access to a person's migration, last address, and death data you must identify him i.e get his SN. This can be performed with the help of the Identification task. Being started as a child process from the MAIN registry, it stores identification results in a special common data structure. If a search prescription contains SN, only one person is identified (the simplest case). In other cases data of several persons may meet the search prescription, and additional information should be taken into consideration (migration data for each of such persons can be viewed, etc.). The information utilised for tracing has been kept in three registries of the data base MAN: Identification registry, Migration registry and Last address registry (Fig. 4, top). The numbers of persons for all registries reflect the condition of data base on December 20, 1994.

After the person becomes identified his SN is the binary search key to other registries. The corresponding data can be viewed and edited. The settlement names are stored as numerical codes in the Migration registry, so special encoders and decoders are used in the editing process. The causes of death and other data on the deceased from DCs are kept in two special registries (Fig. 4, down and right). Comprehensive control of the data for consistency is the main merit of the MAIN registry design. The long-term experience of the URCRM database management is implemented. Checks for consistency include date tests (dates of birth, vital status, settlement evacuation, etc.) and logical tests, some of which are performed as input field filters. Test for inadmissible void fields is also performed. To encode the death causes one more task (besides the Identification task) is started as a child process. It's the ICD-9 disease coder. The ICD-9 Disease Coder data base (Fig. 4, right) contains text and numeric information on the disease classes, groups and subgroups, aetiology links, additional codes (E,V), all stored in RDB relations. The Disease Coder has an interactive multi-window screen interface with the following functions: disease code generation by browsing through text data; getting text interpretation of the entered code; context code search by key words. The sources of information on the causes of death (DCs, Autopsy Protocols, etc) are recorded too. The edited data are saved in temporary buffers (Fig. 4, down and left).

Pedigrees Editor

Pedigrees Editor makes it possible to view and edit a patient's pedigree. At the same time you can view a patient and his parents' family members and his own family members. The patient whose families are currently displayed is called "Center" (Fig. 5). Placing any other relative to the "Center" position you can move up or down the pedigree within the limits of available information. There are six windows on the display screen (see Fig. 5). The lower windows are scrollable. Any window can be activated by mouse or keyboard. An active window has double frame of brighter color. In the active scrollable window any relative in the list can be marked (selected). The selection remains valid after you quit the window. Those who died early in their life can also be displayed. Data is saved also before a new "Center" is identified.

This above mentioned process starts from Identification task as a quest of a real patient and/or reading his medical card record. (see Fig. 6). All members of patients parents' family and own families are found from 6 sorted relations of Pedigree data base (Fig. 6, up and right) which stores information about families where persons are children and where persons are spouses. If the members of family are not exposed information about them is saved in different structure than for exposed members and includes surname, name, father's name, year of birth, or sometimes not so complete. The information about early died children has a following structure. Every new added family member is tested for being suitable and an error or a warning message may be displayed. Among the checked data there are dates (age), sex, surname, father's name, etc. The results of editing actions are kept in temporary buffers which have the analogous structure as the relations of Pedigree data base, but unsorted (Fig. 6, down and right). The administering task changes the Pedigree database taking information from the temporary buffers.

Diagnoses Registry Task

Diagnoses registry task is a problem-oriented editor of a patient's disease-related data. The diseases list has a periodical structure, because examinations are being held periodically. So you can meet a chronical disease several times in a list. A diagnosis can be verified and revised. The task's flow chart is shown on Fig. 7. The data input is started from Identification task (Fig. 7, left). Being started as a child process from the Diagnoses registry, it stores identification results in a special common data structure. After the person is identified, his SN becomes the binary search key to the Diagnoses registry.

To edit the diagnosis code field one more task (besides the Identification task) is started as a child process. It's the ICD-9 disease coder supported by a special data base (Fig. 7, right). The edited data are saved in temporary buffers. Consistent data are also saved before a new patient is identified. When viewed/edited, the diseases in the list are also additionally displayed in the decoded (text) form (Fig. 8). Aetiology can be viewed for a diagnosis, if the diagnosis allows different ways of its coding. Aetiology is displayed as a scrollable list of aetiologicaly linked diseases. A diagnosis can be revised if a patient has recovered or if verification has proved the diagnosis to be doubtful. A diagnosis verification may be performed according to a set of diagnostic criteria and special algorithms which consider each criterion's "weight" in evaluation of the diagnosis' validity degree (True, Probable, Doubtful). Diagnostic criteria and decision tables for validity evaluation are stored in RDB relations and form the Diagnoses Verification data base (Fig. 7, down and right). The verification results in the diagnosis validity sign value displayed. Also a verification report file is produced, which can be printed and pasted into the patient's OPC. The need of verification has become obvious because of the changes which had taken place in disease classification and diagnostic criteria during the 40-year period of the medical observation. Moreover, many diseases had

been assigned codes of an unspecified disease in the data base. The existing medical documents archive makes it possible to set a more correct diagnosis retrospectively in all the above mentioned cases.

Comprehensive control of the data for consistency is one of the key issues of the Diagnoses registry design. The controlled errors include "relic" errors and errors of the current editing. The relic errors appeared during the earlier period of filling the Diagnoses register with the help of general-purpose RDB relation editor (SED) which has no specific error detection. The relic errors are usually contradictions in disease coding. They appear on monitor as blinking symbols that indicate wrong values. The current editing errors include date tests and logical tests, some of them being performed as input field filters. Below there are some errors which generate messages when the diseases list is checked before saving to the disk: "relic errors still remain"; "inadmissible void fields"; "wrong sequence of examination dates"; "the disease contradicts with the patient's sex"; "different examination place code, while the date is the same"; "date beyond admissible margins; incomplete disease code".

The ICD-9 Disease Coder data base contains text and numeric information on the disease classes, groups and subgroups, aetiology links, additional codes (E,V), all stored in RDB relations. The Disease Coder has an interactive multi-window screen interface with the following functions: disease code generation by browsing through text data; get text interpretation of the entered code; context code search by key words.

In Vivo Radioactivity Measurement Task

In Vivo Radioactivity Measurement task (IVRMT) is the part of the Whole-Body Counter Complex (Kozheurov 1994). The following in vivo measurements are being held in the URCRM: whole body counter (WBC); teeth beta count rate; forehead bone beta count rate. IVRMT supports the professional operator in performing the following functions: background measurements for WBC, teeth and forehead detectors; standard sources radiation registration efficiency measurements; control of energy scale peaks position, etc.; identification of patient; measurement results processing (spectra and count rates). IVRMT automatically processes measurement results, saves spectrum, forehead bone and teeth count rates in the special data base (so called Strontium registry) and generates the measurements certificate (which is displayed on the screen and can be printed). Strontium registry contains the WBC measurements for 14,400 subjects; teeth measurements for 15,440 subjects and forehead bone measurements for 12,783 subjects. About 40% of these persons have repeated measurements (up to 46 measurements for the same person).

Strontium registry contains the patients, who are (were) residents of the contaminated regions (the members of MAIN registry), and "background" people (those who were just curious about their body radioactivity). A list of all available measurements for a given patient and his standard certificate are shown on Fig. 9 as an IVRMT screen example. The spectrum of the same patient is on Fig. 10.

CONCLUSION

The data management system MAN (DMS MAN) has been developed for the support of long-term follow-up of population exposed as a result of radioactive releases by plutonium production facility Mayak and environmental contamination in the Urals. The subjects of DMS are 90,000 person exposed in the 1950's in the vicinity of the Techa river and/or as a result of Kyshtym Accident. DMS MAN contains personal data, places of residence within catchment area and last address.

pedigrees, individual dosimetric and medical examination data, the causes of death for the deceased. DMS MAN is based on IBM PC/AT LAN and fits the information sources and data processing realized in the URCRM.

Acknowledgement- We wish to thank Dr. Richard Wilson, Mallinckroft Professor of Harvard University, who has provided us with power file server and LAN media and software, Mr. Lev Koscheev for the help in LAN designing and installation, and Mrs. Tatyana Temirova for computer graphic preparation.

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LEGENDS TO THE FIGURES

Fig. 1. The structure of MAIN registry.

Fig. 2. The information on the members of MAIN registry.

Fig. 3. Identification task screen with identified person.

Fig. 4. The scheme illustrating the work of MAIN Registry Task.

Fig. 5. Pedigree Editor windows.

Fig. 6. The scheme illustrating the work of Pedigree Editor Task.

Fig. 7. The scheme illustrating the work of Diagnoses Registry Task.

Fig. 8. The Diagnoses Registry Task screen.

Fig. 9. An example of the screen of "In Vivo Radioactivity Measurement Task". The list of available measurements and standard certificate (in Russian) are shown.

Fig. 10. An example of the screen of "In Vivo Radioactivity Measurement Task". The spectrum of the patient stored in data base.

APPENDIX. RDB: RELATIONAL DATA BASE SYSTEM

RDB (C) is a general-purpose relational data base developed for work on IBM/PC compatibles under DOS. Any RDB relation consists of corteges (records) of the same length. Each cortege is a sequence of domains (columns). Thus a relation may be thought of as an ordinary rectangular table (Table 1). Each relation is implemented as a two-file set: *.grf - the main file with corteges and relation structure *.adf - the file with columns' names and variable-length data (strings, etc.). The data in relations is stored as internal binary computer formats (Table 2). Relation can also contain undefined data (placeholders) in char, int, long, all float and strings data columns. Relations can be united in libraries, producing *.glb and *.alb files respectively. While maximum number of columns is limited by the size of dynamic memory available, maximum number of corteges is limited by the capacity of the disk used. RDB has a set of general-purpose utilities and program interfaces with C, C++ and Pascal. A C++ interface for MS Windows and Win32 is available.

Table 1. Typical structure of RDB relation

Columns	1	2	...	M
Corteges	Column 1 name	Column 2 name	...	Column M name
Cortege 1	Data	Data	...	...
Cortege 2	...	...	...	...
...	...	...	...	...
Cortege N	...	...	...	...

Table 2. The types and computer formats of RDB data.

Data type	Computer format
char	signed 8 bit (-127 : +127)
byte	unsigned 8 bit (0 : 255)
int	signed 16 bit (-32767 : +32767)
word	unsigned 16 bit (0 : 65535)
long	signed 32 bit (-2147483647 : +2147483647)
double word	unsigned 32 bit (0 : 4294967295)
float	32 bit float (-3.4 e-38 : 3.4e+38)
double	64 bit float (-1.8e-308 : 1.8e+308)
long double	80 bit float (-1.2e-4932 : 1.2e+4932)
fixed strings	strings with fixed length in column
strings	strings with varied length
binary data	binary data up to 64K in length
huge data	binary data up to 4G in length

There are 29 general-purpose RDB utilities, which may be grouped in the following way: relational algebra, mathematics and statistics, general service, import and export utilities. The utilities implementing relational algebra can benefit in the case of sorted relations-operands, dramatically decreasing the operation time.

Relational algebra utilities:

ANR.EXE - intersection program;

DVR.EXE - division program;

JNR.EXE - join program (if no common attributes are found, a Cartesian product of the relations is fulfilled);

ORR.EXE - unite program;

PJR.EXE - projects a relation (selects the given subset of columns and creates a new relation out of this subset);

SLC.EXE - select program (selects data which meet a predefined condition: the program's output can be another relation or an index file);

SUR.EXE - subtract program (allows different structures of relations-operands).

Mathematics and statistics utilities:

FTB.EXE - frequency table creation program (with output to another relation or a pointed output stream);

GRP.EXE - groups data within a column (the groups are given as number ranges, the grouping results in calculated frequency of data falling into each range and the percentage to total amount of the column data);

INV.EXE - inverts index for a relation (thus producing the inverted selection);

MAT.EXE - calculates mathematical expressions and statistics basing on a relation data (if the relation is not used, the program serves as a scientific calculator with a large set of functions and practically unlimited number of variables);

SUM.EXE - sums up numeric data in columns, calculates mean, finds a median (or any quantil), minimum, maximum, standard deviation, excess, variance, asymmetry, middle absolute deviation from median, absolute median deviation;

TRN.EXE - transpose program (converts columns of one relation to corteges of another relation);

UQR.EXE - makes data unique in relation by given attributes (leaves only different data in a column, or leaves only those which are repeated, or those which are unique), the program output can be another relation (even of different structure) or an index.

General service utilities:

CSP.EXE - general service program (add relation, copy column, change format, create index, copy relation, copy structure, change data type, change column width, delete column, delete relation, insert column, create relation, rename column, rewrite using index, set password, show structure, swap columns, compress relation);

MSR.EXE - merges sorted relations (any subset of columns may be sorted);

PST.EXE - pastes relations (analog of join program, but if no common attributes are found, the first relation cortege is pasted to void fields);

REC.EXE - recodes string data in relation (serves to eliminate errors produced by similar appearance of some Cyrillic and Latin letters, and for changing uppercase letters to lowercase ones or back; any text recoding can be done in general);

RLB.EXE - library manager (if an application uses many small relations, a library can be made of them, making data storage more convenient and shortening access time);

SED.EXE - interactive editor, serves to create, edit and view RDB relations, which are presented as rectangular tables on the screen. Supports all (13) RDB data types, has undo/redo feature, 22 command line keys (commands and options) which provide a customized start, a changeable configuration file (screen colors + command line keys), about 100 edit commands, accessible through menus and short-cut keys;

SFS.EXE - sort program (Quicksort method is applied to relation segments with consequent merging of the segments);

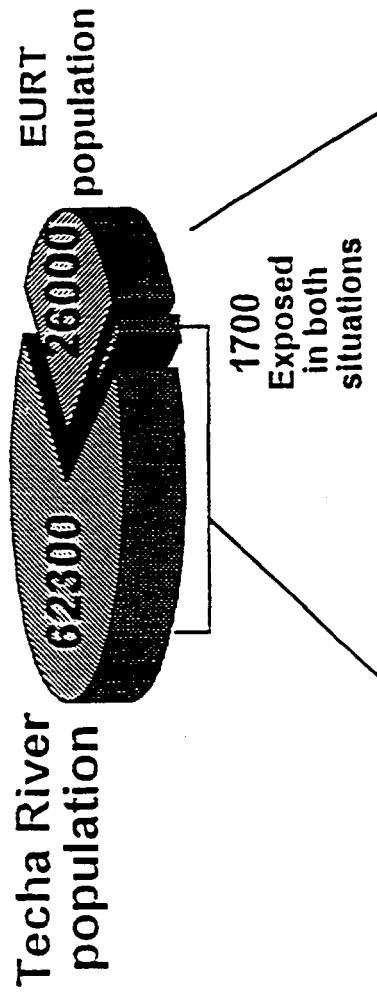
TRP.EXE - test and repair program (checks for integrity and cures a relation in case of errors in structure and data);

TSR.EXE - sort test program (if any subset of columns is supposed to be sorted, this can be checked).

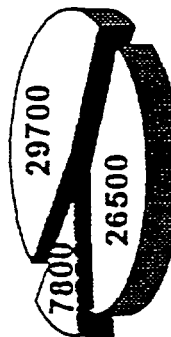
Import and export utilities:

DB3RDB.EXE - converts a dBASE3 relation into RDB relation; ITD.EXE - inputs data from a text file into an RDB relation; PRR.EXE - prints a relation as text table;
RDBDB3.EXE - converts an RDB relation into dBASE3 relation;

MAIN Registry



Exposed *in utero* and the progeny of exposed parents

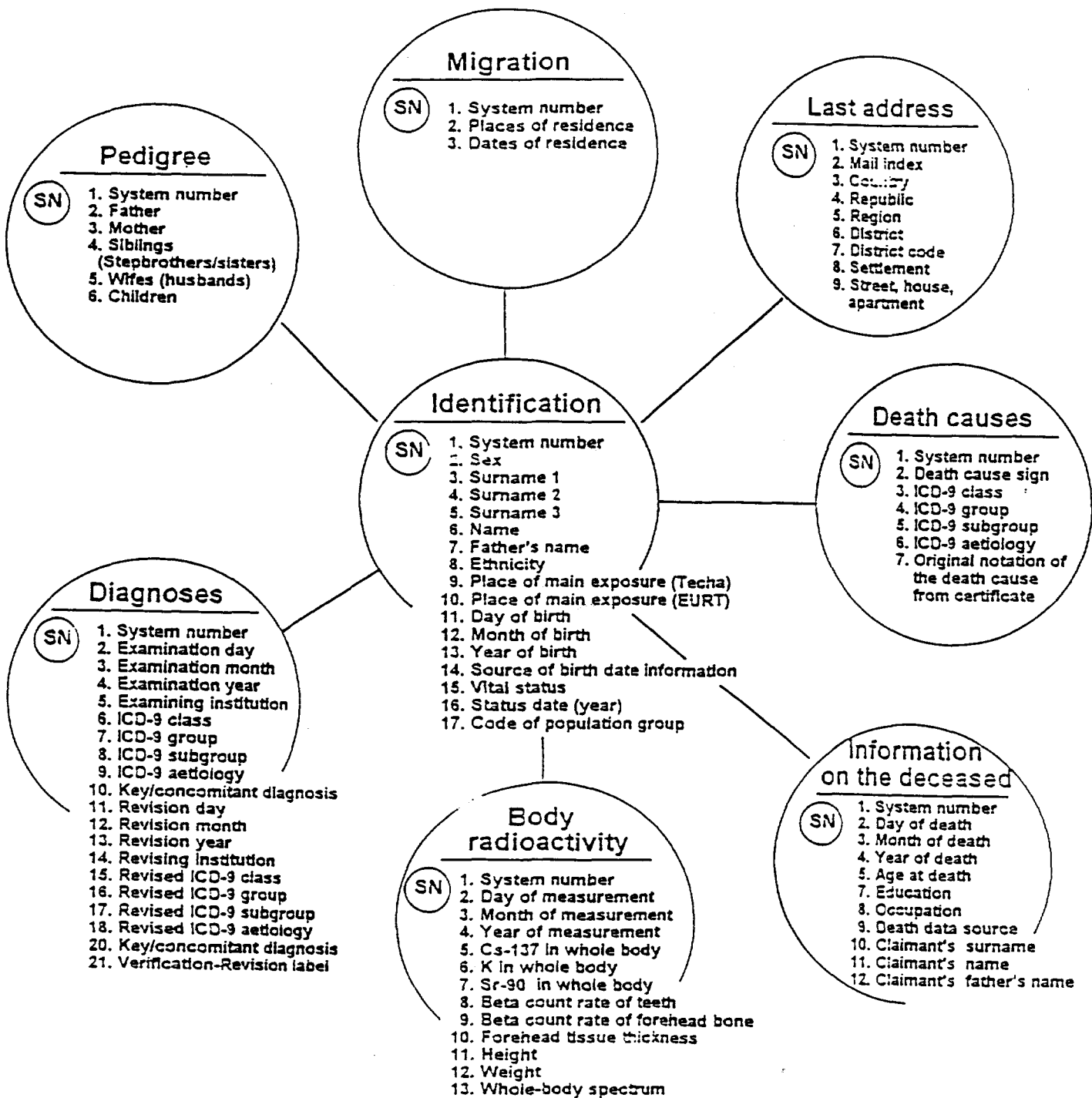


Born after accident

Born before accident



Data Base MAN



F1, F2, Alt+F2, F3, Alt+F3, F4, F5, Alt+F5, F6, F7, F8, F10, Alt+X

View		System Numbers
System Number	* 323.....	323
Sex	Man.....	
Surname 1	AKSENOV.....	
Surname 2		
Surname 3		
Name	VASILY.....	
Father's Name	IVAN.....	
Ethnicity	RUSSIAN.....	
Place of Exposure	METLINO.....	
Place of Exp. 2		
B Year	1930.....	
I Month	3.....	
R Day	20.....	
TH Certificate	Passport.....	
Vital status	Dead, Death Certificate	
Status Year	1971.....	
Group	1000.....	
		Total found: 1

Editor commands(functions):

- F1 - Help
- F2 - Enter search prescription (into the cleared window)
- Alt+F2 - Edit previously entered search prescription
- F3 - Search (Synonyms of surname, name and father's name are tested automatically)
- Alt+F3 - Search, but test only the first letters of name and father's name (if there are any)
- F4 - Change search key settings (only for the attributes, which can serve as search arguments)
- F5 - Add a new person to the register (with temporary system number)
- Alt+F5 - Add a new person with a given system number
- F6 - Edit(Update) data of a found person
- F7 - Delete data on a person from the register
- F8 - Fix a connected sytem number in case of addition/deletion
- F10 - Stop (or return to parent task) with saving data to tempora buffers
- Alt+X - Quit without saving

Fig. 3. Identification task screen with identified person

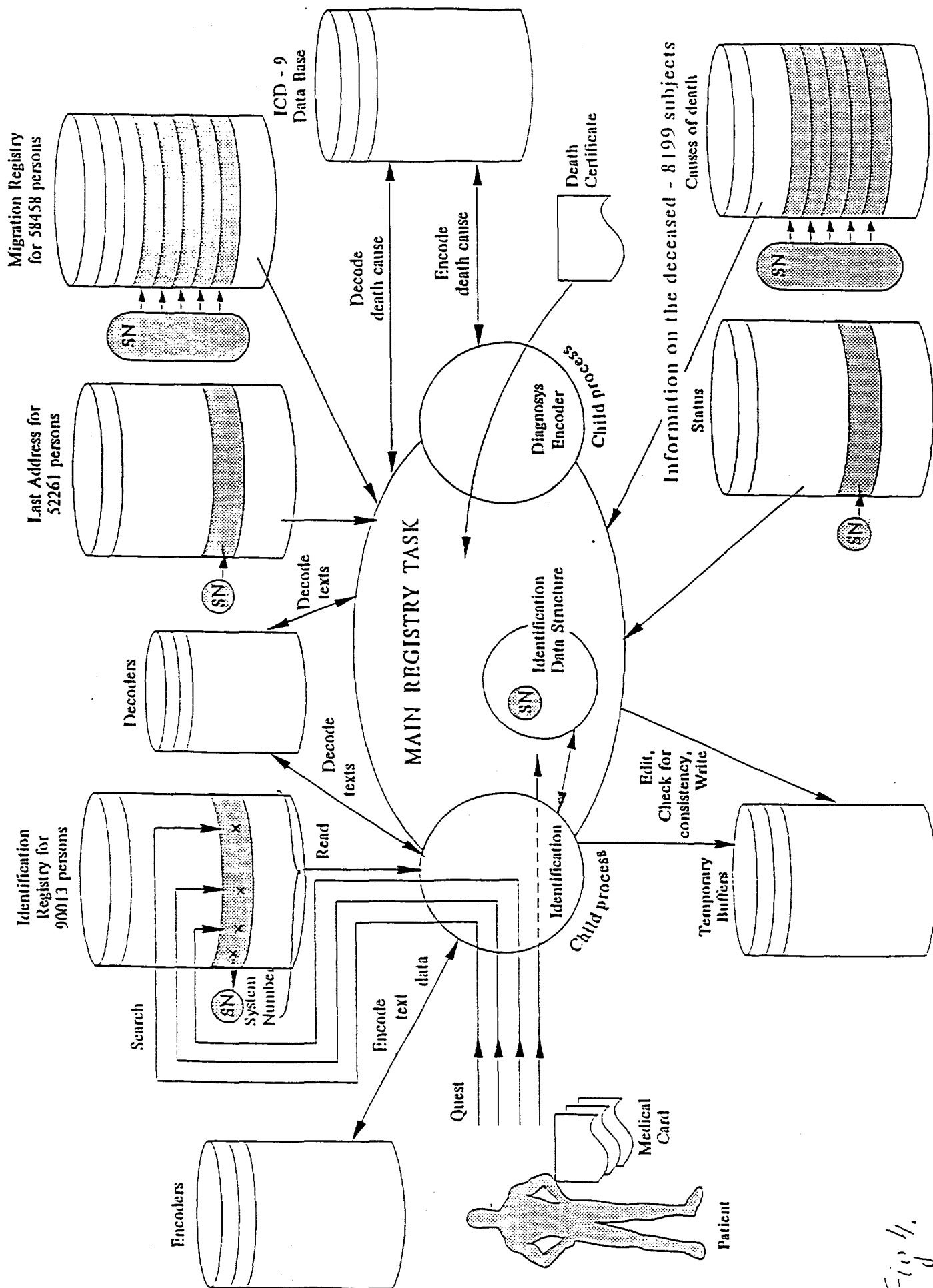
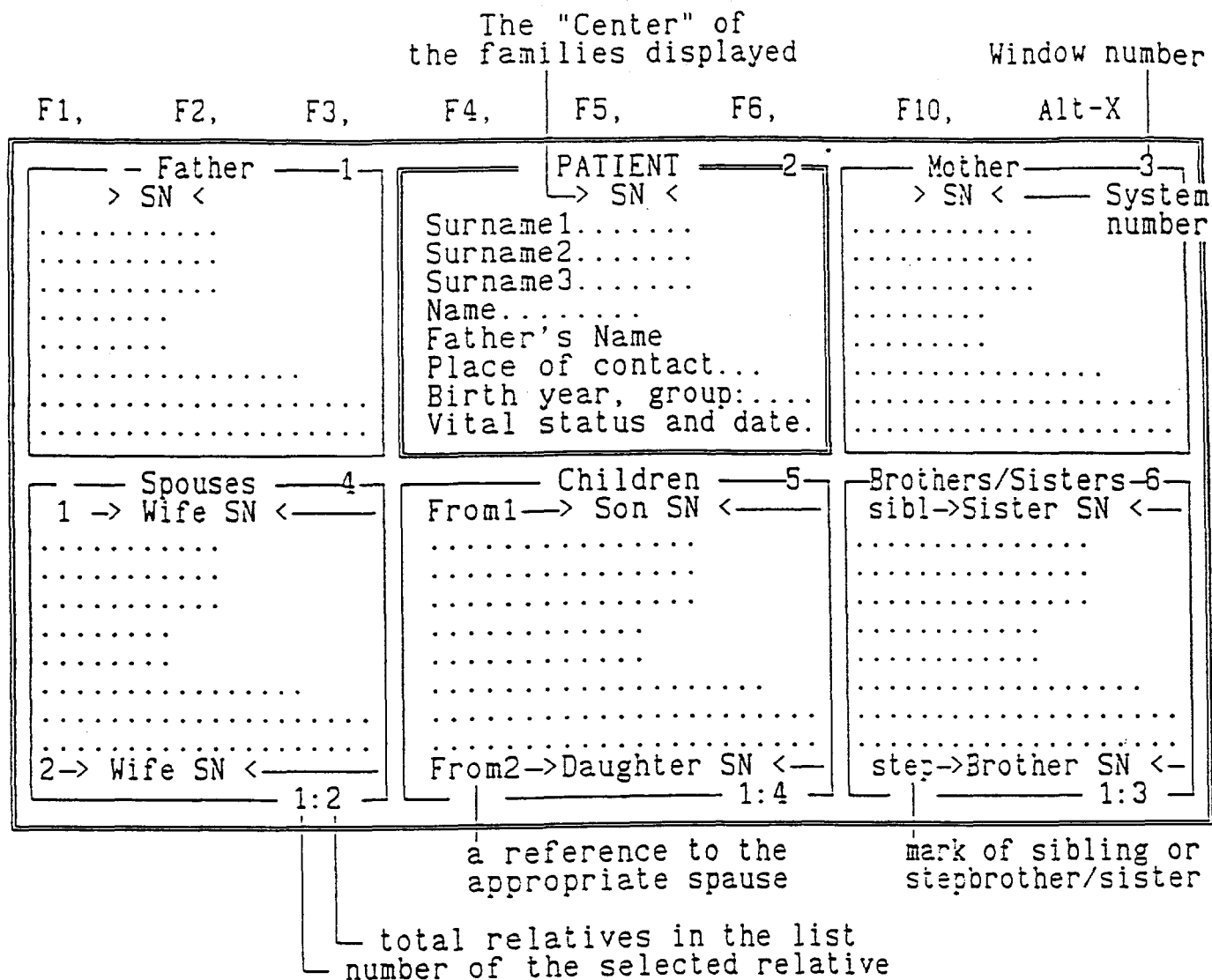


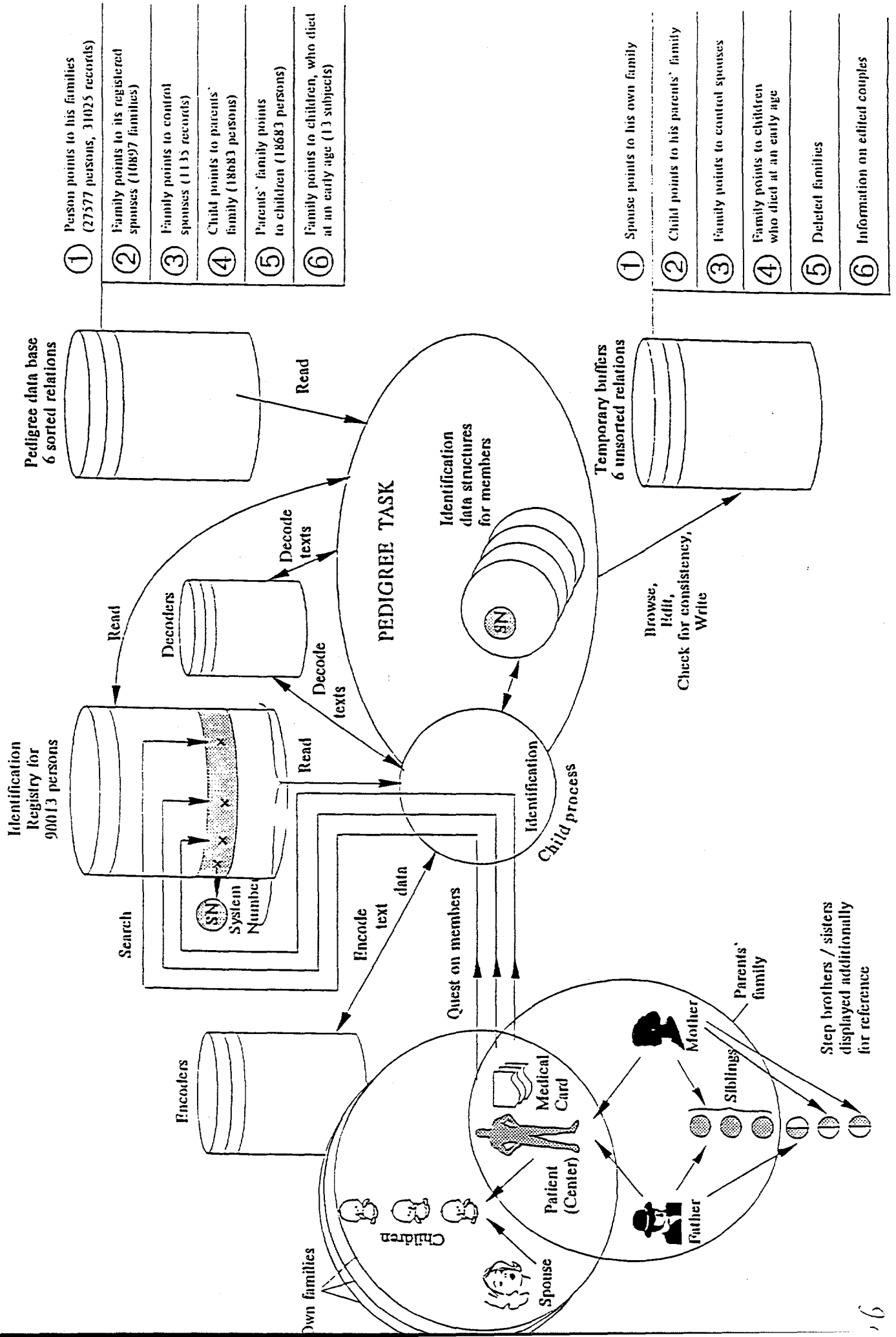
Fig 4.

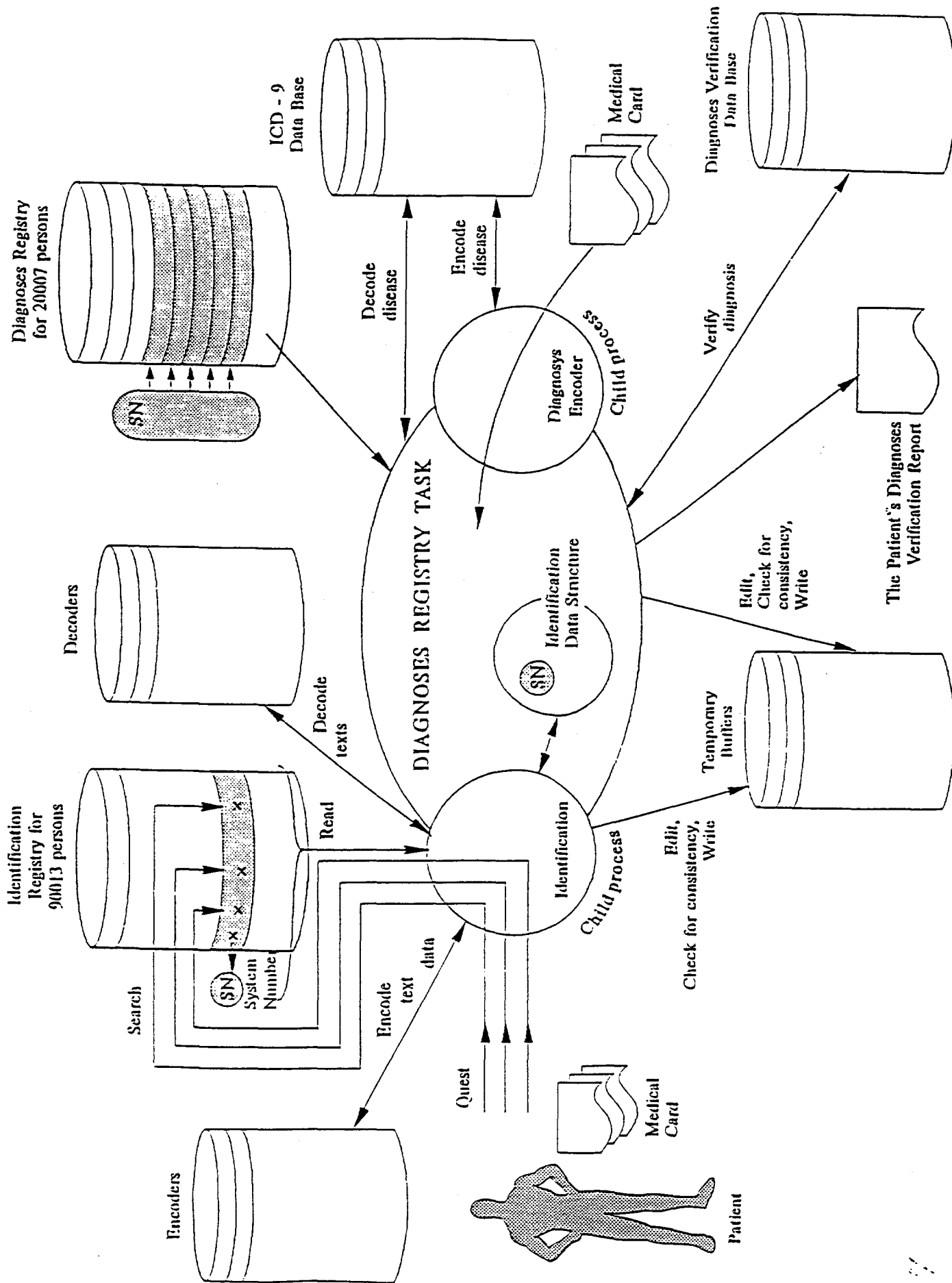


Editor commands(functions):

- F1 - Help
- F2 - Add a relative into the active window by starting the Identification task as a child process.
- F3 - Move the selected relative to the "Center" (thus viewing an upper or lower pedigree)
- F4 - Swap between 25 or 43/50 screen lines
- F5 - Move a message window (if there is any on the screen)
- F6 - Delete the selected relative from the active window
- F10 - Stop editing and save the results in temporary buffers
- Alt-X... - Stop without saving

Fig. 5 Pedigrees Editor windows.





F1 , F2, F3, F4, F5, F6, F7, F10, Alt+X

AKSENOV 1000		VASILY METLINO		IVAN ONIS		System Number: 323	
Date of birth		Certificate		Status			
20. 3.1930		Passport		1971 Dead, Death Certificate			

Key/concomitant diagnosis		Aetiology		Verification-Revision label	
Examination date	Where	ICD code	II	Subgroup	
19. 6.1953	320	1 17.990.4		irradiation effects	
20. 6.1954	320	1 17.990.4		irradiation effects	
14. 6.1955	320	2 8.478.0		other diseases of upp.respir.tract	
14. 6.1955	320	1 17.990.4		irradiation effects	
15. 6.1956	320	1 17.990.4		irradiation effects	
17.11.1956	230	2 12.680.2		furuncle	
17.11.1956	230	2 12.683.		acute lymphadenitys	
17.11.1956	230	1 8.487.1		influenza	
14. 3.1959	110	1 17.990.4		irradiation effects	
18. 1.1960	110	1 17.990.4		irradiation effects	

irradiation effects	1: 25
chronic radiation disease I degree, unspecified stage	

number of row —
total diagnosis in the list

The Diagnoses Registry commands (functions):

- F1 - Help
- F2 - Start Identification task (as a child process)
- F3 - Correct crucial identification data without restarting Identification
- F4 - View/Edit diagnoses list
- F5 - View aetiology list for the disease (if any)
- F6 - Revise the diagnosis
- F7 - Verify the diagnosis
- F10 - Stop with saving data
- Alt+X - Quit without saving

Fig. 8 The Diagnoses Registry View/Edit task skreen.

Patient Ident.	Measurements	Hardware Adj.	Administering	Quit
----------------	--------------	---------------	---------------	------

Date	Height cm	Weight kg	Cs-137 nCi	Potass. g	Sr-90 nCi	Forehead counter cpm	Teeth counter cpm	Forehead tissue thickness
25-02-1976			8	152	755	35		
14-08-1986			49	129	655	19		
19-08-1986			34	138	555	22		
20-08-1986			37	148	564	20		
22-08-1986			35	135	590	14		
25-08-1986			36	131	585	16		
26-08-1986			37	151	593	21		
19-08-1987			73	144	620	23		

Date: 1995-01-06 Birth date: 1938-02-05		Name: B. MOCEEB	
Cs-137: 5 nCi		Sr-90: 294 nCi	
10056:2 (System number)		Cs-137	Sr-90
% of admissible body content for professional workers		0.02	14.7

Fig. 9. An example of the screen of "In Vivo Radioactivity Measurement Task". The list of available measurements for the given patient and his standart certificate are shown. (In original in Russian naturally).

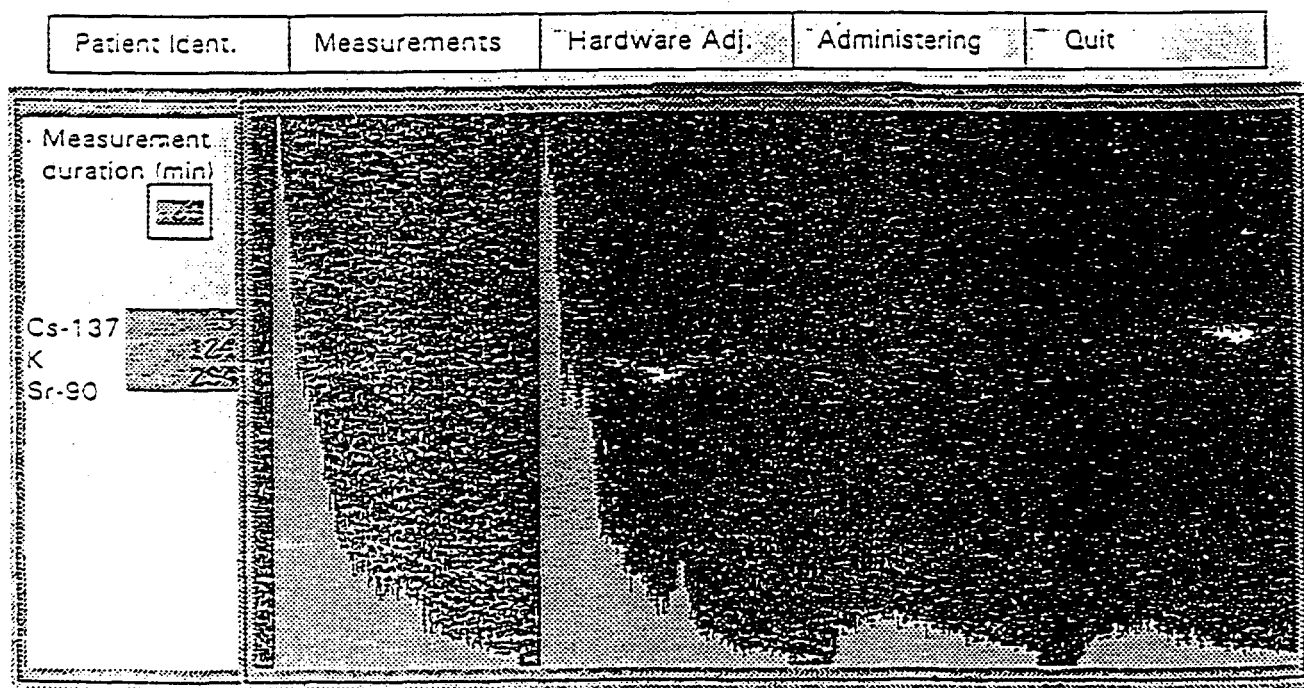


Fig. 10. An example of the screen of "In Vivo Radioactivity Measurement Task". The spectrum of the

