

French-German Initiative for Chernobyl

Radioecology Project Synthesis Report

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Abstract

Ten years after the Chernobyl accident, the "Institut de Radioprotection et de Sûreté Nucléaire" (IRSN) and "Gesellschaft für Anlagen- und Reaktorsicherheit" (GRS) decided to start an initiative, called the "French-German Initiative for Chernobyl" (FGI), to evaluate the consequences of the accident. The French-German Initiative for Chernobyl consists of three parts: the project 1 "Shelter", the project 2 "Radioecology", and the project 3 "Health consequences". According to the general agreement between IRSN for France, GRS for Germany and the Chornobyl Centre for Ukraine as the beneficiary, the radioecology project started at the end of 1998. Its purpose was to collect, validate and secure existing data and create a database which could be used for further investigations, too.

The selected topics addressed the most relevant transfer paths of radionuclides into the biosphere, i.e. transfer from soil to plants and from plants to animals, transfer from ground surface runoff to rivers and lakes, accumulation in the aquatic environment, and also transfer in the urban environment. Further important topics dealt with waste disposals and their management as well as with countermeasures and their efficiency in urban, agricultural and natural environments. Available data were compiled in specific databases and collected under the shell of a common database called REDAC (**R**adio**E**cological **D**atabase **A**fter **C**hernobyl). This also includes a copy of a website of the main results of the "Radioecology" project to inform the public and the mass media. Goals of the project have been achieved in most of the sub-projects and the main results of the work of the last four years are very satisfactory. REDAC, the soft-integrated database, contains substantial information for further scientific use and also for decision-makers.

Data on ecological information and environmental contamination have been collected and are presented together with local digitised maps to give a portrait of the studied regions. These maps can be used as a supplementation of the contamination maps of the European Council.

The results of the radionuclide transfer through food chains are presented, verified, quantified and compared with model assessments. All data are associated with a confidence index of the scientist to increase the credibility of the results.

All of the wastes disposals, sites have been identified in Russia and Belarus, but only partially in Ukraine. The characterisation of the waste (nature, quantity, radionuclide inventories) and the size, volume and radionuclide inventory and of the disposals have been characterised and stored in the database.

Countermeasures in urban and agricultural environment have been classified and their efficiency evaluated for post-accidental management purposes.

Good and trustful co-operation and partnerships have been established in the course of the project between French, German, Belarusian, Russian and Ukrainian teams, which promises to be a solid basis for the completion and total integration of the REDAC database, and further joint scientific work, e. g. in other ecological areas.

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1 Introduction

On 26 May 1986, the reactor n° 4 of the Chernobyl Nuclear Power Plant (ChNPP) was completely destroyed and approximately 11 EBq¹ of radionuclides were released up to hundreds of meters high into the atmosphere and spread in the environment all around the site and up to thousands of kilometres. The most contaminated zones are in the vicinity of the release point, but also in Ukraine, Belarus and Russia, where about 30.000 km² have a radioactive contamination density exceeding 185 kBq m⁻². In addition, nearly 8 PBq¹ of high-, medium- and low level-radioactive waste was buried in about 800 or more temporary disposal sites.

During the IAEA conference in Vienna in April 1996, on the tenth anniversary of the Chernobyl accident, the French and German Ministers of Environment decided to start actions for evaluating the consequences of the accident and help the three countries affected, i. e. Ukraine, Belarus and Russia, to overcome those consequences.

This French-German Initiative (FGI) for Chernobyl was realised by an agreement signed by the Institut de Radioprotection et de Sûreté Nucléaire, (IRSN²), France, and Gesellschaft für Anlagen- und Reaktorsicherheit (GRS), Germany, and the International Chernobyl Centre (ICC), Ukraine, as beneficiary. The French-German Initiative (FGI) includes three projects, Project 1, Shelter, studying the status of the Sarcophagus, Project 2, Radioecology, for evaluating the radioecological consequences of the accident, and Project 3, Medical consequences, for the health effects of this major accident.

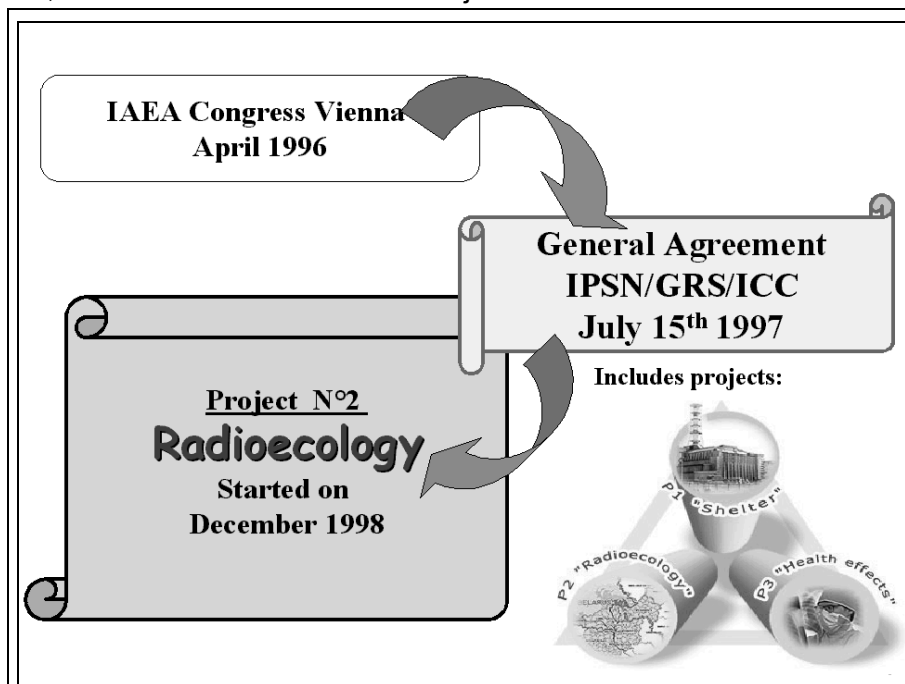


Figure 1-1 History of the Radioecology project

Project 2, dedicated to Radioecology studies, started at the end of 1998 with the signing of specific agreements between IRSN/GRS and the national institutes involved of Ukraine, Belarus and Russia. Each agreement covered a specific sub-project (SP) with selected radioecological or radiological subject areas.

1.1 Purpose

The purpose of Project 2 covered the following areas:

¹ 1 EBq = 10¹⁸ Becquerels – 1PBq = 10¹⁵ Becquerels

² Institute for Radioprotection and Nuclear Safety, previously IPSN : Institut de Protection et de Surete Nucleaire (Institute for Protection and Nuclear Safety)

- to collect, secure and validate existing radioecological data for setting up a database called REDAC (**R**adio**E**cological **D**atabase **A**fter **C**hernobyl),
- to use the data for the validation, adaptation and development of radioecological models,
- to give information or generate elements for developing tools to be used by decision-makers in post-accidental management,
- to inform about consequences of the accident for the environment.
- to support laboratories and institutes in the Community of Independent States (CIS).

1.2 Structure

The structure of the project was developed on the basis of the most interesting and relevant radioecological topics for Ukraine, Belarus, Russia, IRSN and GRS .

Three main of topic areas were jointly defined:

- Radionuclides in the environment
 - Terrestrial environment: transfer from soil to plants, then to animals,
 - Transfer to aquatic environment by surface runoff,
 - Aquatic ecosystems: transfer through the trophic chain,
 - Study of the transfer of radionuclides in urban environment.
- Radioactive waste
 - Inventory and characterisation of disposals sites
 - Characterisation of waste (nature and quantity)
 - Impact assessment and management strategies
- Countermeasures
 - for urban environment,
 - for agricultural, semi-natural and natural environments.

According to the purpose and the topics, the project was organised in ten sub-projects (Figure 1-2), namely:

- SP0 - Ecological Portrait of the Contaminated Regions
- SP1 - Contamination of the Environment
- SP2 - Waste Dumps and Waste Strategies Management
- SP3a - Soil-Plant Transfer
- SP3b - Plant-Animal Transfer
- SP3c - Run-off in Natural and Agricultural Environment
- SP3d - Transfer in Aquatic Environment
- SP4 - Urban Environment and Countermeasures
- SP5 - Countermeasures in Natural and Agricultural Areas.
- SP6 - Soft Integration of Project 2 "Radioecology" Databases

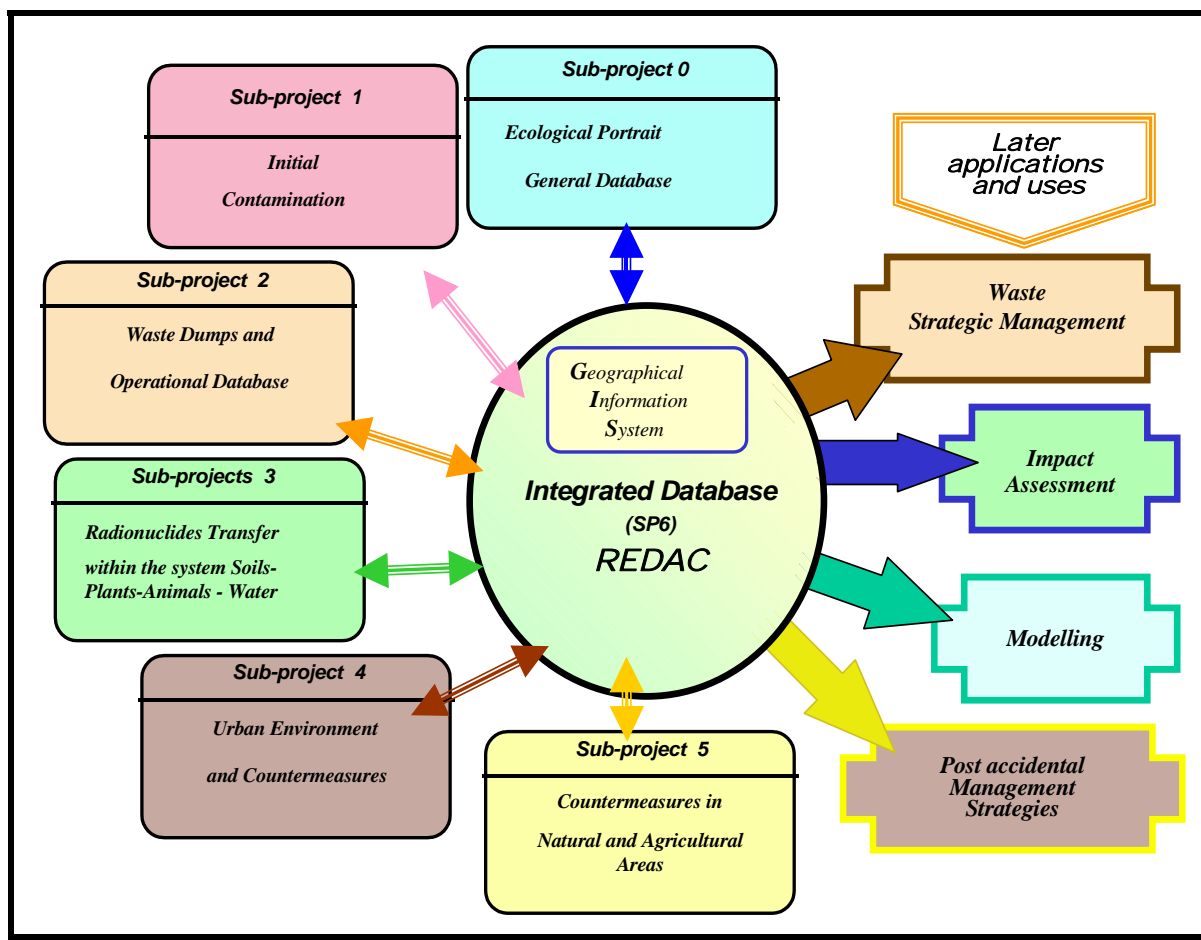


Figure 1-2 General structure of Project 2 - Radioecology

1.3 Requirements

At the beginning of the project, the following requirements were stated: First, it was decided that in each of the sub-projects, at least one institute or laboratory of each of the three countries (Belarus, Russia and Ukraine) should participate. Second, there was to be one scientist in each sub-project responsible for the co-ordination of work and reporting before delivering to the project leaders the mutual consent of all partners.

Many scientific institutes and organisations from the three countries participated in this project. The main participants are listed in Annex1.

2 Ecological Portrait of the Contaminated Regions (SP 0)

2.1 Goals

The general objective of the sub-project is to prepare a georeferenced database with the most important and relevant environmental and ecological parameters of the contaminated regions in the Ukraine, Belarus and the Russian Federation. This database will be used as the spatial basis for the others sub-projects 1 to 5 and for illustrating and evaluating the radioactive contamination.

The most important environmental parameters are: country, administrative oblasts (provinces) and raions (districts); settlements' names and locations; rivers', lakes' and ponds' names and locations; highways, roads, railways; nature conservation areas; land cover (including forests, vegetables, land use, etc.).

2.2 Areas of investigation

The areas of investigation are the oblasts in **Belarus**, namely Vitebsk, Grodno, Brest, Gomel, Minsk, Mogilev; in **Russia**, namely Briansk, Kaluga, Orel, Tula; and in **Ukraine**, namely Volyn, Zhitomir, Kiev, Rovno, Poltava, Chernigov, Sumy, and the Exclusion Zone.

The selected parameters for the ecological portrait were: climate, relief, hydrography, soil and vegetative cover, land use of territory.

Table 2-1 Layer name of the ecological parameters and source

Layer Name	Ecological parameter	Source of information
Topographical base	Settlements, roads, relief	Topographical maps of 1:500,000 scale
Climatic	A long-term annual air temperature distribution, atmospheric precipitation, direction and speed of wind; a duration of cold period with a stable snow cover, height of snow cover, moisture stored within the snow cover to the beginning of the thawing of the snow, depth of freezing of soils	data of meteorological servers; appropriate subject maps
Hydrographics	Rivers, lakes, bogs, artificial reservoirs	Topographical maps of 1:500,000 scale
Soil	Type and mechanical structure of soils, soil-forming breeds	regional soil maps
Vegetative	Woods and forests with indication of predominant types of wood breeds, places of disafforestation, bush, meadow, bog	Large-scale topographical maps (1:50,000), regional maps of woods
Agricultural lands	arable lands, deposits, haymakings, pastures, gardens	Large-scale topographical maps (1:50,000), regional maps of land use

2.3 Specific methodology

The first step involved the compilation and analysis of the most important and common parameters in SP 1 to 5. The second step comprised the designing of the database scheme and then the creation of a development plan. The following products were developed according to the delivery process:

- prototypes of the global databases «Topography», «Administrative-territorial division» and «Contamination» (with the participation of sub-project 1) for selected raions of the

three countries

- prototypes of the intermediate databases «Soils» and «Land use» in the Ovruch raion of the Zhitomir oblast in Ukraine.
- the first releases of :
 - the global database «Topography» of the six oblasts shown in Figure 2-2
 - the global database «Administrative-territorial division» of the Gomel and Mogilev oblasts of Belarus, the Bryansk, Kaluga, Oryol and Tula oblasts of Russia, and the Volyn, Zhitomir, Kiev, Chernigov, Rovno oblasts of Ukraine
- the second release of the sub-project 0 database, consisting of the updated databases "Topography" and «Administrative-territorial division», the database "GeoObjects"³ and the database "Extensions". The database "Extensions" includes progress and working reports, presentations and a web page.

The methodology of "soft" integration of the Project 2 databases was developed. The essential part of soft integration methodology - geointegration - was realised in the database "GeoObjects".

2.4 Structure of the database

The conceptual database scheme of sub-project 0 is shown in Figure 2-1.

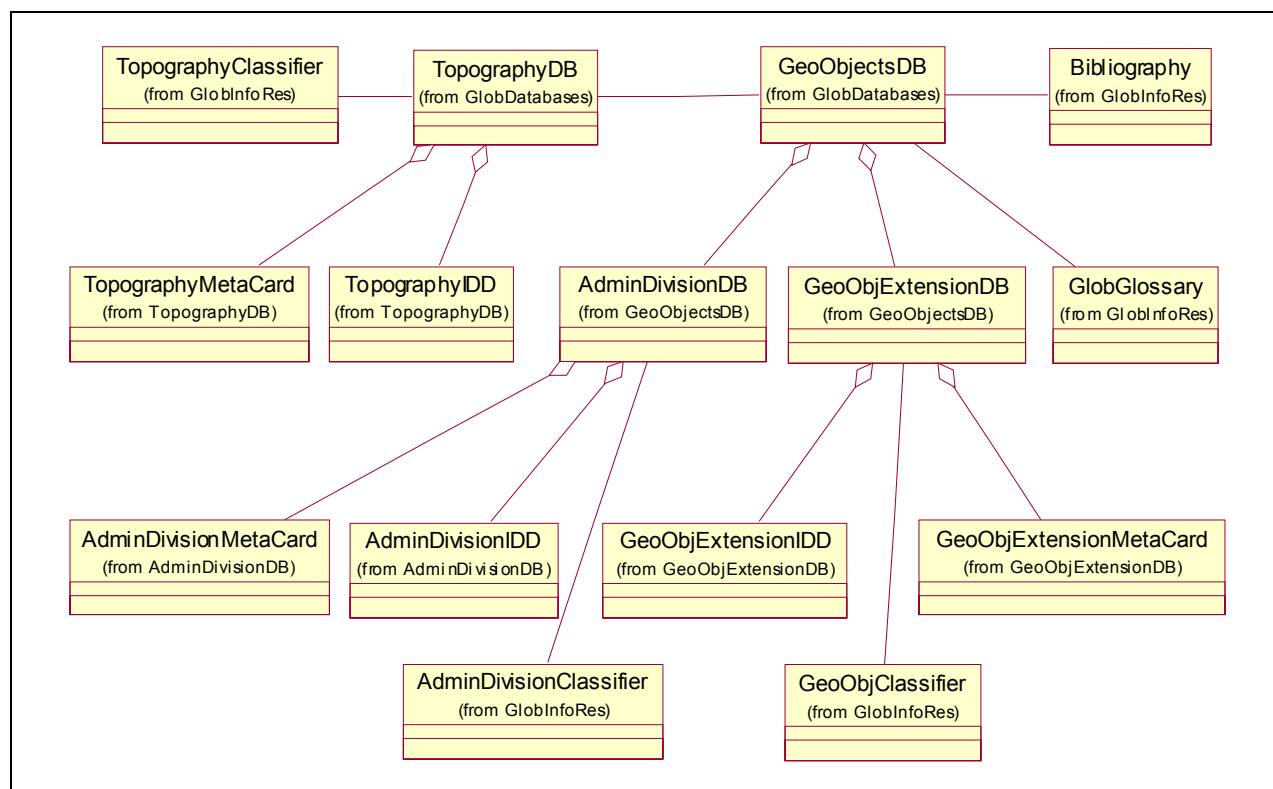


Figure 2-1 Conceptual database scheme of Sub-Project 0

Description of the components of the scheme can be found in the thematic synthesis report

2.5 Main scientific/technical results

The database "Topography" contains six MapInfo databases working with MapInfo software (scale: 1:500,000 for Belarusian and Russian oblasts and 1:200,000 for Ukraine).

³ GeoObjects are all entities to which geographical references are attached (georeferenced objects)

- GomelO1S500 – Topography of Gomel Oblast, Belarus, at scale 1:500,000,
- MogilevO1S500 – Topography of Mogilev Oblast, Belarus, at scale 1:500,000,
- BrianskO1S500 – Topography of Briansk Oblast, Russia, at scale 1:500,000,
- KalugaO1S500 – Topography of Kaluga Oblast, Russia, at scale 1:500,000,
- ZhitomirO1S200 – Topography of Zhitomir Oblast, Ukraine, at scale 1:200,000,
- KievO1S200 – Topography of Kiev Oblast, Ukraine, at scale 1:200,000.

This database is complemented by the Information Description document, Classifier and MetaCard. The main investigation area of the project, built on the database "Topography", is shown in Figure 2-2.

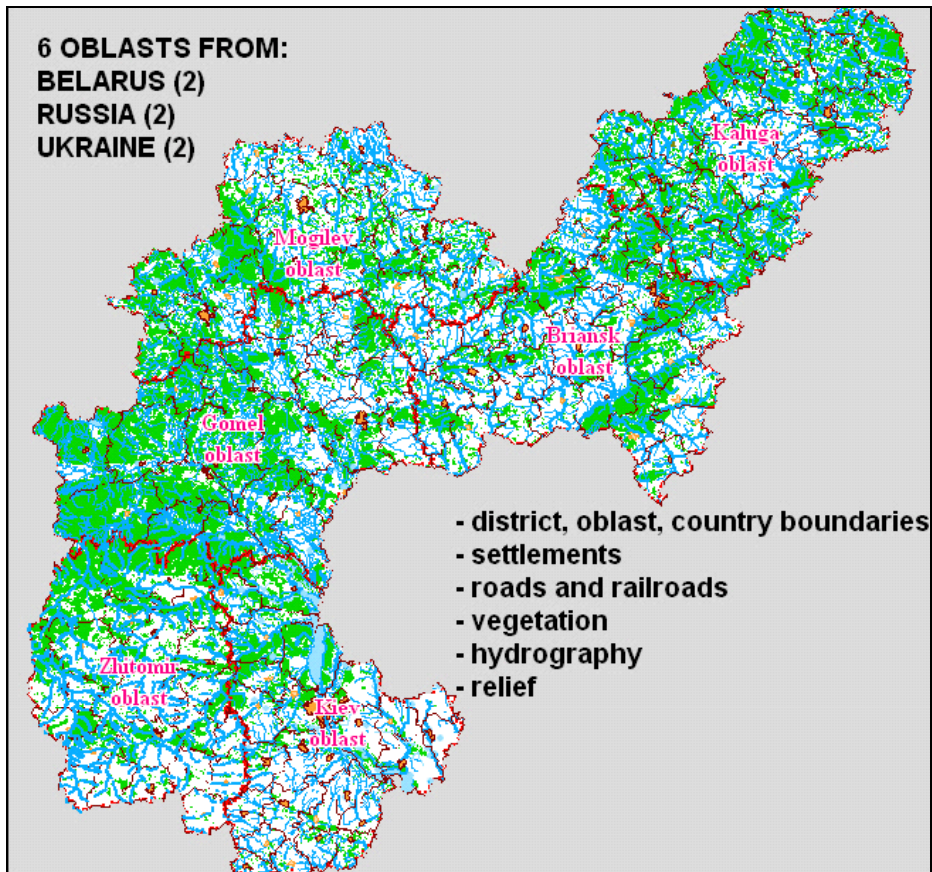


Figure 2-2 Main investigation area (built on database "Topography")

The database "Administrative-Territorial Division" (AdminDivisionDB) is implemented in Access and complemented by the Information Description document, Classifier and MetaCard⁴. The main information of AdminDivisionDB is about settlements, 30909 records are registered. For the six oblasts, these settlements are related to records from the database "Topography".

The Code of Classes of the database GeoObjects (REDAC_codeGC) is a code through which transition to an individual code of geobject is carried out, as e. g. to the GEO_CODE from the database "Topography", REDAC_ADCODE from AdminDivisionDB used for settlements, and to the INDIVIDUAL CODE of information databases from the sub-projects. For example, in sub-project "Waste Dumps and Waste Strategies Management", the number of storage StorNr is used as the unique identifier in the database "Tombs". For tasks of "soft" integration, the code REDAC_codeGC is entered into all sub-project databases.

⁴ MetaCard contains all information about the document concerned

The classification of the separate copies of geobjects of each separate class was developed by each sub-project separately.

The GeoObjects database is implemented in Access. This database is complemented by the Information Description document, Classifier and MetaCard.

2.6 Conclusions and outlook of sub-project 0

The database "Administrative–territorial division" is used in all the others thematic sub-projects 1-5 and databases.

The databases " Administrative-Territorial Division" and "Topography" of SP0 are used in the other thematic sub-projects, except SP3d and SP4, which use their own topography maps.

The GeoObjects database and other SP0 results are used in the soft-integrated database REDAC3W. An example of use integrating the results of different sub-projects is shown in Figure 2-3.

The sub-project SP0 results can be used in the project 3 "Health" of the French-German Initiative (Medical consequences of the Chernobyl accident on the affected populations).

The results can also be used as spatial base for other «territorial» ecological projects in the same regions of the three countries.

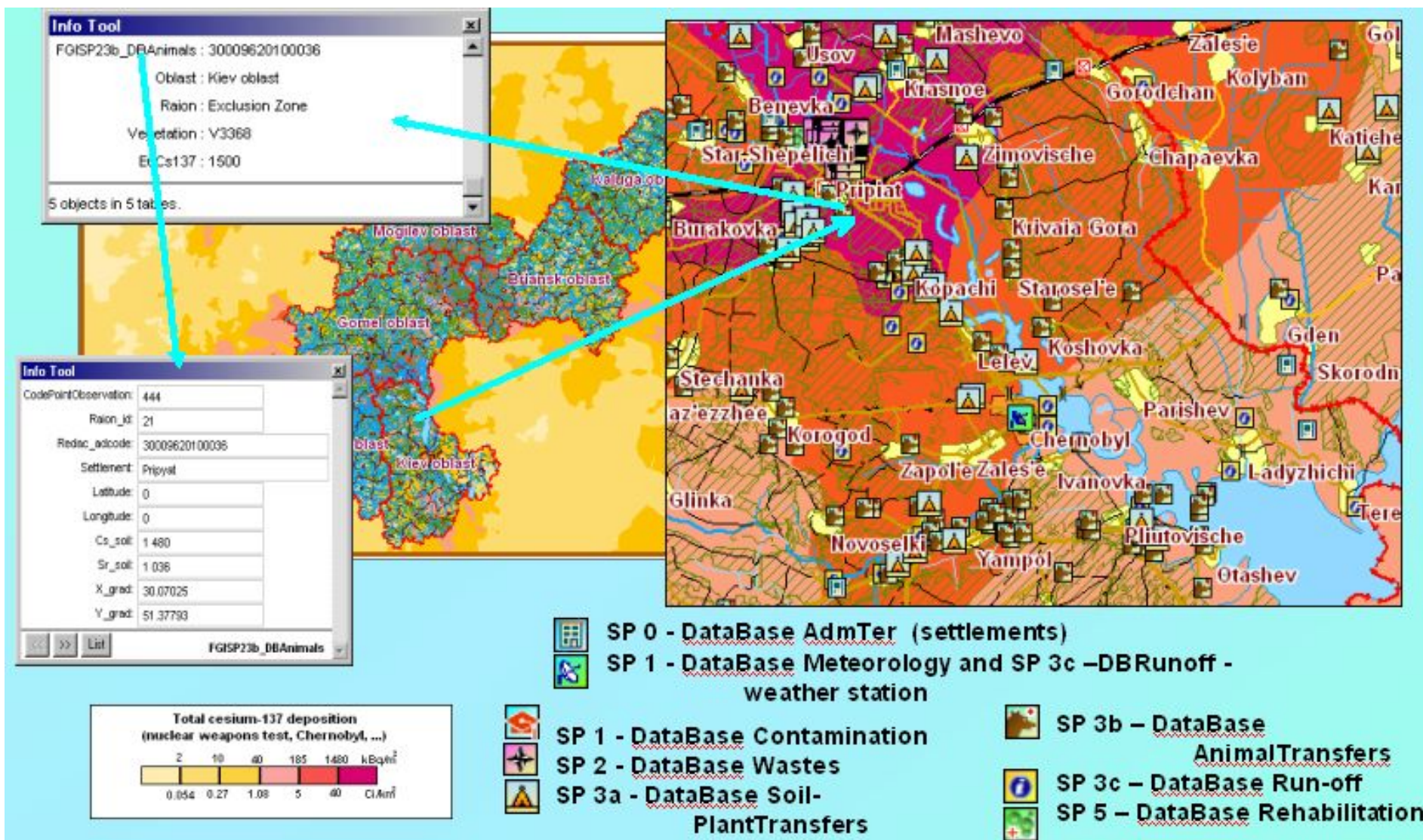


Figure 2-3 : Cartographical representation of GeoObjects DB (the working space contains sets of the sub-projects' 1-5 thematic data and data sets from the global databases "Administrative-territorial division", "Topography" and "Contamination")

3 Contamination of the Environment (SP 1)

3.1 Goals

The general objective of the sub-project is the analysis and verification of data on Chernobyl contamination and its changes that occurred during the whole post-accident period, as well as the completion of the databases on soil contamination and meteorological conditions during fallout.

3.2 Methodology

During the first stage of the sub-project, the chronology of the accident was analysed from the point of view of release dynamics and the radioactive contamination of territories. Available information on the kinetics and properties of radionuclide release during the active stage of the accident was collected and verified. The collected information included the data on the activity of radionuclides accumulated in the reactor before the accident, the data of radioactivity measurements in a near zone (less than 10 km), and results of estimations of the amount of fuel that has remained within the reactor unit. The results of the work of ten organisations were taken into account.

Based on these data, the expert recommendations on the activity of fission products and transuranic elements accumulated in the reactor of the fourth unit before the accident were elaborated. For ^{137}Cs , this value equals $2.6 \cdot 10^{17}$ Bq, for ^{90}Sr - $2.3 \cdot 10^{17}$ Bq, and for ^{239}Pu , - $9.2 \cdot 10^{14}$ Bq. The results of the analysis of soil contamination measurements showed that the activity of radionuclides released and deposited in the exclusion zone around the Chernobyl NPP does not exceed 2.1 % for ^{137}Cs , 2 % for ^{90}Sr and 1.5 % for $^{239+240}\text{Pu}$.

According to the results of investigations that were carried out over the 15-year period after the accident, the main conclusion is that more than 96 % of the total radioactivity remain inside the object «Shelter».

The second part of the subproject was devoted to the creation of databases on soil contamination of selected territories of Belarus, Russia and Ukraine. For the creation of these databases, all available information on the results of inspections of contamination measurements in settlements has been used. Archives and databases of different organisations were used as sources of information.

The analysis of available information showed that it is necessary to create databases of two types.

The database of type 1 contains data on average soil contamination values in the settlements. These data are used for decision-making (so called "official" data)

Another database contains data on sampling in the settlements. This database includes results of direct measurements of soil contamination density (so called "original" data). The database of type 1 contains general administrative descriptions of settlements, geographical coordinates, data on average soil contamination density in settlements by ^{137}Cs , ^{90}Sr , Pu (kBq/m^2), and the date of the revision of averaged data.

The database of type 2 also contains administrative and geographical characteristics of settlements as well as data on direct measurements of the soil contamination density in settlements (kBq/m^2) as well as the date of measurement (sampling).

The following sources of information were used to process databases of both types especially from the data bank "Center of Radiation Control and Environment Monitoring" from Belarus, the archives of the Scientific Production Enterprise "Typhoon" from Russia, the Central Data Bank of Generalized Data of IBRAE from Russia, and the data bank of the State Committee on Hydrometeorology of Ukraine.

3.3 Database

To create databases, six oblasts in Belarus, Russia and Ukraine were selected, the same as in sub-project SP0 (two oblasts per country – Gomel, Mogilev, Briansk, Kaluga, Kiev, Zhitomir). Databases contain information for 1011 settlements (251 – Belarus, 468 – Russia, 292 – Ukraine).

The database of type 1 contains average values of soil contamination densities, which are officially approved by the state authorities of each country. The database of type 2 includes more than 31000 results of measurements in these settlements. The data cover the period from 1986 until 1998. Databases have been structured and built for studying the different aspects of the radioecological consequences of the accident. They include different types of settlement (urban and rural), various weather conditions during release (dry and wet), and different types of soil. The range of the contamination of settlements covers values of ^{137}Cs density from 5 kBq/m² to 8000 kBq/m².

The database on meteorology was created for the three affected countries. The structure of the tables is quite different for each country. In general, the databases contain general administrative descriptions of meteorological stations (settlements) where meteorological conditions were registered during the accident. Data on weather conditions include temperature (°C), wind direction (degree), wind velocity (m/s), amount of daily precipitation (mm). The database contains information on weather conditions during the first weeks after the accident (till July 1986). More than 8000 records are included in the database.

The databases have unified codes, which provide soft integration in databases and electronic maps developed within the framework of subproject 0 as well as in other databases.

The databases on soil contamination integrate the atlas of caesium deposition on Europe (JSP-6). Electronic maps from the atlas were added to the databases of type 1 as attributive information. Contamination of settlements is indicated as points that belong to different zones of contamination. Therefore, it is possible to compare vector maps containing JSP6 data with databases of SP1. All data were verified by technical and scientific methods including geostatistical approaches. A geostatistical estimation of data about ^{137}Cs contamination was made. Spatially distributed data on soil contamination density in selected areas were analysed and uncertainties of measurements were estimated. As an example, the prediction map of contamination was processed using spatial interpolation methods.

3.4 Results

A comparison of contamination levels in settlements with the atlas isolines (JSP6) published by the European Union showed differences in some cases.

Databases on soil contamination and meteorology were used for the reconstruction of initial soil contamination. For this purpose, the "NOSTRADAMUS" 3D Lagrangian model of atmospheric dispersion was used.

The work on the reconstruction of processes that led to the primary contamination of some territories was based on the following main data sets:

- amount of radionuclides that had accumulated in the reactor of the 4th power unit of the Chernobyl power plant until the day of the accident;
- amount and dynamics of transfer of various radionuclides into the environment;
- characteristics of meteorological conditions for the periods of active release;
- radionuclide composition of the fallout;
- dose rate;
- results of reconstructed fallout for various radionuclides (caesium, iodine, strontium maps);
- milk contamination levels during the initial period;
- measured and reconstructed levels of thyroid contamination among the population.

The migration of the radioactive materials released from the reactor from 06:00 a.m. until 03:00 p.m., during the first hours following the accident, on 27 April 1986 was considered. This release caused most of the contamination of territories, which was studied within the subproject.

Using modelling results, contamination maps of selected regions were drawn up, showing the contamination with caesium and other radionuclides. Reconstructed maps were

compared with available official maps. The total nuclide fallout calculated by the model was close to the experimental evidence. The calculated value of the ^{137}Cs fallout amounted integrally to 8.6 PBq⁵, which corresponds to about 92 % of the field-research estimate. At the given stage, such agreement was considered sufficient.

3.5 Surface activity for caesium isotopes

In addition, in order to have a reference to be compared with soil contamination in the other parts of Europe, especially western parts, UIAR⁶ provided some data of caesium concentration for the typical isotopes ^{137}Cs and ^{134}Cs .

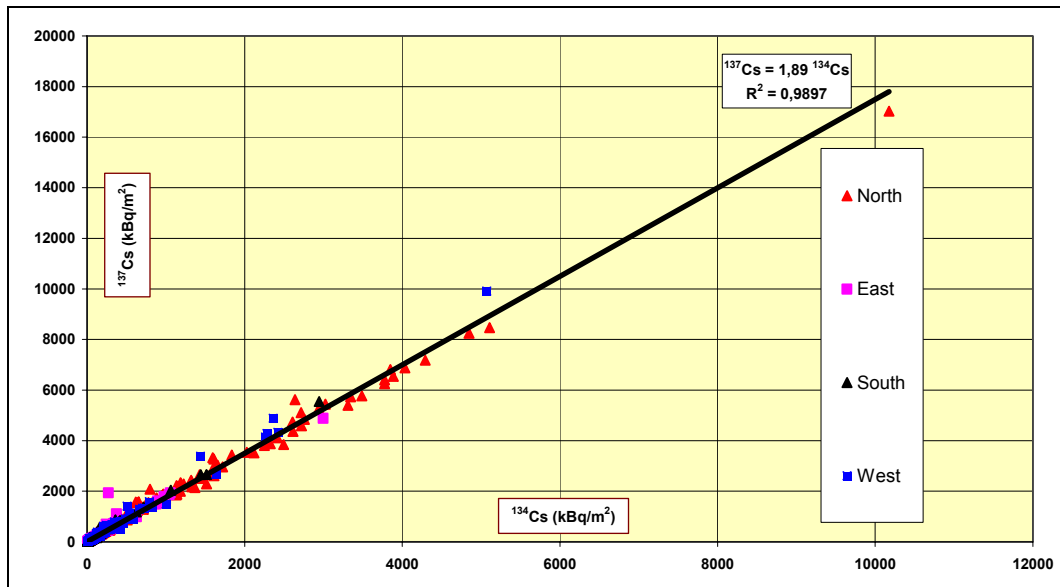


Figure 3-1 : Comparison between ^{137}Cs and ^{134}Cs surface concentration in CIS

The mean ratio of concentration is 1.89 (Figure 3-1) In France, for example, this ratio was 2 just after the deposition on soils.

When classifying according to the quadrants in which sampling has been performed, (Table 3-1) taking into account the dispersion of results, there are no significant differences for the four main directions, perhaps except for the northern points for which the ratio is somewhat lower and values are less dispersed.

Table 3-1 : $^{137}\text{Cs} / ^{134}\text{Cs}$ ratio according to direction

Quadrant	Directions		$^{137}\text{Cs}/^{134}\text{Cs}$		No. of measurements.
	from	to	Mean value	Standard deviation	
North	320°	40°	1.85	0.21	123
East	50°	130°	2.00	0.57	104
South	140°	220°	2.09	0.64	105
West	230°	310°	1.94	0.43	116
All	10°	360°	1.89	0.49	448

When classifying in the same manner the values according to distance from the release point, there is no clear influence of the distance on the $^{137}\text{Cs}/^{134}\text{Cs}$ ratio.

⁵ 1 PBq = 10¹⁵ Bq

⁶ Ukrainian Institute of Agricultural Radiology (Kiev) [Activity (Bq/m²) for 26.04.86, sampling in 1987]

3.6 Conclusion

In conclusion, it should be mentioned that databases on soil contamination and meteorology can be used:

- for the assessment of the current radiological situation in territories affected by the Chernobyl accident;
- for the reconstruction of the contamination of the environment;
- for the preparation of electronic maps on soil contamination;
- for making forecasts on future periods;
- for use as a basis for emergency response in case of a radiation accident.

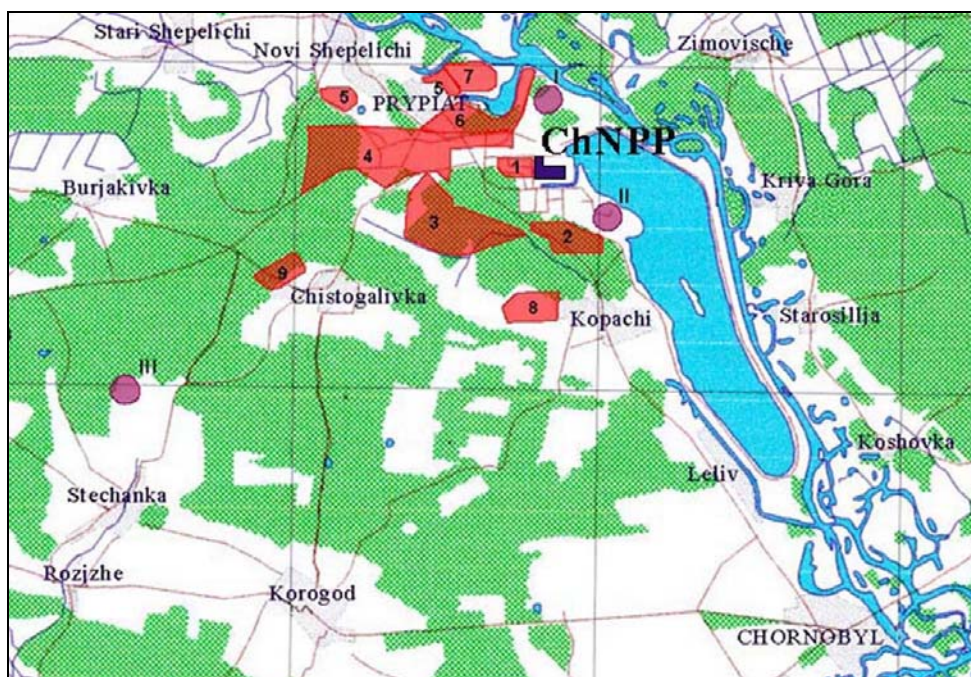
3.7 Outlook

Discrepancies between results of this sub-project and European Commission maps (JSP6) should be solved by appropriate means.

4 Wastes dumps and waste strategies management (SP2)

4.1 Aim of the sub-project

During the decontamination process for the area polluted as a result of the accident at Chernobyl NPP, the enormous volumes of radioactive material and substances were collected in more than 1000 disposal sites of Ukraine, Belarus and Russia. The major part of radwaste was disposed in trenches and dumps not isolated from the environment. Radwaste varies significantly in kinds of materials (contaminated soil, wood, elements of ironworks, ferro-concrete blocks, equipment, mechanisms, parts of dwelling houses, etc.) and radioactivity levels. A considerable proportion of radwaste contains fragments of nuclear fuel and reactor graphite. The major nuclides of the radwaste are ^{137}Cs , and ^{90}Sr ; waste also contains TRU elements.



PZRO: I – “Podlesnyi”; II – “3rd stage of ChNPP”; III – “Buriakovka”.

PVLRO: 1 – “Staraia Stroibaza”; 2 – “Novaia Stroibaza”; 3 – “Ryzhyi Les”;
4 – “Stantsyia Yanov”; 5 – “Town of Prypiat”; 6 – “Neftebaza”;
7 – “Peschanoie Plato”; 8 – “Kopachi”; 9 – Chistogalovka”.

Figure 4-1 : Location of PZROs and PVLROs within the Exclusion Zone

The aim of this sub-project is the creation of a database of the disposal sites and radwaste, the evaluation of the environmental impact from the radwaste disposal sites, the collection of information on available radwaste management strategies, and the selection of optimum strategic decisions to avert potential hazards of radwaste for the environment.

4.2 Methodology

The available information received in various ways in different fields of radioecology was obtained and structured. Disposal sites examined most completely by means of well-known methods were selected to be included in the database and used for further investigation.

A unified radwaste and disposal sites categorisation for the three countries was created as a necessary step towards the general analysis of the potential risk for different sites. The unified categorisation of the localised radwaste was created taking the National Normative Documents, general IAEA principles and specific features of Chernobyl waste into consideration. Radwaste categorisation was made on a two-criteria basis: ^{137}Cs -specific activity and specific $\bar{\alpha}$ activity (Figure 4-2).

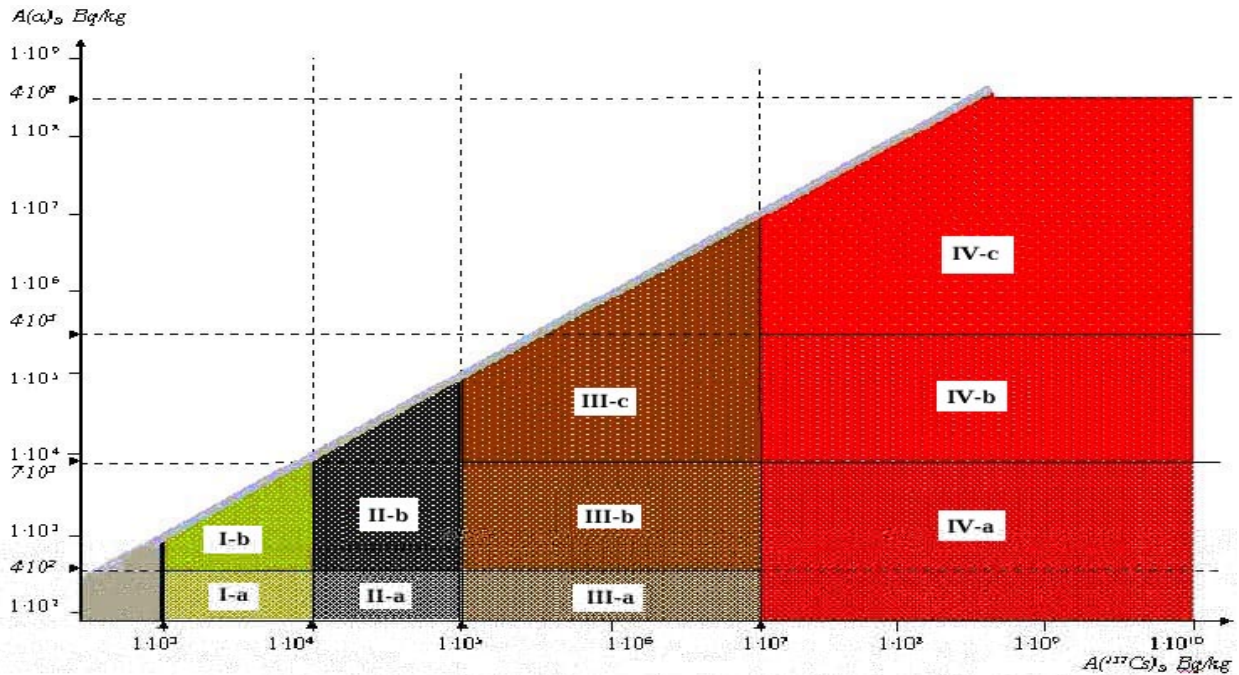


Figure 4-2 : Unified categorisation of localised radwaste

Depending on the location of a waste disposal facility, the presence (or absence) of engineered barriers, the presence (or absence) of isolation, the radwaste emplacement mode and the availability of radwaste packages, all Ukrainian, Belarusian and Russian radwaste disposal sites were divided into 5 categories.

The existing radwaste treatment techniques were analysed in order to take the optimum strategic decisions and specific measures on Chernobyl radwaste management.

Five groups of radwaste management techniques have been discussed – compaction, decontamination, valorisation, re-excavation and stabilisation.

Stabilisation techniques, in particular the construction of barriers preventing radionuclide migration from disposal sites into the environment, are most promising for potential risk minimisation without waste retrieval from radwaste disposal sites. A general technological scheme of re-excavating radwaste containing significant amounts of transuranic elements has been developed in Ukraine.

4.3 Database structure

The database represents a system of seven information blocks interconnected by a universal identifier (Figure 4-3).

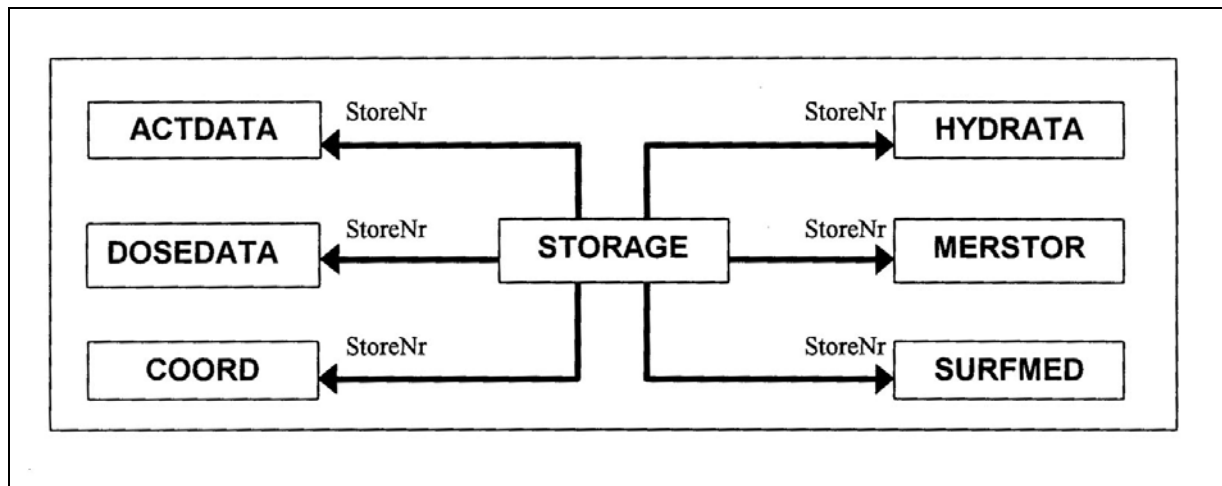


Figure 4-3 : Database structure

The block named “Storage” contains general information on radwaste disposal sites. The block “Actdata” comprises information on radwaste activity, “Dosedata” information on equivalent dose rate above the surface of radwaste disposal sites, “Coord” location coordinates, “Hydrata” hydrological characteristics, “Merstor” measurements which are carried out at present, and “Surfmed” information on radionuclide contamination of the surface near the radwaste disposal sites.

4.4 Scientific results

Inasmuch as less than 50% of the disposal sites for waste of Chernobyl origin have been inspected so far, it is impossible to evaluate at full measure the real volumes and activity of the radwaste, its environmental impact, and its radiological hazard.

The major task of scientific substantiation was to assess the impact of the radwaste on the environment, based on available data compilations and statistical data manipulation.

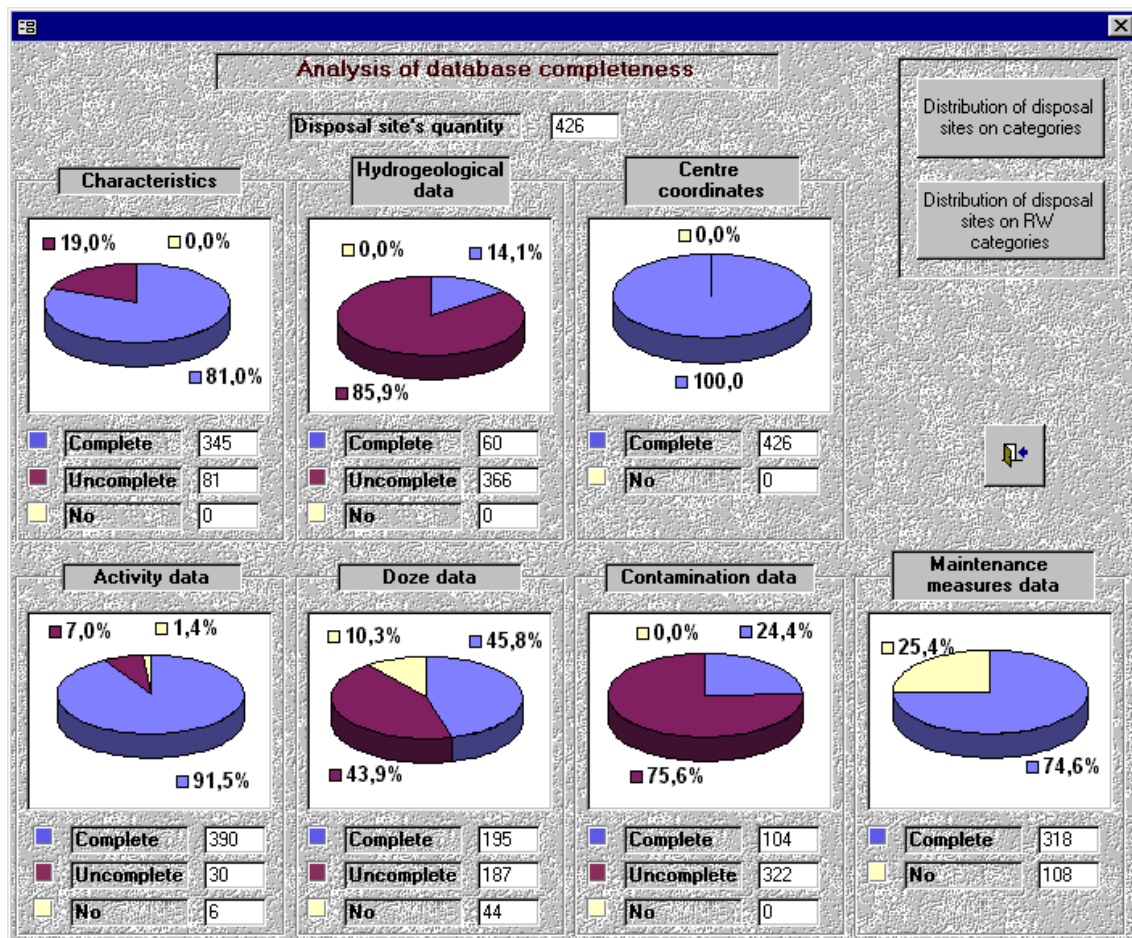


Figure 4-4 Example of database analysis

The impact of the radwaste disposal sites on surface contamination is ascertained against the background of general surface contamination.

The radiation equivalent dose rate above the surface of the radwaste disposal site correlates with the activity level of the localised radwaste. The radiation equivalent dose rate of the radwaste disposal sites that are periodically flooded is on average considerably higher than that of non-flooded ones.

The largest variations of ¹³⁷Cs- and ⁹⁰Sr- specific activity in ground water are observed near radwaste disposal sites without engineered barriers. Smaller variations of specific activity are registered near facilities with engineered barriers. The smallest ones are in the areas, where radwaste disposal sites are absent.

Calculations of annual ^{90}Sr migration into ground water from radwaste disposal sites have shown that the most dangerous dumps are the partially flooded ones, whose contribution to ground water contamination by ^{90}Sr reaches 60%.

Priorities and principles of a strategy of action

Based on the analysis of the available information, the radwaste disposal sites are subdivided into four groups: (Figure 4-6)

The first group comprises radwaste disposal sites whose radiological hazard is estimated to be insignificant according to the data of the studies carried out.

The second group comprises radwaste disposal sites whose influence on the environment is not registered by the existing monitoring system but may turn out to be significant in the future.

The third group comprises radwaste disposal sites which have an extensive influence on the environment due to the absence of engineered barriers. In this case the near geological environment can be considered as the natural barrier partially decreasing the intensity of radionuclide entry into ground water.

The fourth group comprises radwaste disposal sites whose influence on the environment most severely resulted from direct interaction between radwaste and ground water owing to imperfections of the engineered barriers or their absence.

The major versions of the strategy of minimising the hazards posed by the waste disposal site are the following:

0. "Wait and see" strategy;

1. Minimisation of radiological hazards by improving the existing barriers or constructing new ones;

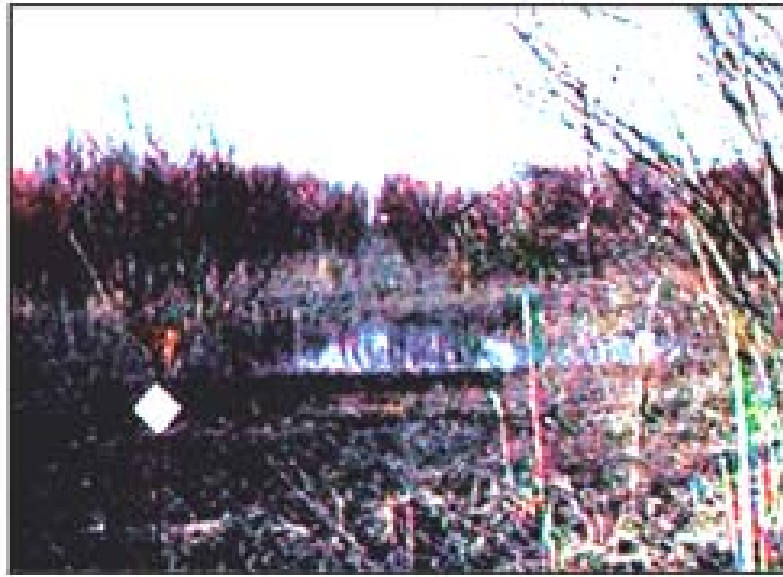
2. Radwaste retrieval from waste disposal sites.

The general strategy of action should combine these three versions at certain optimum proportions.

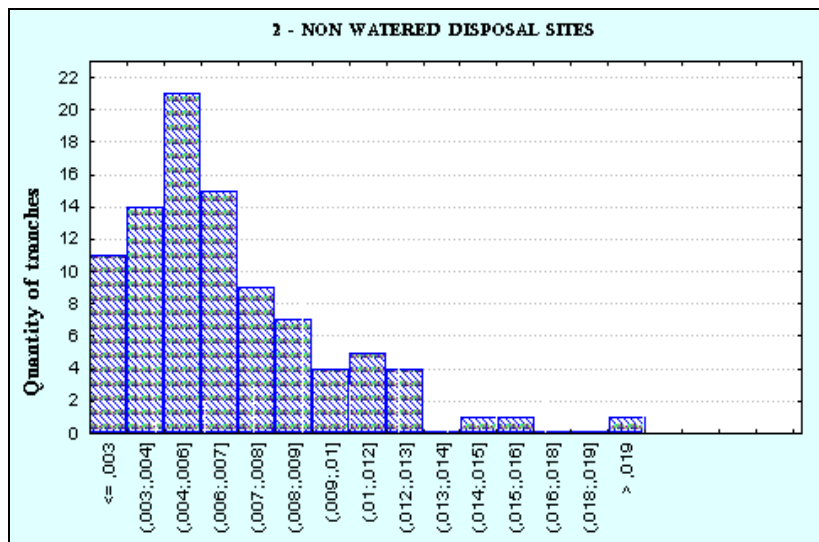
Conclusions

The main difficulty in implementing sub-project 2 of the project "Radioecology" was the lack of reliable information on the radwaste disposal sites. At present, less than half of the disposal sites located within the Chernobyl zone have been inspected. For the majority of sites, inspection has been by imperfect methods yielding no reliable data on ^{90}Sr and transuranics concentrations in the waste.

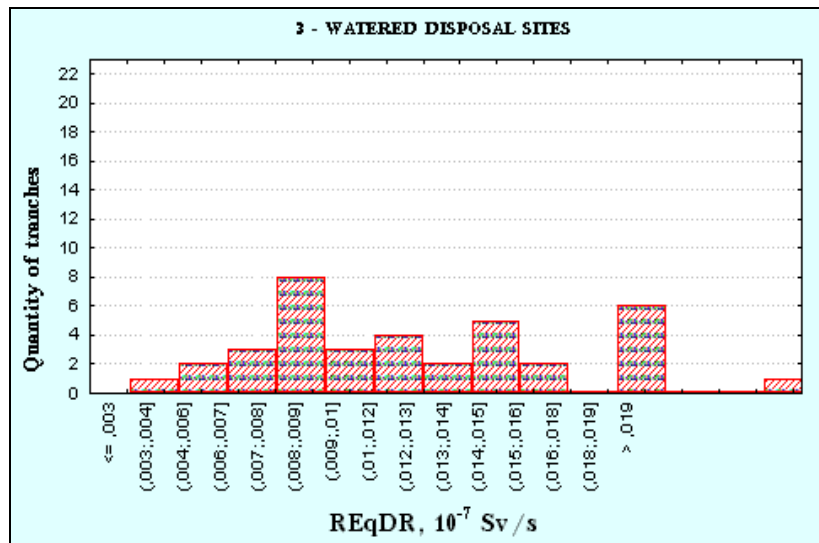
The assessment of localised impact of the radwaste on the environment, especially the ground water, is complicated by the general contamination of the area. The problem of the radiological impact of the localised radwaste should be solved together with the problem of the radiological impact of the surface contamination. For the purpose of solving this problem and choosing the strategy on radwaste management it is necessary to work out criteria and models for an integrated assessment of the radiological hazard represented by localised and non-localised radionuclide contamination by studying parameters of radionuclide migration into the environment.



a



b



c

Figure 4-5 Trenches of “Neftebasa” PVLRO flooded in the spring of 1999 (a); distribution of equivalent dose rate (ReqDR) on non-flooded trenches (b) and periodically flooded trenches (c)

			Locality category			
			A	B	C	D, E
Radwaste category	IV	IV - c	2			
		III	III - c		4	
	III - b					4
	II	II - b			1	3
		II - a				3
	I	I - b			1	1
		I - a				1

Group	Impact of disposal sites on the environment	Strategic tasks
1	Disposal sites' impact on the environment is insignificant.	Maintenance of safety of a disposal site.
2	Disposal sites' impact on the environment is insignificant at present but it can increase in future.	Ensuring long-term safety of a disposal site.
3	Disposal sites' impact on the environment is significant. Near field acts as a natural barrier.	Assessment of radiological hazard of a disposal site. Assessment of necessity of carrying out measures on minimization of a disposal site's impact on the environment.
4	Disposal sites' impact on the environment is significant. Adjacent medium has no properties of a natural barrier.	Assessment of radiological hazard of a disposal site. Taking measures on minimisation of a disposal site's impact on the environment.

Figure 4-6 Strategic tasks related to localised radwaste management

5 Soil-Plant Transfer (SP3a)

5.1 Introduction

In 1986, immediately after the Chernobyl NPP catastrophe, the surface contamination of vegetation with short-lived radioisotopes of iodine $^{131,133}\text{I}$ prevailed. Since 1987 $^{134,137}\text{Cs}$ and ^{90}Sr root accumulation from soil has been the key process determining the behaviour of long-lived radionuclides in food chains and agroecosystems in general.

Hundreds of thousands of measurements of radionuclide content in soils, plants and agricultural products were carried out in Belarus, Russia and Ukraine during the post-accidental years. This was done as part of the state programmes on radiation control as well as in scientific investigations under strongly controlled conditions. Due to the huge scope of the Chernobyl emergency, the real results on radionuclide transfer from soil to plants in dynamics including a wide range of agricultural and forest plants in different soil and climatic and in landscape conditions were obtained by various institutions. As different methods of sampling and activity detection were used, the generalisation and application of the data for prognoses was complicated. The FGI made it possible to systematise and verify these data and make them accessible to the scientific community. The database (DB) that was created became a basis for the development and verification of models; it permitted a significant reduction of the conservatism of forecasts.

The principal idea of sub-project FGI 3a "Soil-plant transfer" was to collect, store and validate existing data and to establish a database in order to provide objective information for decision-makers, for planning remedial actions, for the information of the public, and for further scientific work.

5.2 Main goal

The main objective of sub-project 3a consists in the creation of a reliable basic and general tool for the interpretation and prediction of the long-term behaviour of the relevant radionuclides in a soil-plant system under different ecological conditions, based on the data available in Ukraine, Belarus and Russia after the Chernobyl accident.

5.3 Methodology

The collection of coupled soil and plant contamination values (for ^{90}Sr and ^{137}Cs) over the time and over the area covered by geographical co-ordinates was realised with reference to the items presented below:

Sampling locations: detailed description of administrative and geographic co-ordinates for each location of sampling, methods of determination and uncertainties, types of agriculture and land-use are presented;

Contamination of soil: the dates of measurements, methods and parameters of soil sampling (date, area and depth of sampling), density of contamination and specific activity of ^{90}Sr and ^{137}Cs in a soil layer (vertical distributions of radionuclides in a soil profile for natural ecosystems), physical and chemical forms of radionuclides, detailed description and methods of investigation including uncertainty for each parameter are presented;

Characteristics of soil: the type of soil and its location, method and parameters of soil sampling (date, area and depth of sampling) for determination of soil characteristics, main agrochemical characteristics of soil are presented. Types and varieties of soil are presented both according to the international classification system FAO-UNESCO and to CIS classification;

Contamination of plants: the quantity of paired soil and plant samples, date and method of plants sampling, plant type and part of the plant, determination of botanical family, genus and variety, age and stage of vegetation periods, status of maturity, water content, productivity, specific activity of ^{90}Sr and ^{137}Cs in plants and uncertainty of detection, as well as calculated values of transfer factors (TF) and concentration rates (CR) of radionuclides are presented.

The technical standards of the different institutes which provided the data and information varied considerably. To provide an equally high standard of the data, an additional field was

added to all information called «degree of belief», differentiated by grades 1 to 5, where grade 5 is attributed to the value with highest authenticity. The degrees of belief were based on the plausibility of a single value in comparison with its conformity to the other values in the database. For example, values with a «degree of belief» of less than 2 were excluded from statistical analysis but remained in the database. An additional criterion “expert mark” was introduced to give an expert opinion about the overall data of soil, plant, and radioactive contamination and transfer behaviour.

The database was established methodologically following the instructions of REDAC to be able to couple the results with those of sub-projects SP3b, SP3c and SP5.

5.4 Results

6574 records of conjugated “soil-plant” couples were filled, including 3214 for agrocœnoses on arable lands, 1254 for semi-natural cœnoses, i.e. meadows and pastures, and 1917 for forest ecosystems.

The number of records is evenly distributed among territories of Belarus, Russia and Ukraine. The data characterise the $^{134,137}\text{Cs}$ and ^{90}Sr transfer in soil-plant system in agricultural ecosystems in the regions most affected.

The database (DB) contains 18 different types of soils including chernozem, grey forest, soddy-podzolic and peat, meadow and soddy soil, differing by humus and exchangeable cations contents, acidity, granulometric composition and nutrition elements contents, which are representative for Europe on the whole. The DB is also representative by the composition of plant species; it includes twenty food and forage crops, about ten species of mushrooms, and about twenty species of herbaceous forest plants.

So, the fifteen-years (?) period after the Chernobyl accident from 1986 to 2000 is realised in the database with the most important agricultural data. These data allow the study of the dynamics of radionuclide species transformation in soil influencing the biological availability to plants.

Information characterising the behaviour of the radionuclides in soil and their accumulation in the vegetation of the 30-km Chernobyl zone is included in the DB. The total number of records on ^{137}Cs transfer from soil to agricultural crops (field experiments) and natural meadow pasture amount to 385, the number of records on ^{90}Sr transfer to 164.

The fact that the main part of ^{90}Sr and ^{137}Cs radionuclides that fell out within a 30-km distance consisted of fuel particles with different sizes caused complicated dynamics of mobile, biologically active forms of radionuclide accumulation and binding in soil. To understand the dynamics of the transfer of radionuclides from soil to plants, additional information on exchangeable and mobile ^{137}Cs components in the soils of the 30-km Chernobyl zone was included in the database.

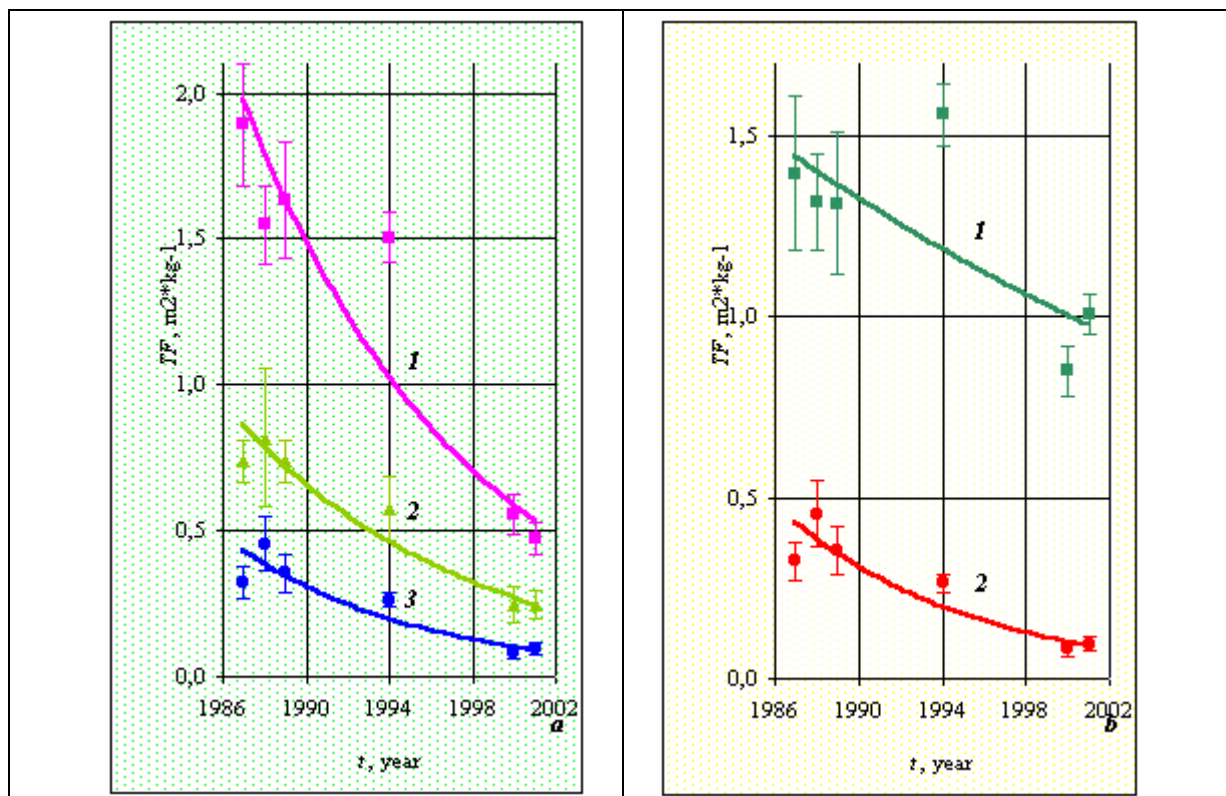


Figure 5-1 Example of transfers factors for ⁹⁰Sr

- The DB contains generalised data of several research reports on landscape and geographic as well as on the ecological conditions of the contaminated region, on the nuclide composition of fallouts, the incorporation of different forms of caesium and strontium radionuclides into soils and their transformation during their stay in soil, on the biological availability and peculiarities of the accumulation of radionuclides in agricultural, meadow and forest plants and mushrooms in the nearby (30-km zone) and remote traces.
- More than 15 000 records on agrochemical characteristics and more than 1500 data on granulometric composition of soil are filled into cards of the DB. Agrochemical characteristics of soils are widely dispersed within a single group of soil. For example, humus content varies in a range of 2.5 times, pH in a range from 4.8 (acidic) to 6.5 (neutral) times, and exchangeable Ca by 10 times in a group of soddy-podzolic sandy and sandy loam soils. These variations for chernozems are somewhat less but also significant. This fact allows studying the connection between TF and main soil properties determining the nature of radionuclide interaction with soil and their availability to plants accumulation even within a single group.
- ¹³⁷Cs TF values from soil of various types to plants are characterised by significant variability. This property is apparent especially for natural meadow and forest ecosystems. The results of the investigation showed that observed differences of ¹³⁷Cs availability to root accumulation are determined by vertical distribution of ¹³⁷Cs in the soil profile, as a part of an exchangeable radionuclide fraction in different soil horizons and the distribution of the plant root system in soil.
- An analysis of several models describing radionuclide migration in a soil-plant system was carried out. The FORESTGAME and TYPHOON models were verified and parameters adjusted. It was shown that the information in the database makes it possible to develop new and improve existing models describing radionuclide migration from soil to plants.

Examples of the results concerning the transfer factor of ^{90}Sr are shown in Figure 5-1

A method of complete estimate of soil properties (CESP) was developed, and its use for the prediction of the radionuclide transfer from soil to plant and the description of TF dependence on soil properties is envisaged. The CESP method takes the soil into consideration as a three-phase system consisting of liquid (soil solution), solid (mineral matrix) and quasi-liquid or quasi-crystalline (organic matter) phases. CESP can be assessed quantitatively as triangle area with apexes lying on axes of three-dimensional space in points equal to the standardised meaning of parameters characterising soil phases, as pH-value (pH), cation exchange capacity (E), and organic matter (OM). Studies showed that the transfer factor (TF) dependence in CESP can be described by power equation dependence in a whole range of soil properties included in the "Transfer Soil-Plant" DB. So this allows transfer factors (TF) to be calculated from soil parameters with a high degree of reliability and to continually interpolate them. In this way, the forecasts' uncertainty of radionuclide transfer in the terrestrial ecosystem is significantly reduced.

5.5 Conclusions

The results of sub-project 3a compiled in the "Soil-Plant Transfer" DB gives an excellent overview of plant and soil contamination in the most highly contaminated regions of Ukraine, Belarus, Russia, which characterise almost all types of European soils. To ensure a scientific approach, a lot of additional information was included such as soil types and soil properties, agricultural and ecological conditions etc., by the Chernobyl side and the most affected territories of the three CIS countries. So the database information contains a wide range of soil and climatic conditions and agricultural techniques. The data cover the period 1986-2000, thus allowing the study of the dynamics of radionuclides in the natural environment over time. The physical and chemical parameters of soils allow the study of their influence on migration in the soil-plant system. The data were obtained under realistic conditions so that the results can be used with a degree of high credibility in models for emergency situations.

Due to the high quality and quantity of ^{137}Cs and ^{90}Sr data in the soil/plant system under agricultural and semi-natural conditions, the "Soil-Plant Transfer" database should become a reference database for scientists, members of regulatory bodies, designers and operators of nuclear installation, and also for the interested public.

5.6 Outlook

The executors of SP-3a are inclined to believe that based on the results of subproject 3a, performing the following studies could be useful:

- Comparative analysis of data from investigations of the subproject SP-3a DB with data obtained in other European countries for various soil-and-climatic conditions; integration of data in the database, resulting in a representative, global and reliable database on radionuclide transfer from soil to plant and an extension of the sphere for results application;
- Completion of the SP-3a "Soil-Plant Transfer" database by adding information about the transfer from soil to plants of other long-lived radionuclides such as ^{36}Cl , ^{99}Tc , ^{129}I , ^{235}U , $^{238-240}\text{Pu}$, ^{241}Am etc.;
- Development and parameterisation of dynamics models for the transfer of long-lived radionuclides from soil to the yield of cultivated and natural crops, taking into account accounting soil and climatic conditions, radionuclide transformation in soil, vertical migration of radionuclides, distribution of root systems in soil, and the influence of micro-organisms in the soil. etc.;
- Prediction of countermeasures efficiency with the developed model;
- Application of the soil-to-plant transfer principles characterising the artificial radionuclides for the prediction of the behaviour of natural radionuclides and heavy metals in terrestrial ecosystems.

6 Transfers to animals (SP 3b)

6.1 Introduction

One of the most important pathways of radiation exposure to the population after the disaster in Chernobyl was the contamination of foodstuff. It was therefore a great concern to collect and process the accumulated information about the radionuclide transfer to animal fodder, from fodder to animal and animal products, and also to game.

The work for sub-project 3b included:

- covering the contaminated areas of the Polesye (Ukraine), Gomel (Belarus), Briansk and Kaluga (Russia) regions by the radiological and natural characteristics;
- creating a data-base on the transfer of ^{137}Cs and ^{90}Sr to animal feed;
- creating a data-base on the transfer of ^{137}Cs and ^{90}Sr to animal products of livestock (beef, pork, milk) and venison;
- creating a database on the transfer of ^{137}Cs from hay and grass to milk in the private holdings;
- qualitative analysis of the determination of radionuclide transfer factors to animal production and animals feeding.

In this sub-project the main tasks consisted in developing the structure of the database, publishing a clear description of the database, compiling and evaluating reliable data of radioactive contaminated fodder and meat, editing adequate materials for the website, and providing an extended documentation of scientific reports.

6.2 Main Goal

The main objective of this sub-project consisted in the creation of a reliable basic and general tool for the interpretation and prediction of the long-term behaviour of the relevant radionuclides in a fodder-animal /animal product- system under different agricultural and time-specific conditions based on the data available in Ukraine, Belarus and Russia after the Chernobyl accident.

6.3 Methodology

The conceptual scheme of the database is given in Figure 6-1. The boxes indicate the compartments of the model and arrows the ways of radionuclide transfer. The database contains information on the specific activities in the indicated subjects and the corresponding transfer factors from one compartment to the other.

The database is based on the results from environmental sample measurements in the three CIS countries (Belarus, Russia, Ukraine) in six regions: Gomel, Briansk, Kaluga, Kiev, Rovno, and Zhitomir. A total of 23 districts were covered (8 - Belarus, 10 - Russia, 5 - Ukraine).

In accordance with the conceptual scheme, the database is presented as interrelated files of tables containing results from measurements of the radionuclide content in fodder, milk and meat. Each file of tables finishes with a table that contains estimated values of the transfer factor (TF).

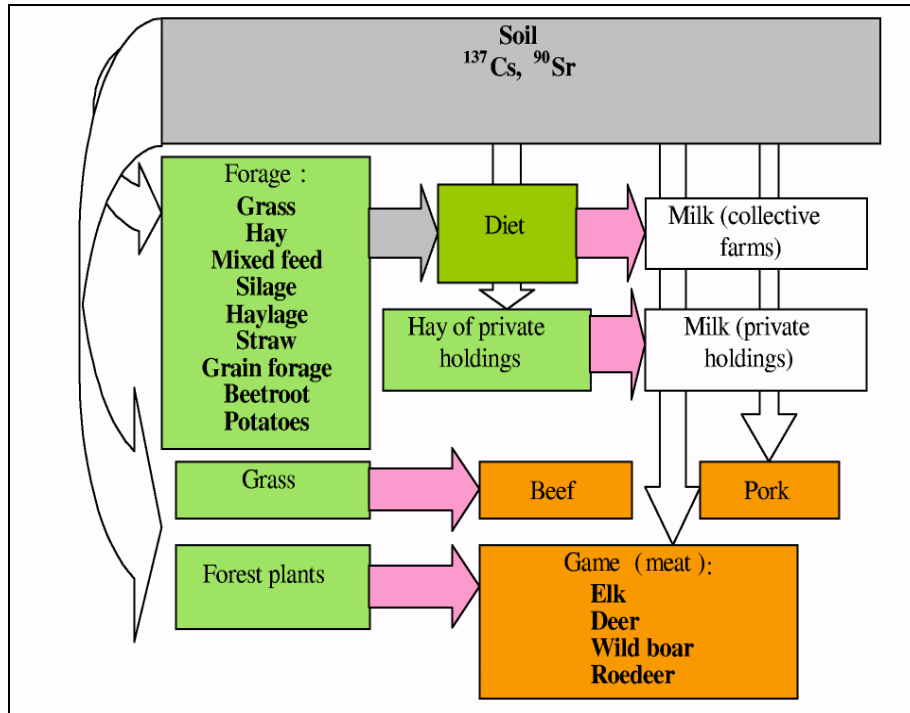


Figure 6-1 Conceptual scheme of the database

The database contains experimental information on the contamination of soil, forage, animal products and venison. The data are related to the territory affected by the ChNPP accident. A total of 584 settlements have been examined.

The database contains data of long-term observations.

The database contains values of steady-state transfer factors for the entire "soil fodder-meat (milk)" chain

The influence of factors such as daily milk yield, nutritive value of fodder and season on radionuclide TFs to milk has been investigated. Figure 6-2 illustrates experimental data and the empirical dependence describing them.

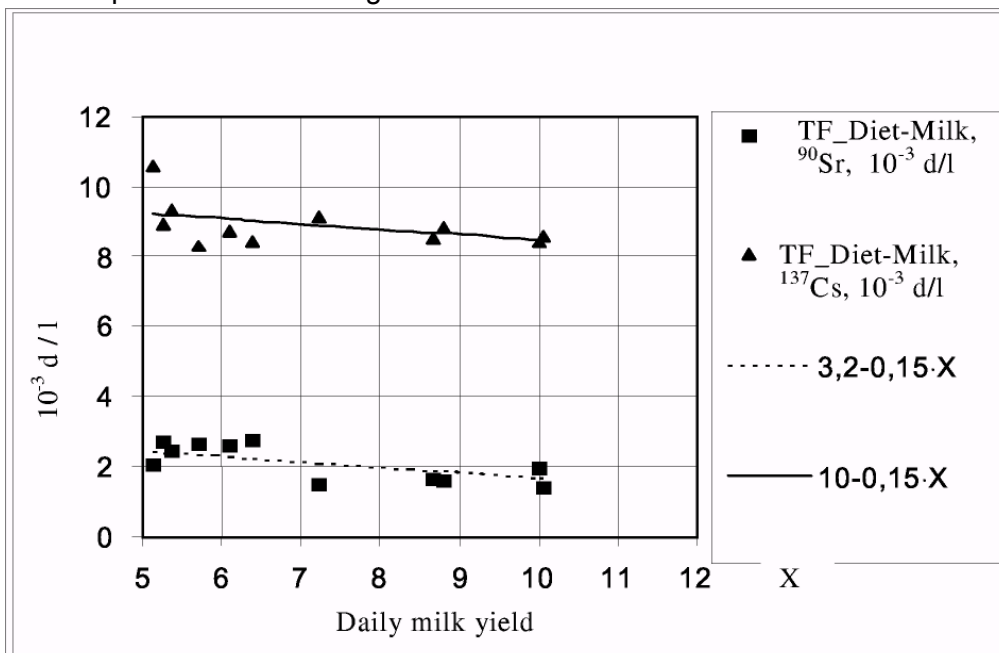


Figure 6-2 Diet-to-milk TFs ^{137}Cs and ^{90}Sr as a function of daily milk yield.

The figure shows that the milk transfer factors for ^{137}Cs are in the range of $9 \cdot 10^{-3}$ d/l and for ^{90}Sr in the range of $2 \cdot 10^{-3}$ d/l.

Data on ^{137}Cs content in milk make it possible to investigate TFs variations with time in the "soil-milk" chain. It was found that the half-life period of ^{137}Cs in milk is increasing over time and is approximately 6.2 years for the period of 1992 to 1998.

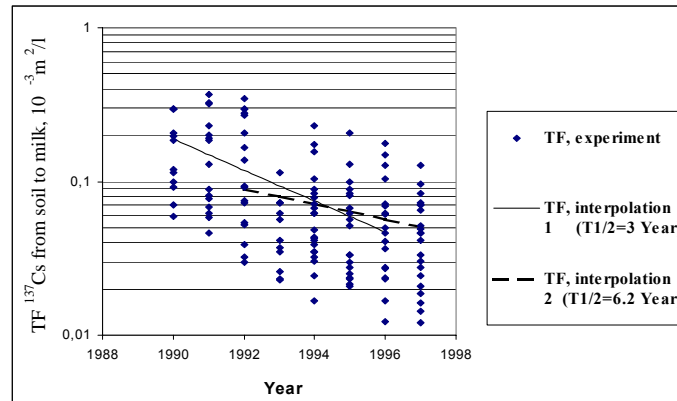


Figure 6-2 : Time dependance of transfer factor

The ^{137}Cs transfer factor from diet to cattle meat is in the range of 0.024 ± 0.013 d/kg, values of ^{90}Sr are not available here. The values are in very good agreement with recommended values in national and international guidelines. A comparison of radioactive meat contamination of domestic animals and game of the same territory shows that the venison is more contaminated by up to a factor ten in comparison with the meat of domestic animals.

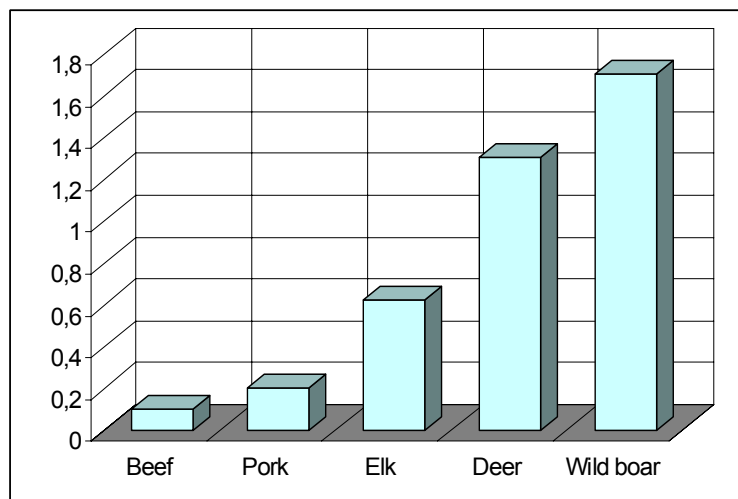


Figure 6-3 : Transfer factors of ^{137}Cs from soil to meat of livestock and game

6.4 Application of the data base

The database can be used:

- as a reliable information basis for the evaluation of the environmental impact from releases of radioactivity in the terrestrial ecosystem;
- as an information support for the selection of adequate countermeasure strategies for contaminated territories;
- for the validation and verification of parameters of the environmental pathway model "fodder–meat" in natural and seminatural ecosystems;
- in practical work of radiation monitoring services for the quality control of measurements;
- for the calculation of control limits of radionuclide contamination in various kinds of forage to produce animals products;

- for the calculation of the radioactive contamination of venison.

6.5 Proposals for future research

- Studies of the influence of the animal diet properties on ^{90}Sr and ^{137}Cs transfer to animal products.
- Investigations into the radionuclide transfer from diet to poultry and eggs and some other relevant domestic animals like bees, sheep and goats and their special products (honey, milk, cheese).
- Studies of the transfer of natural and additional artificial radionuclides including nuclear fission products and transuranic isotopes to animal organs and tissues, and relevant products.

7 Radionuclide transfer by surface runoff (SP3c)

7.1 Specific goals

After the Chernobyl accident, soils in the zone around the power plant were highly contaminated by radionuclide deposition. This zone and its surroundings are very flat with a highly developed hydrological network (Dniepr, Pripjat, ...) with a large number of tributaries. According to this configuration of the landscape and the characteristics of the local climate, one of the most important ways of transfer for radionuclides out of the contaminated zone is surface runoff as a consequence of rain, flooding and snowmelt. The goal of the "Runoff" sub-project (SP3c) was to create a tool for testing and validating models of radionuclide migration in soil-water systems.

7.2 Area of the work

For this purpose, it was undertaken to gather data from river contamination and from results of experiments undertaken by Belarusian, Russian and Ukrainian organisations within national programmes on surface water monitoring in the areas contaminated by the Chernobyl accident.

7.3 Methodology

The methodology adopted for the "Runoff" sub-project was organised in four main tasks.

The first task was to draw up an overview and a critical analysis of existing models of radionuclide migration in rivers and on catchments. The list of models taken into account is rather long and world-wide⁷. Then, information required for the various methods of runoff modelling was analysed.

The second main step was to specify requirements for the database and its structure as follows:

- the database structure must be based on model requirements and availability of data.
- the parameters collected in the database must not be directly linked with any specific model or models
- the database must contain only the results of measurements, without any calculated parameters.












The following task was to gather data for rivers, soils and meteorological data related to river cross-sections, runoff plots and meteorological stations, and to main characteristics (geographic coordinates and administrative division units). A detailed map of the local watersheds, with all characteristics, was established in this context.

Finally, in addition, quality control was carried out on the basis of a specially developed QA/QC programme.

7.4 Main structure of the database

The structure of the database is very clear and data are organised in four tables as follows:

- meteorological data,

 ⁷ AGNPS (Agricultural Nonpoint Source Pollution Model) - USA
 SWRRBQ (Simulation for Water Resources in Rural Basins - Water Quality) - USA
 MARTE (Model for Assessing Radionuclide Transport in aquatic Environment) - EC
 SHE (Système Hydrologique Européen) - EC
 CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems) - USA
 HSPF (Hydrological Simulator Program-Fortran) - USA
 EPIC (Erosion/Productivity Impact Calculator) - USA
 ARM (Agricultural Runoff Model) - USA
 RESRAD, CalTOX and other derived models - USA
 Dynamic model of SPA "Typhoon" - Russia
 RETRACE (RODOS module) - Russia for EC

- radionuclide concentration and hydrological data,
- results of experiments on runoff plots,
- characterisation of soils and radionuclide species.

7.5 Results

The final results of the "Runoff" sub-project are first the creation of the database a such and second the general results of testing the models in different ways.

Database content

The database contains:

- 3622 concentration values in terrestrial environment, shared between experimental plots (568) and soils (3054),
- 7401 concentration values in the aquatic environment for rivers (6961) and sediments (440),
- 2126 runoff values for rain (1977) and for snowmelt (149).

General main results

The model developed by Typhoon is straightforward in its conception but needs complex input information. Nevertheless, it takes into account the major processes governing the dynamics of radioactive contamination of river water.

The model was tested using the data on concentrations of radionuclides in water available in the "Runoff" database. The ^{137}Cs concentration in river water has been shown to be directly proportional to the relative fraction of its exchangeable form in the surface soil layer. This applies to both rivers with catchments contaminated with the condensation fallout and rivers with fuel particles depositions.

Examples of the model validation are given in Figure 7-1 for small rivers of the exclusion zone (Uzh, Irpen and Teterev) and show good agreement between model assessments of up to 13 years and observed monitoring results.

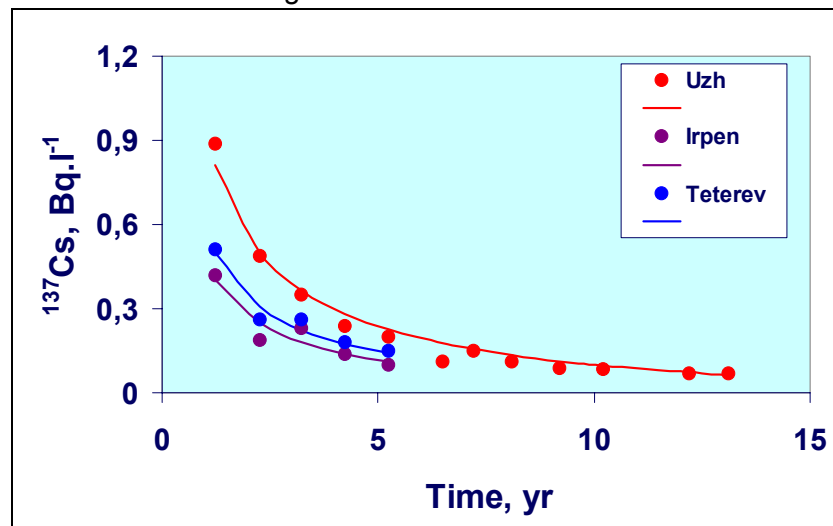


Figure 7-1 : Model validation in small rivers of the exclusion zone

Data from the "Runoff" database on vertical distribution of radionuclides in soils were also used for testing different models of vertical migration in the upper layer of soil (10 cm), examples of validation are given in the thematic report for sub-project 3c.

7.6 Conclusions

- The database on radioactive contamination of rivers and runoff plots was developed according to the term of reference on the basis of experiment results in the areas most contaminated by the Chernobyl accident.

- The "Runoff" database contains numerous data on activity concentrations of ^{137}Cs and ^{90}Sr in river water, bed sediments, soils on watersheds, and results of experiments on runoff plots.
- Data on the vertical distribution and speciation of ^{137}Cs and ^{90}Sr in soils, soil properties, and results of meteorological and hydrological observations are included in the database.
- Some additional work has been done testing and validating models of radionuclide runoff and vertical soil migration.
- The "Runoff" database is a good tool for testing and validating models of radionuclide migration in soil-water systems.

7.7 Outlook

According to the conclusion, different possibilities could be found for using the results of this "Runoff" sub-project.

The database and results included could be used for the testing and validation of various other models:

- of radionuclide wash-off to rivers from contaminated watersheds;
- of radionuclide transport in river systems;
- of vertical migration and transformation of radionuclide species in soils;
- hydrological models;

The estimation of model parameters by model calibration using experimental data is one other good way of validating the database content.

Associated with the database of the aquatic sub-project (SP3d), a study of the features of formation of radioactive contamination in rivers and in aquatic organisms would promise to be very fruitful.

The results and data gathered could be one of the main tools for implementing impact assessments by reconstructing radiation doses received by the population of the contaminated areas through the aquatic pathway.

Recommendations, such as a manual, could be prepared for emergency response, actions and countermeasures in case of a potential nuclear accident.

8 Radionuclide transfer in aquatic environment (SP 3d)

8.1 Introduction

Due to the importance of the local and national hydrological system, contamination from the Chernobyl zone will spread through the local hydrological system and finally will end up in the Dniepr Reservoir, which is the main source of fresh water for the city of Kiev. Consequently, aquatic contamination has to be taken into account because of its importance with regard to the resulting doses and also to drinking water and agricultural water management.

Modelling the radionuclide transfer in aquatic organisms is a major method for assessing environmental and human contamination and exposure.

8.2 Main goal

Sub-project 3d was devoted to the testing and validation of the TRANSAQUA model⁸ with the following specific goals:

- collection, assessment and harmonisation of available data for the validation and parameterisation of the TRANSAQUA model for ¹³⁷Cs behaviour;
- assessment of the influence of main biotic and abiotic factors on the levels and kinetic of ¹³⁷Cs accumulation by various fish species, selected for the model validation;
- sensitivity and uncertainty analysis of model parameters;
- development of recommendations on improving and developing the TRANSAQUA model;
- comparison of TRANSAQUA simulation results with other models;
- widespread models of forecasting the radioactive contamination of water ecosystems.

8.3 Area of the work

The work was limited to ecosystems of water bodies with various hydrology, ecological characteristics, levels and forms of radioactive contamination due to the impact of the Chernobyl accident (Belarus, Russia and Ukraine). For this purpose one water body was chosen in each country: Svyatskoe Lake (Belarus), Koshanovskoe Lake (Russia) and Kiev Reservoir (Ukraine)

8.4 Methodology

The methodology for implementing the TRANSAQUA model in the sub-project included three phases.

First of all, data collection and pre-processing was performed through analysis of the available information for the three typical water bodies selected for the study, and creation of the database (DB) for the validation of the model.

Then the main tables of the database were constructed, based on the data necessary for the model validation and on the preliminary processing of the monthly averaging data and on a selection of data within the limits of the agreed confidence interval of the observation quality.

The second step was to study the theoretical basis of the methodology of TRANSAQUA modelling and model validation and to select the most adequate managing model parameters. Three groups of parameters were to be considered: abiotic, biotic and kinetic exchanges.

The final task was the comparison of TRANSAQUA assessments with the collected data and also with other assessment models. This was performed through harmonisation of all available data in the database, analysis of other mostly applied methods of simulation of the accumulation and removal of radionuclides from hydrobionts, and comparison of the results with similar calculations performed with the TRANSAQUA model.

⁸ Developed in 1995 previously by IRSN - France

8.5 Main structure of database

The TRANSAQUA database is organised in three main parts: general information, data, and model validation (Figure 8-1).

The data are organised according to the water body they describe. For each water body the structure is based on the nature of the parameters:

- abiotic: radionuclide (RN) concentration in water and sediments, zooplankton, zoobenthos, radionuclide half-life period, ...
- biotic: age, diet, growth coefficients for prey and predators
- kinetics of exchange: accumulation and elimination coefficients

The model validation part includes a general scheme of validation, a case study, a sensitive analysis and results and conclusions.

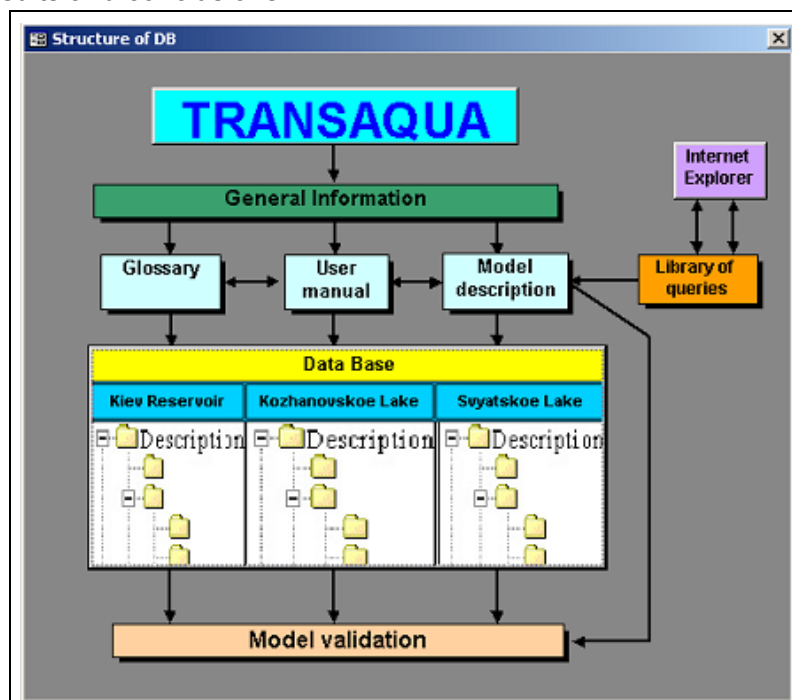


Figure 8-1: Structure of the TRANSAQUA database

8.6 Results

Database content

The TRANSAQUA database contains a large amount of values for all the three water bodies, organised with ergonomic tools for searching and showing results for the three lakes considered.

TRANSAQUA validation

For the three water bodies, case studies give the results of the TRANSAQUA model validation for ^{137}Cs accumulation in different parts of the aquatic organisms including non-predatory fish (bream, roach and goldfish) and in predatory fish (pike) compared to monitoring data. Agreement between the calculated and measured data depends on different cases, and needs to be more accurately studied. Accordingly, recommendations for parameter values are proposed for better to increase agreement.

8.7 Sensitive analysis

A sensitivity analysis has been performed for all the biotic parameters. It appears from the analysis that the kinetics parameters of accumulation and excretion are the most influencing on the results of assessment.

8.8 Comparison with other models

Additional work was performed within the framework of the sub-project by comparing assessment of other models with TRANSAQUA and experimental data. Four models were chosen: LAKECO, VAMP, ECOMOD and MOIRA.

The results of these comparisons are presented here.

- *LAKECO & TRANSAQUA*

The models have different structures and equations, but results show very good agreement of ¹³⁷Cs accumulation modelling in different fish species using LAKECO and TRANSAQUA. The common approach of these models shows that the description of the physical processes which control radionuclide accumulation in aquatic life by these two models is adequate.

- *VAMP & TRANSAQUA*

The VAMP model incompletely takes into account the hydrological, hydrochemical and hydrobiological characteristics of water bodies, but includes some parameters not considered in TRANSAQUA. VAMP does not model the ¹³⁷Cs content in zooplankton and uses completely different approaches to calculating the amount of ¹³⁷Cs entering the biosystem at the moment of initial fallout and the following supply from the catchments. The sub-model of initial fallout influences the modelling results much more.

- *ECOMOD & TRANSAQUA*

Both the ECOMOD and the TRANSAQUA⁹ model provided good results in comparison with the existing data for non-predatory and predatory fish from Lake Kozhanovskoe. The dynamic approach to the radioecological modelling used in the TRANSAQUA and ECOMOD models can be considered as successful and can be recommended for the reconstruction and prediction of ¹³⁷Cs dynamics in freshwater non-predatory fish living in the natural water bodies affected by Chernobyl radionuclides.

- *MOIRA & TRANSAQUA*

TRANSAQUA showed good results for modelling of ¹³⁷Cs concentrations in prey and predatory fish in the Cooling Pond of ChNPP. Running on the same input variables, TRANSAQUA and MOIRA showed a discrepancy of results for ¹³⁷Cs concentrations in prey and predatory fish with a factor of about 10. Concentration factors calculated for quasi-equilibrium conditions with the TRANSAQUA and MOIRA models showed a discrepancy with a factor of about 10. In addition, the experimental values seem to be geometric mean of the calculated values.

8.9 Conclusions

- TRANSAQUA can be applied for the estimation of ¹³⁷Cs migration in natural ecosystems without substantial modification of the model assumptions and equations.
- The kinetic parameters of ¹³⁷Cs accumulation and elimination are the key values of the model.
- The use of the value kinetic parameter of ¹³⁷Cs accumulation determined in laboratory experiments could lead to an underestimation of the actual levels of fish contamination in natural water bodies. It has to be adapted to natural conditions.
- Recommendations for values of key parameters in TRANSAQUA have been given by comparing measured and assessed data.
- There is a good agreement between the TRANSAQUA assessment and existing data for the long-term period (10-15 years), confirming the adequacy and success of the validation procedure. **Outlook**

⁹ using the adapted parameters adjusted within the framework of this sub-project

- The database could be completed by equivalent data for other radionuclides such as ^{90}Sr and transuranics.
- The database can be used for other model validations and model tests.
- The results and experience of the co-operation between France, Germany and Ukraine-Belarus-Russia in developing the database and in model validation can be applied to other Radioecological Case Studies including data available in Germany and France.
- The project results should be circulated, used and developed as part of other CEC research projects (EVANET, MOIRA and others).
- If linked to the database of the Runoff sub-project (SP3c), the data on aquatic life and then TRANSAQUA and other models could be tested and validated for such comprehensive natural compartment systems as « River-Lake-Reservoirs »; such studies of the features of formation of radioactive contamination in rivers and in aquatic organisms would be very fruitful.

radiation exposure dose rate above the surface of the ground; β -flows from various surfaces, and radionuclide content in objects of external medium determined by spectrometers.

A review of some existing models of radionuclide transport in urban environments has been done to determine the main relevant processes and parameters which govern the behaviour of radionuclides in urban environments and contribute to the external doses to the population (Figure 9-2).

The main processes considered in such models were analysed as dry and wet deposition, weathering, runoff from the decontamination of surfaces, and shielding properties of urban objects considered.

The inclusion of these parameters and factors in the database, given experimental data, will make it possible to address the following tasks: testing of the existing models accounting for the radionuclide behaviour in urban environments; development of new models; dose reconstruction for contaminated areas; calculation of input model parameters at different values of factors of urban environments, and refinement of available and development of new methods for estimating input model parameters as a function of urban environment factors.

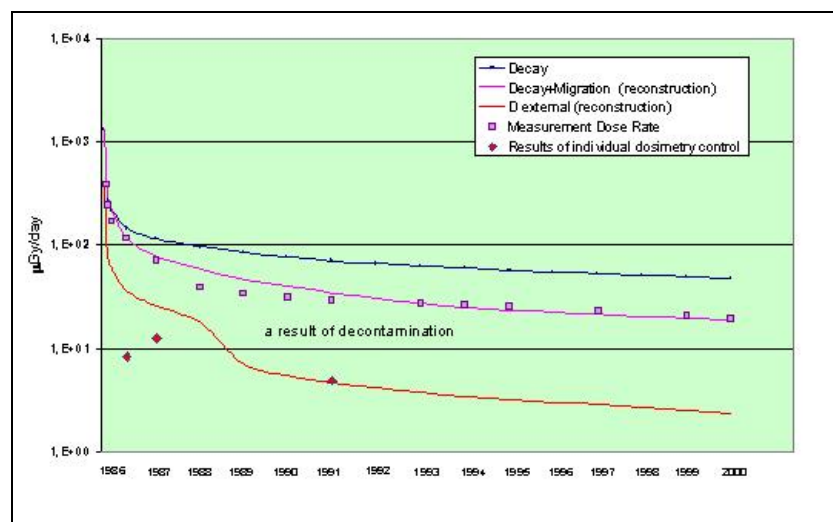


Figure 9-2 : Dynamics of exposure dose rate and external exposure dose for the population of the Mirny settlement

The TACTUS model of the Danish National Laboratory (RISØE) was chosen, but some adaptations are still necessary to apply it to our specific urban environment.

A review of the countermeasures applied after the accident and their efficiency has been done. In theory, any surface in an urban environment can be decontaminated in a physical or chemical way. However, the Chernobyl experience has shown that some countermeasure variants are impracticable due to their costs, their very low efficiency, or the specific characteristics of the surface.

9.3 Database structure

The structure of the specific database URBDECON as a tool for consequence analysis has been developed in MS-ACCESS 2000 in English and Russian.

In the project, the database was created mainly on the basis of the kind of experimental materials that should enter the GIS simultaneously.

Such a database structure can be considered as a first step towards the development of a full-scale database on a residential environment. Applied countermeasure and decontamination factors have been included.

9.4 Main results

In the FSU countries, very little has been done over the last 15 years in radiation ecology in connection with studies of radioactive substance behaviour in the practical plan within the

urban environment. The present project was actually the first step towards understanding the experimental materials in this important direction.

Apart from the URBDECOR database construction, the following results of this study can be summarised:

- average contamination in inhabited localities is comparable to the meadow or agricultural-soil level, and 1.2 to 1.8 times below the surrounding forest soils.
- for the inhabited localities considered (rural type), the soil covering is the main depot of radionuclides, showing about 80 % of the fallout activity during the initial time and 95 % after the first winter season of 1986/87. Approximately up to 20 % of trees and gardens can retain caesium isotopes, roofs about 1% of radioactive fall-outs for considered settlements (Figure 9-3).

The contribution to the external exposure dose for the inhabitants for dry and wet deposition is made by four walls (30%) and the roof (10%). The typical external dose from ^{137}Cs some years after the accident in the inhabited locality is 80 % due to soil contamination, 10 % to individual houses, and 10 % to household items, e. g. clothing.



Figure 9-3 : . A part of Novye Bobovich territory.

For the countermeasure part, the efficiency of decontamination methods and techniques is expressed by the Decontamination Factor D_f . In the majority of cases in the first years after the accident, the factor of decontamination came to 10-12, but after ten years it was 1.4-1.7, confirming those of the European project ECP4.

The low efficiency of decontamination ($D_f < 1.2$) of various objects after the Chernobyl accident demonstrates that the interaction of radioactive substances with the surface and construction materials requires further investigation.

9.5 Conclusions

In this work, a great amount of experimental material already received has been characterised and its systematisation has been completed. Dosimetric measuring results have been collected and verified. The database and maps were prepared for six inhabited localities in a rural environment. External doses to the population were calculated for some settlements on the basis of existing models.

However, the analysis of all archived experimental material on personal dosimetry has received little attention and can be a future step.

The efficiency of decontamination is directly dependent on the level of contamination; the time elapsed after the accident, and the organisation of the work. The wrong choice of measurement device used to determine the D_f may cause a misleading interpretation of the results. The low efficiency of decontamination of various objects after the Chernobyl accident witnesses that interaction of radioactive substances with the surface and construction materials requires further investigation. It is necessary to study the mechanisms of

interaction between radionuclides and the surface of traditional and modern building materials, to trace dynamics of interaction between a contaminant and the surface of building materials in the long run both in decontaminated inhabited localities and in those subjected to natural self-cleanup processes (weathering). Work at the present project has opened a wide field for further investigations and emphasised some key problems of composition of the urban environment methodology investigations.

European scientists have estimated in previous studies that approximately 70 % of the population of modern developed countries live in urban agglomerations. This shows the need for studies into the behaviour and paths of contaminant distributions, including artificial radionuclides, in large and small cities.

For this reason, it is necessary to study mechanisms of interaction between radionuclides and surfaces of modern building materials and to extend the research to urban areas of sizes larger than the rural settlements studied in this sub-project. The economics and social consequences of the countermeasures also need further investigation.

10 Countermeasures in natural and agricultural areas (SP5)

10.1 Introduction

Countermeasures are obligatory measures for reducing the radiation load on the population through the decreasing of radionuclide concentration in foodstuff produced on radioactively contaminated land after the Chernobyl accident. The wide range of countermeasures was developed and applied on the territories of Belarus, Russia and the Ukraine over the 16 years of the post-accident period. Their efficiency depends on many factors like type of radioactive fallout, time period after failure, soil and plant properties, etc. Some countermeasures were widely usable, while others were useless.

The compilation of information over a range of countermeasures, the conditions for their execution and the evaluation of their radiological efficiency have high significance for Belarus, Russia and Ukraine. First, the internal exposure of people, as a consequence of the consumption of food products containing radionuclides, contributed more than 40-50 % of the total radiation dose in the Chernobyl-affected zone. On land of predominantly poor sod-podzolic and peat soils, the contribution from internal exposure goes up to 70-80 %. Secondly, the reduction of internal exposure is easier to accomplish and more economically feasible than the reduction of external exposure. Thirdly, the compilation and analysing of experimental data will allow improving the strategy of countermeasure application in future. Finally, the exclusion of agricultural food products with a radionuclide content exceeding the permissible level is socially and psychologically very important for preventing the spread of radiophobia among people.

10.2 Main goal

The goal of the “Countermeasures in natural and agricultural areas” sub-project within the framework of the “Radioecology” project of the French-German Initiative for Chernobyl is an evaluation of the efficiency of countermeasures carried out in natural and agricultural ecosystems on radioactive contaminated territories after the Chernobyl accident.

The tasks of the sub-project are:

- description of countermeasures;
- countermeasure classification;
- development of database (DB) structure;
- compilation of data and filling of DB;
- evaluation of countermeasure efficiency.

10.3 Methodology

A sequential system of differentiated countermeasure application to restrict soil-to-foodstuff radionuclide transfer comprises the methodological approach for the development of the conceptual structure of the DB. The information in the “Countermeasures” DB is based on experiments with the application of countermeasures to reduce the final food-product radionuclide concentration. Changing the final product's specific activity is a main criterion to evaluate countermeasure efficiency.

10.4 Results

The “Countermeasures” DB is a joint multi-discipline product of radioecology experts from Belarus, Russia and Ukraine in co-operation with scientists from France and Germany. The DB includes 5261 experiments carried out on territory affected by the Chernobyl accident during 1987-1999 and consists of six separate sub-databases (sDB): namely *Plant production*, *Stockbreeding*, *Meadow and forest ecosystems*, *Hydrological systems* and *Technological processing*.

Countermeasures *in sDB Plant production* are classified in four groups: change of crop type and variety, agrochemical countermeasures, application of plant protection means, and soil

cultivation. Changing of crops and fertilisation are most effective countermeasures in plant production. The efficiency of countermeasures expressed by the reduction factor (RF¹⁰) of radionuclide concentration in the final product lies within a range of 3.0 - 9.0, depending on soil and crop properties. For example, a high rate of application of potassium fertiliser is effective on soil with poor potassium status and vice versa (Figure 10-1).

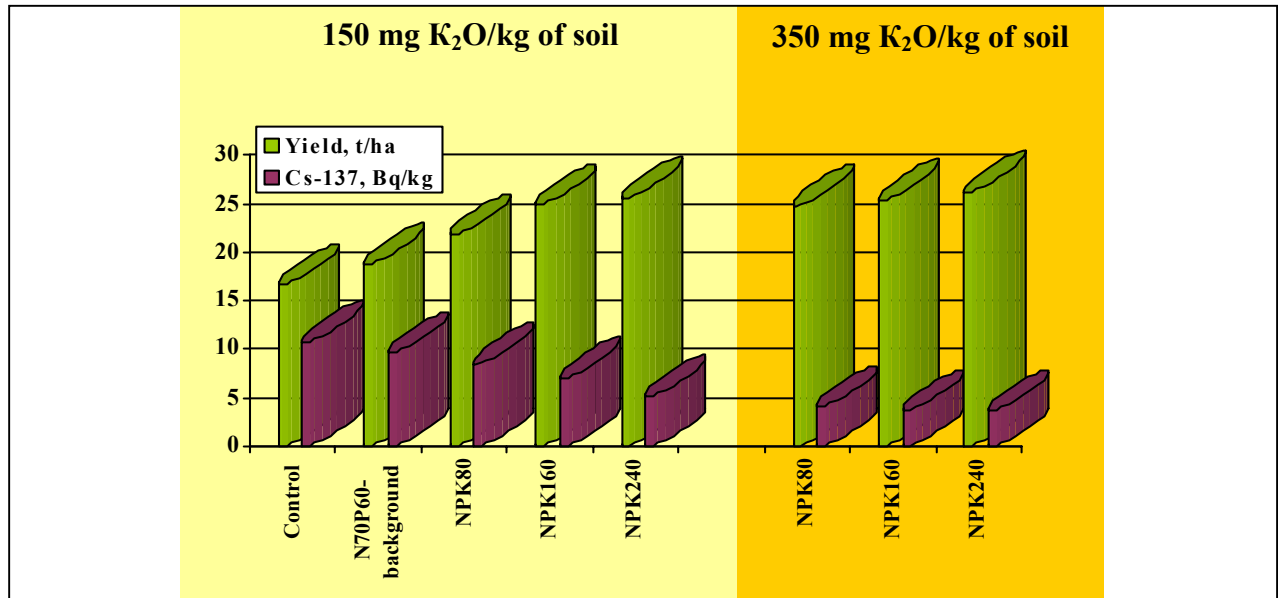


Figure 10-1 Yield and ¹³⁷Cs activity in potatoes depend on rates of K fertilizers and soil K status.

The use of insecticides, herbicides and fungicides as plant protection means increases the yield of crops and improves product quality. Thus, the reduction factor RF for soil-to-plant radionuclide transfer is 1.2 - 1.6 under these conditions. Soil cultivation was an effective countermeasure on radioactive land only in the early period after fallout.

Surface improvement and the radical improvement of meadows are the most practical countermeasures to use in contaminated meadow ecosystem. The RF of ¹³⁷Cs grass activity of radical improvement is about 4 averaged over all meadows and the average RF for soil treatment up to 16 - 20 (Figure 10-2). The efficiency of surface meadow improvement is on average lower and is associated with an RF of 3.5. The main factors determining countermeasure efficiency are the types of meadow and the soil properties.

¹⁰ Reduction factor (RF) is the ratio of initial specific activity to the specific activity in products after countermeasure application

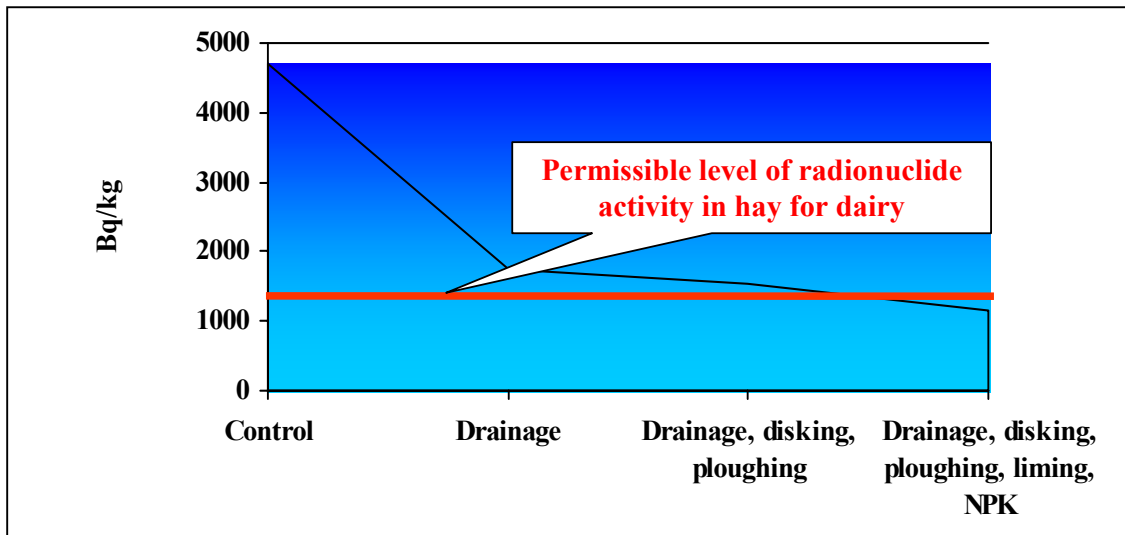


Figure 10-2 ¹³⁷Cs concentration in hay depends on type of meadow improvement (deposition by ¹³⁷Cs - 370 kBq/m²)

Veterinary countermeasures in stockbreeding are based on reducing assimilation and accumulation of the radionuclides in animals by using chemicals and sorbents. The efficiency of veterinary countermeasures depends on the type and rate of chemical ¹³⁷Cs binders used and is associated with an RF of 2-6 (Figure 10-3). Zootechnical countermeasures include the pre-slaughter fattening of animals with “clean” fodder, the rational use of hay-land and pastures, and a selection of fodder in animal diets. The efficiency of zootechnical countermeasures varies widely with an RF between 2 and 15.

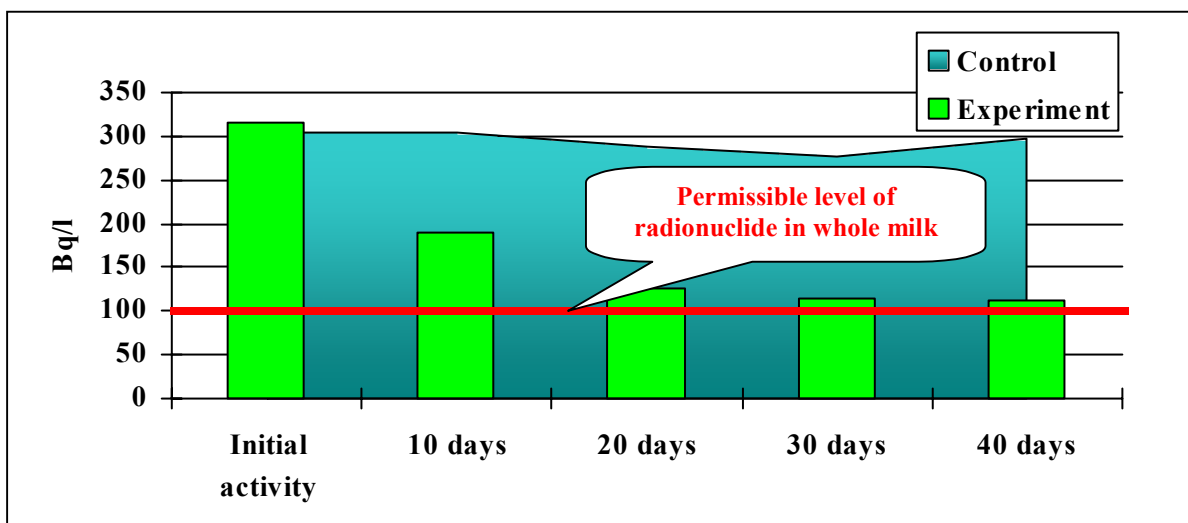


Figure 10-3 Dynamic of ¹³⁷Cs content in cow's milk after Cs-binders (boli) application

The restrictive-access countermeasures *in forest ecosystems* are the most effective in the short-term period after accident fallout. These include restrictions on the working time for foresters and restricted areas of using forest products like wood, mushroom, berries and medical herbs. The adverted dose of radiation depends on the type of restriction and could be as effective as about 1-6 mSv/year. The efficiency of restricted-access/usage countermeasures decreases with time. The application of agrochemical measures would be effective but is not affordable.

Technological processing of plant and animal products can greatly improve the quality of foodstuff. The technological processing efficiency depends on the type of the processing and varies widely, removing 50-98 % of ¹³⁷Cs or ⁹⁰Sr, e.g. during butter and casein processing (Figure 10-4).

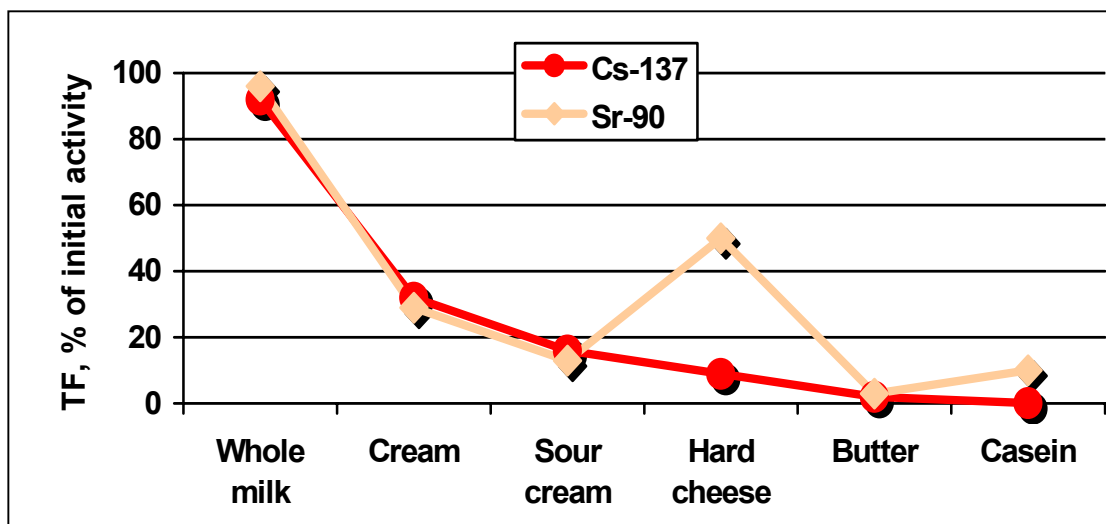


Figure 10-4: Efficiency of milk processing

The sub-DB “Hydrological systems” contains a lot of information about countermeasures applied for reducing the radioactive contamination of water resources. There is information and some data for administrative and hydrotechnical countermeasures, radionuclide flux control, and decontamination.

10.5 Conclusions

The DB “Countermeasures” is a joint multi-discipline product of radioecology experts from Belarus, Russia and the Ukraine in co-operation with scientists from France and Germany. The DB includes 5261 experiments carried out during 1987-1999 on territory affected by the Chernobyl accident.

The DB “Countermeasures” has wide potential fields of application. The DB contains valuable information for scientists and decision-makers. It could be used for a review of countermeasures applied in Belarus, Russia and the Ukraine following the Chernobyl accident for research and education. Comparative analyses of natural and human factors influencing the radioactive contamination of food, the assessment of countermeasure efficiency depending on site-specific conditions, the prediction of radioactive food contamination and the justification of countermeasure application could be performed on the basis of the compiled data. The DB can be used as a tool for the prediction of radioactive food contamination level and for the justification of countermeasure application.

11 Soft integration of the Project 2 "Radioecology" databases (SP6)

11.1 Goals

The general objective of sub-project 6 is to create a "soft" integrated RadioEcological Database After Chernobyl (REDAC) system, based on the Project 2 "Radioecology" sub-project SP0-SP5 databases and satisfying the requirements that all information and software elements created in Project 2 should be imported in the REDAC database and should be accessible through the user-friendly interface. Principal REDAC database characteristics are:

- common databases developed in sub-project 0: administrative-territorial division, topographic and geobjects are incorporated in sub-project 1-5 databases.
- the specific system database catalogue is created. This catalogue includes: integrated glossary, integrated classifiers, integrated data dictionaries, integrated database scheme.
- the data of all thematic sub-projects 1-5 (contamination, wastes, runoff etc.) are geocoded on a unique topographic map.

11.2 Area of investigation

The area of investigation comprises the Project 2 sub-project 0-5 databases with the following themes:

- FGI20: Ecological portrait,
- FGI21: Contamination of the environment,
- FGI22: Waste dumps and waste strategies management,
- FGI23a: Soil-plant transfer,
- FGI23b: Plant-animal transfer,
- FGI23c: Runoff in an agricultural or natural environment,
- FGI23d: Transfer in aquatic environment,
- FGI24: Urban environment and countermeasures,
- FGI25: Countermeasures in natural and agricultural areas.

The main question of investigation was "How to reach representation of the nine sub-project databases for application or use as a logically unique database?"

11.3 Specific methodology

On creating REDAC3W, the methodology consisted in the regular application of the Project Solutions Framework (ProSF). ProSF is a system of practically verified patterns intended for the simplification of the main project activities:

- manufacturing intermediate and final products of the project
- the organisation and support of the project implementation process
- publication of materials about the production and project implementation process
- performance of the project service functions
- support of the project basis - the system of patterns and the elements intended for the performance of the soft integration of project elements.

On ProSF application, developers adhered to the following principles:

- The resulting system should be an information system in a wide sense (ISW). The ISW is the totality of the entire formal and informal data representation and processing activity within an organisation (for example, Chernobyl Centre), including the associated communication, both internally and with the outside world. The ISW should be developed as the project portal.
- The project portal should be a soft integrated information system:

- 1) commonly used data should be found and embedded as a global database layer in the Project 2 sub-project databases,
- 2) HTML should be used as a main tool for linking all information and software objects in resulting the ISW.
 - The project portal should be a geoinformation system - all thematic spatial data should be geocoded by the means of a uniform topographical map. Geoinformation tools should be used for the manipulation of these data.
 - Developments should be carried out on staged delivery model. Development of the prototype should precede the release of each version. In Project 2, 3 basic versions were released over 4 years: REDAC1W, REDAC2W, REDAC3W, and set of intermediate versions (for example, 1.1, 2.5, etc.).

11.4 Structure of the database

REDAC3W is a set of 5 packages containing the elements: Publications, Products, Processes, Services, Basics. Certain relations are created between these packages. Contents and relations of packages are determined by the ProSF concept.

The **Products** package is intended for users who are interested in having direct access to the "classical" information products prepared according to the templates from the Basics package. It contains the basic electronic results of each sub-project: databases, applications and the accompanying documents including Information Description Document, Metacard, Glossary, Classifiers, User's Guide, Synthesis and final reports, References.

The **Publications** package is intended for the storage of open publications of sub-project results. It includes materials for the creation of the Project 2 website (web pages), presentations of the products of sub-projects and Project 2 itself (Power Point presentations), scientific publications, examples of the data (fragments of sub-project results).

The **Processes** (sub-project) package is intended for the managers of Project 2 and also for managers who will solve similar tasks in similar projects. It contains two sections: Working Plans & Reports, Management Process. The Working Plans & Reports section contains quarterly and semestrial reports of all sub-projects of Project 2 for 6 working periods. Semestrial reports contain detailed working plans for the subsequent period. Many reports have annexes consisting of separate documents. The Management Process section contains the Configurator of final production, and also the additional information describing processes of creation of the Project 2 results: specific agreements and detailed working programmes.

The **Services** package contains service information and software objects. Service information objects are: information about Project 2; on-line help; connection with electronic storage of original products of Project 2; file of the description of all printed products received by the Chernobyl center and stored in the paper storage; information about Project 2 participants; service design elements. The basic service software object is ISGeo TripleNet Suite (ISGeoTriNet, TriNet) - the software of support of system work. It includes the components TriNet User Services, TriNet Business Services, TriNet Data Services, and TriNet Admin Services.

The **Basics** package is intended for the storage of the information objects determining the system development processes or the project implementation processes, and for the organisation of all information and software objects of the sub-projects in a "weak-" or "soft-" integrated system. The ProSF section contains a subset of the Project Solutions Framework which was used in the Project 2. The GlobInfoRes section contains the base (topographical) map, the DB of administrative-territorial division, the DB of geobjects, the global glossary, classifiers, and data dictionaries.

11.5 Main scientific/technical results

The main scientific and technical result of sub-project SP6 (FGI26) is the soft-integrated geoinformation system REDAC3W including all final results and the important intermediate results of the Project 2 on Radioecology.

Soft integration concerns both software and information methods and tools. All elements of production of Project 2 are organised in a special storage which is referred to as the Element / Document library. Work with this storage is carried out by TriNet software. In TriNet, there are special mini-applications realising business functions and processes. They are referred to as Portlets. Portlets consist of Web parts. Presentation layers (the layers visible to the user) of Portlets and Web parts form the Digital Dashboards (DDB). Digital Dashboards are gathered in the DDB site. DDB sites are adjusted to the needs of the concrete user, depending on his rights of access.

For coordinators, all change is authorized, authors are authorised to change certain documents, and readers are authorised to read certain documents. In REDAC3W, only 2 groups of users are possible: coordinators and readers.

Document library Portlet

A typical Document library Portlet view is shown in Figure 11-1. The file of SP5 "Countermeasures in Natural and Agricultural Areas" is chosen as an illustration. (FGI25_DB_V2_RuEn.mdb). It includes the Web parts:

- **GlobalFunctions** - connection with other Portlets simplifying work with documents.
- **LibraryLocator** - shows the location in the library.
- **ContentsTree** and **SubContents** help to carry out navigation within the library. In Figure 11-1 the ContentsTree shows the structure, content and names of library folders. SubContents shows expanded information about folder content when a certain folder is selected. **Thumb** shows the thumbnail image which is put in conformity to the element / document of the library and which characterises this element / document most clearly. In Figure 11-1 file FGI25_DB_V2_RuEn.mdb corresponds to the picture of the interface of the Project FGI25 database.
- **MetaView** shows metadata - the data about elements / documents in the library. The displayed data have been taken from the Metainformation card, and also from other products of sub-project FGI25. This information was then structured on Profiles. Profiles unite those or other properties of the document. In Figure 11-1 properties of four Profiles are shown: Standard (in the top part of the Web part - it is displayed for all documents), Office Document, AdminInfo, Database.
- **ProductRelations** - shows the relations established between a database file and the documents describing it: References, Information Description Document, Metainformation card, Glossary and Classifiers. The listed elements and relations between them form a product of the sub-project. It is important to note that the documentation structured in this special manner is an integral part of a product of each sub-project of the Project 2.
- **DocView** (not shown in Figure 11-1) displays the file / document loaded from the Web server.

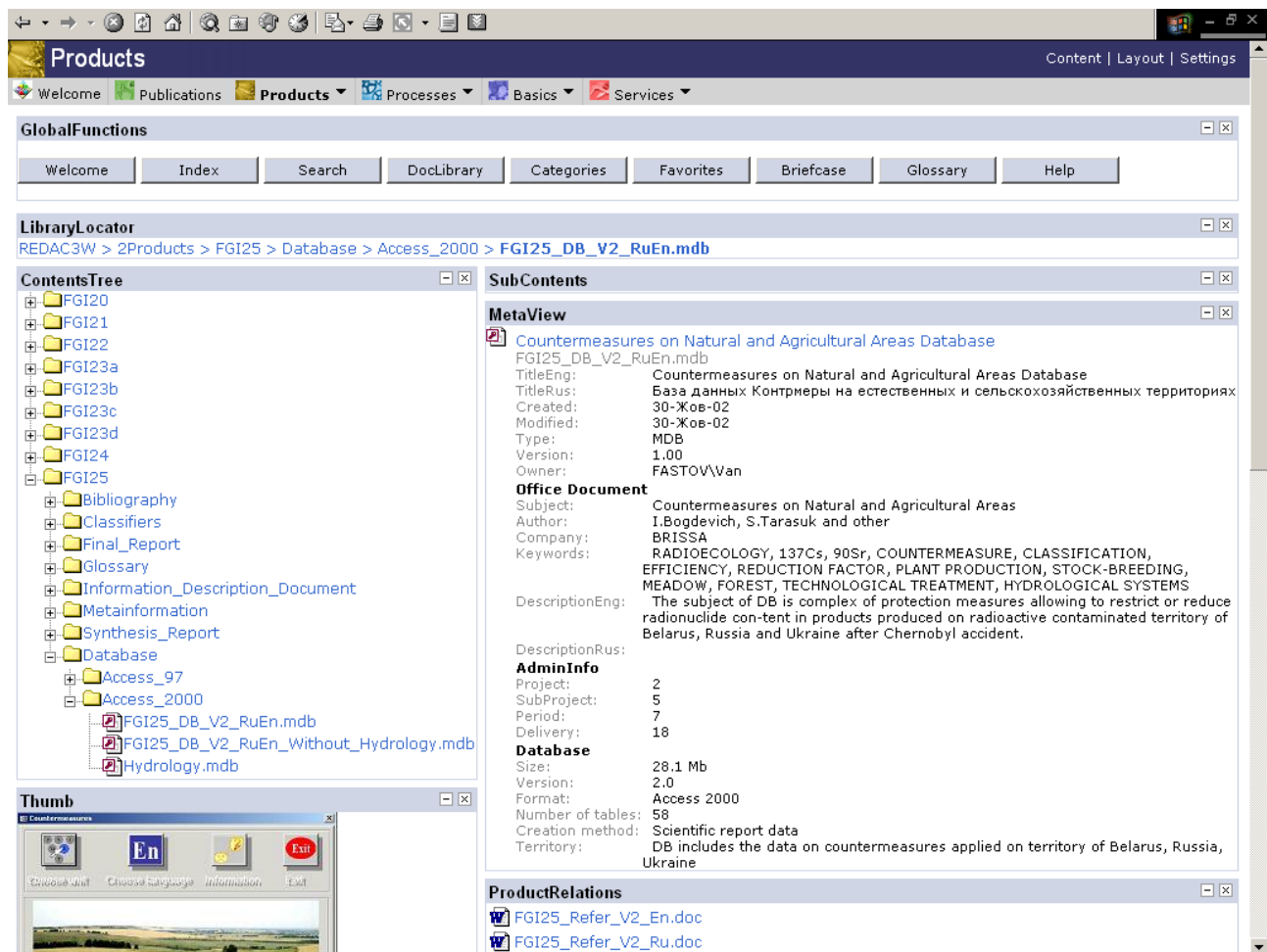


Figure 11-1 Document library Portlet interface - example of the sub-project FGI25 product

Portlets supplementing the Document library

The Document library Portlet is connected to other Portlets through the **GlobalFunctions** Web part:

1. **Index Portlet** - search of documents by the index, i. e. a beforehand-prepared list of keywords.
2. **Search Portlet** – search of documents by the auxiliary words, properties, file extensions, categories.
3. **DocLibrary Portlet (Document Library)** – is described above. In this case provides an exit in a root of document storage and access to the above-described navigation and visualisation functions.
4. **Categories Portlet** – work with document categories. The Categories mechanism allows the creation of virtual groups of documents in addition to the groups which are created physically at the creation of system folders on a hard disk. Files are thus stored only once in a special folder. With Categories it is possible to create as many categories as necessary and to relate in these categories the necessary files. Thus, for example, a file physically stored only once with the report can be related to the category DepartmentReports and to the category QuarterReports.
5. **Favorites Portlet** – the user can generate a set of files by chosen principles (for example, most-often-used files).
6. **Briefcase Portlet** – the necessary files can be transferred to the Briefcase so that after the end of a session they can be downloaded to the user's computer.

- Glossary Portlet** – supports work with the Global glossary of Project 2. The Global glossary is constructed on the basis of the glossaries of the sub-projects. Each term in the Global glossary has a reference to the source glossary.

Cartographical integration

The map of the Project 2 territory created in sub-project FGI20 (with the data from the DB "Topography") by means of the DBs GeoObjects and AdmTer has been integrated with the thematic databases of the sub-projects. The results of the integration have been loaded into the library of documents as documents of a special kind: MapLayers and MapSpaces. MapLayers and MapSpaces can be viewed by means of the ISGeo Internet Map Server which is provided with the TriNet software. Figure 11-2 shows the result of a MapSpace visualisation intended for work with the geocoded data from the "Waste" database of sub-project FGI22. As it is possible to see from the figure, a large set of cartographical functions intended for the visual analysis of the data is provided to the user: scaling, navigation, extracting of the information on objects, management of displayed layers.

It is important to note that thematic databases are external in relation to MapLayers and MapSpaces. This means that they can be arranged without changing a cartographical part of the system architecture.

It is also important to note that the received cartographical results became possible due to application of the method of geointegration. The method of geointegration was developed in sub-project FGI20 as a core of weak integration. This method is used for geocoding special attributes of the GeoObjects DB doing away with the need to apply imperfect and hard-accessible cartographical DB.

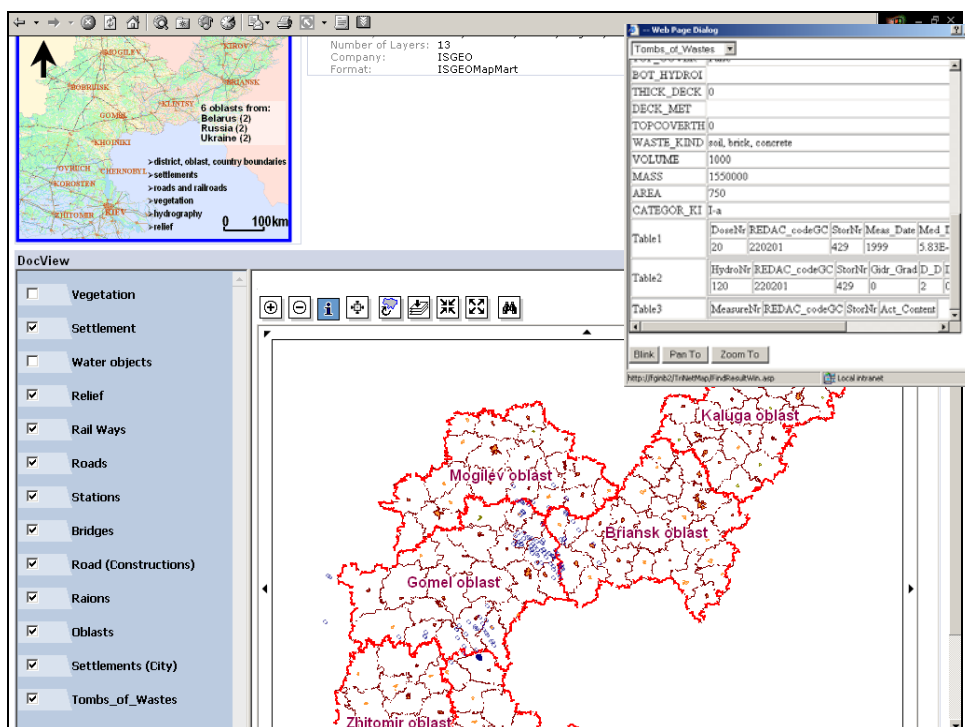


Figure 11-2 Result of downloading the Project 2 territory map into the DocView Web part and selection on the map (by the "i" tool) of the information about waste dumps of I-a category (from the sub-project FGI22 database)

11.6 Conclusions

REDAC3W is powerful and rather useful tool for work both with the radioecological databases and with other results obtained in Project 2 "Radioecology".

All elements of final and important intermediate production of Project 2 are processed and placed in special storage, i. e. the Element / Document library. Elements placed in the Document library are soft-integrated. For the integration, the following tools and means are used:

1. Access to all elements is carried out uniformly by the browser and with use of modern Digital Dashboard technologies.
2. The main results of the Project 2 sub-projects - databases – are constructed by an aggregation of files of databases and the by the documentation accompanying them. The result of the aggregation is referred to as a product. Relations are established between the different product elements.
3. All elements of production are provided with the structured metainformation. For structuring, the method of document Profiles is used.
4. There are two mechanisms of search of the necessary elements - index and auxiliary. Auxiliary search is carried out by the definition of any words, properties, file expansions , or categories.
5. Besides the physical structuring of elements - their writing in certain library folders - structuring is also realised by categories mechanism.
6. On the basis of the glossaries of the sub-projects, the Global glossary of the Project is constructed. Each term in the Global glossary has a reference to the source glossary.
7. All spatial data are geocoded by means of the databases of sub-project FGI20: Topography, GeoObjects, AdmTer. Thematic cartographical working spaces (MapSpaces) have been established which display the thematic structure of Project 2.

In the opinion of the developers, the following results are of most greatest interest from a scientific and technical point of view.

№	Result	Useful to whom and in which way
1	Soft-integrated Project 2 production database	After the end of Project 2, full information about Project production can be accessible for use and for presentation to the potential users by request. Actually, Chernobyl Centre, IRSN and GRS have not received a big set of isolated elements of production that are difficult to use but an information system that is convenient in daily use
2	The tools and means of soft integration listed in this section	Each of the seven tools and means can be used both separately and together. In case of sharing, it is possible to speak about a technique of soft integration
3	The concept of the organisation of the Project 2 results. All results are organised in 5 packages: Publications, Products, Processes, Services and Basics. Each package has an assignment, which is clear from the package name. Elements of separate package, too, have quite certain structures and assignments. Packages should be harmonised.	Application of this concept will simplify the management of similar projects, the decision on questions concerning the organisation of the project, and the definition of the project results. The concept asserts that it is necessary to define, control and harmonise activities, provided of the 5 listed packages of results are available. Due to identification and receiving of five kinds of results (according to the packages), the needs of various groups of users will be satisfied: the public, experts, decision-makers and the project personnel.
4	Experience of construction and use of the specialised project portal which in Project 2 is referred to as an information system in a wide sense	In Project 2, templates of the Project Solutions Framework ProSF have been checked up. Other projects can reuse these templates, seeing results of their application in Project 2.
5	Experience with the application of the staged delivery process model in the international scientific project.	Users of Project 2 results should pay attention to the presence of the Processes package of production. As a matter of fact it is the materialisation of the way of receiving the final product. It is recommended to use the Configurator of final product for the precise definition of expected results right at the beginning of the project.

11.7 Outlook for SP 6

Nearest outlook

In the near future it will be expedient to work in two directions:

- Development of some additional and principal REDACW functions - REDACW, Version 4.0 (REDAC4W) release.
- Scientific support and maintenance of REDA3W operation at the Chernobyl Centre (Kiev) and at the International Chernobyl Center (Slavutich).

REDAC4W release

In REDAC3W, all elements are soft-integrated on macro level, or level 1. This means that soft integration relations are built between files mainly.

For the real analysis of Project 2 results, soft integration on micro level, or level 2, is necessary. This means that soft integration relations should be built between specific objects which are included in the files. The examples of such objects are: tables in the database file, terms in the glossary file, chapters in the document file etc. The most principal additional functions are described below:

- The REDAC3W GeoObjects database includes records, describing geographical objects. The analysis should be done and relations should be constructed between GeoObjects DB records and tables and records in the thematic Project 2 databases. Navigation, visualisation and querying of these relations should also be done.
- The same work should be done from the cartographical viewpoint, in the cartographical part of the REDAC3W database.
- Intellectual cartographical navigation should be developed. This means (as a minimum) the construction of a specific cartographical navigation layer. Then the cartographical navigation layer objects (like sub-project study objects) should be related with REDAC3W elements.
- The REDAC3W glossary terms in the glossary file are presently only related with sub-project glossary files. Relations should be made between terms and tables inside the thematic databases. Again, navigation, visualisation and querying of these relations should also be done.

Scientific support and maintenance of REDA3W operation

It is expected that the installation and operation of REDAC3W at the Chernobyl Centre in Kiev and of REDAC3W clients at the International Chernobyl Centre in Slavutich will be complicated work. Many mistakes in the thematic databases are expected when operation will start. Somebody should identify and correct these mistakes. Some mistakes can be corrected by the developers only. In this case, the request should be prepared and sent, and results should be received.

Training is needed. Integration with the Chernobyl Internet/intranet Information System of the FGI is needed. The list of work concerning the scientific support and maintenance of REDA3W operation can be continued.

Distant outlook

Apparently, results of operating REDAC3W will only strengthen confidence that so-called "strong" integration is necessary for the radioecological data. "Strong" integration can be carried out in two basic directions:

- thematic integration

➤ information integration.

Within the framework of thematic integration, it is necessary to offer decisions on the integration of the databases of all sub-projects. Combinations of thematic integration and links are possible. Information integration should consist in the decision of "classical" information tasks of construction of the integrated database, and also in information support of all the combinations of thematic integration listed above.

12 General Conclusions

The main conclusion that can be drawn in connection with the "Radioecology" project is that the goals of the project have largely been achieved in line with contractual agreements specified at the beginning. This applies to all sub-projects, except in one case for which some restrictions have been made.

The central and most important element of the project is the REDAC database system.

The REDAC database system is, in a wide sense for its version 3W, an information system that administers scientific, radioecological, environmental, administrative and geographic information resulting from the different sub-projects.

The system is now available and operable. It has a very user-friendly interface. The data and the information in the system have been validated, verified and secured by the contributors and have, for some of them, been associated with an index of confidence resulting from expert judgement.

REDAC3W also includes a copy of a website that presents the global results of the project and indicates where further details can be obtained.

The system, installed at the Chernobyl Centre, beneficiary of the work, and at IRSN and GRS as owners of the results, is at present being tried by potential users at IRSN and GRS in order to correct the remaining errors both in the thematic data bases and in the functionalities of the system. All results of the project included in REDAC will obviously be available to the contributors to the different sub-projects.

The results of the sub-projects are generally satisfactory, with some restraint in one case. This also applies to many of the individual databases and their user-friendly surfaces.

In sub-project 0 "Ecological portrait", the maps showing the most relevant cartographical and ecological material were prepared for further use in the other sub-projects. However, only maps with a small scale have been officially cleared for public use. This restricts the use of the maps on a regional or local level. The maps available were accurately processed.

Sub-project 1 "Initial contamination" provides a good tool for assessing the contamination of the studied zones in the future and shows the need to amend and enhance some previous contamination maps.

In sub-project 2 "Waste", the database, the information and the measuring data are good; for reasons of funding, however, only part of the waste disposal sites in the Ukraine could be covered. A further drawback was that measured values only exist for ^{137}Cs ; for ^{90}Sr values, some are measured and others calculated with correlations. For transuranics values, all were calculated with correlation models. These correlations need to be analysed in more detail.

Sub-project 3a "Soil-plant transfer" and **sub-project 3b "Plant-animal transfer"** contain operable databases as well as comprehensive measured data for all countries concerned.

In sub-project 3a, functions related to the soil-vegetation transfer in dependence of soil parameters were derived, which would be worth comparing with the results of other national or international investigations.

In project 3b, transfer factors were determined which correspond largely to those used in Western Europe after Chernobyl. Special features are the results relating to game which have so far not been collected at such a quality and quantity anywhere else.

Sub-project 3c "Runoff" contains a database on the runoff effects with which generally used models can be tested. The practicability and quality of the database was tested in several scenarios.

In sub-project 3d "Aquatic environment", the trophic chains in several lakes and river system were investigated in detail, and the radionuclide accumulation in the food chain was analysed. A comparison with conventional models showed that the more theoretical

parameters and models derived under laboratory conditions could be improved in several areas.

Sub-project 4 "Urban environment" was one of the most complex sub-projects. It globally confirms the previous results obtained within the framework of the European action ECP4. The behaviour of radionuclides in settlements is not sufficiently well described. Only few countermeasures in urban environment are included in the database for different reasons linked to the low reliability of the first actions, which could not be taken into account within the framework of this sub-project.

In sub-project 5 "Countermeasures in agricultural and semi-natural environment" an excellent database was created in which the different effects of countermeasures in the agricultural field and in industrial and domestic food processing was registered.

Another important and more general consequence of the Project 2 "Radioecology" within the framework of the French-German Initiative (FGI) was the very good opportunity to establish close co-operation between France, Germany, Belarus, Russia and Ukraine in the field of radioecology. It also allows restoring scientific and human links between institutes of Community of Independent States (CIS) which had been untied by the political developments in the region in the 1990s.

13 Outlook on the "Radioecology" Project

According to the success of the "Radioecology" Project it would be useful to take advantage of the dynamics of the joint work during the last four years. The following outlook is based on the results of the project and aims at completing the most important results obtained and gathered in the REDAC database system.

13.1 REDAC strong integration

So far, the REDAC database system is a "soft" integrated database. Each of the thematic sub-project databases is included in the REDAC database, but more or less independently from the others. The databases share common a glossary and index and all structures as well as ergonomic and operational aspects. Therefore, it makes sense and would be expedient to integrate all databases totally in one overall structure, called "strong" integration. This allows to provide all available data of the different subprojects specific to a defined point or area at the same time. In this way a real geographical information system would be realised.

13.2 Further scientific developments based on the results and data.

The below studies could follow up the "Radioecology" Project for large scientific interest:

- collection of the missing waste disposal sites and performance of some programmes measuring transuranics in the waste;
- application of the results of the soil-plant transfer functions to national conditions;
- completion of the database for other radionuclides, especially transuranics;
- use of a runoff model, validation with the data sets of the project;
- studies relating to the results of the aquatic environment and comparison with national models;
- complete study and modelling of the radionuclide transfers from surface contamination to aquatic biota by combining runoff and aquatic transfer;
- analysis of the results concerning the countermeasures for the derivation of strategies and practical application in urban areas as in natural or agricultural areas;
- practical proposal for the implementation of the results of the "Countermeasures" project in the area of agriculture on the example of a village or region in Belarus and the Ukraine with information and education of the public.

13.3 REDAC management

The REDAC database is (and databases from the two other projects will be) installed at the Chernobyl Centre, the beneficiary of the work, with copies at IRSN and GRS, the owners of the results.

It is expected that the installation and operation of REDAC3W at the Chernobyl Centre in Kiev and at other users, especially at the International Chernobyl Centre in Slavutich, may lead to the discovery of some unavoidable mistakes, which can be corrected by the developers only. In this case the request should be prepared and sent and results should be received.

Some evolutions are desirable, as a "strong" integrated database, the addition of new data from studies to be implemented, or comparisons with other existing databases (IUR, IAEA, IRSN, ...) ¹¹.

Data would also be provided to the international scientific community for special research.

For all these purposes, REDAC must be technically managed by an administrator from the Beneficiary, under the control of the owners. Scientific users needing access to REDAC must be defined and authorised.

¹¹ IUR International Union of Radioecology, IAEA International Atomic Energy Agency

The most efficient way of managing the database has to be defined. This should probably be by setting up a database Management Committee, on which representatives of IRSN, GRS, the Chernobyl Centre and the scientific contributors would work together in order to optimise and control the use of the database.

Table A1- 1: Institutes and organisations involved in the Radioecology Project

Country	Name	
UKRAINE (8)	IEG	Institute for Environmental Geochemistry (National Academy of Sciences)
	IHB	Institute of Hydrobiology – National Academy of Science
	IMMSP	Institute of Mathematical Machine and System Problem (National Academy of Sciences)
	ISGEO	Intelligence Systems GEO Ltd
	MECA	Ministry on Emergencies and Affairs of population protection from the consequences of Chornobyl catastrophe
	SSSIE “Ecocentre”	State Specialized Scientific & Industrial Enterprise "Chernobyl Radioecological Centre"
	UHMI	Ukrainian HydroMeteorological Institute
	UIAR	Ukrainian Institute of Agricultural Radiology
RUSSIA (5)	CSRVL	Central Scientific Radiological Veterinary Laboratory (Moscow)
	IBRAE	Nuclear Safety Institute (Russian Academy of Sciences)
	RIARAE	Russian Institute of Agricultural Radiology and AgroEcology (Obninsk)
	RRCKI	Russian Research Centre “Kurchatov Institute”
	SPA TYPHOON	Scientific and Production Association “Typhoon” (Obninsk)
BELARUS (7)	BRISSA	Belarus Research Institute for Soil Science and Agrochemistry
	BSU	Belarus State University (Minsk)
	Com Chem	Chernobyl Committee
	IRB	Institute of Radiobiology (National Academy of Sciences)
	IREP	Institute of Radioecological Problems (National Academy of Sciences)
	RCRCM	Republican Centre of Radiation Control and Environment Monitoring
	RIR	Research Institute of Radiology (Gomel)

Table A1- 2 : Main participants in the Radioecology Project

Name	Institute	Country	Sub-project
Ageets Vladimir	RIR	Belarus	3b , 4, 5
Alexakhin Rudolf	RIARAE	Russia	3a, 5
Antsipov Gennady	Ch Committee	Belarus	2
Averin Victor	RIR	Belarus	3b , 5
Bakin R.I.	IBRAE	Russia	4
Belan Tamara	BRISSA	Belarus	5
Bogdevitch Iossif	BRISSA	Belarus	5
Borovoi A.A.	IAE	Russia	1
Bondar Yuri	IRB	Belarus	3a
Bulgakov Anatoly	SPA Typhoon	Russia	3c, 3d, 4
Chabanyuk Viktor	IS Geo & ChC	Ukraine	0, 1, 6 , co-ord
Dzuyba Natalia	UHMI	Ukraine	3d
Fedorenko Yuri	IEG	Ukraine	4
Fesenko Serguey	RIARAE	Russia	3a , 5
Germenchuk Maria	RCRCM	Belarus	1, 3c
Golovko Natalia	IEG	Ukraine	2
Grutsyuk Nathalie	UIAR	Ukraine	3a
Isamov Nizam	RIARAE	Russia	5
Ivanov Yuri	SSSIE	Ukraine	3a
Ivanova Tamara	BSU	Belarus	3a
Ivanova Tatiana	UIAR	Ukraine	3a , 5
Kanivets Vladimir	UHMI	Ukraine	3c, 3d
Kashparov Valery	UIAR	Ukraine	3a, 3b, 5
Kisselev Vladimir	IBRAE	Russia	0,1
Kolimasov Ivan	IS Geo	Ukraine	0
Konoplev Alexey	SPA Typhoon	Russia	3a, 3c, 3d
Konoplja Yevgeni	IRB	Belarus	3a
Kryshev Ivan	SPA Typhoon	Russia	3d , 5
Kudas Leonid	IS Geo & ChC	Ukraine	co-ordination
Kutovaya Ludmila	IS Geo & ChC	Ukraine	co-ordination
Kuznetsov Vladimir	RIARAE	Russia	5
Lazarev Nikolaï	UIAR	Ukraine	3b
Linge Igor	IBRAE	Russia	0, 1, 2 , 4
Lutkovskiy Vladimir	UHMI	Ukraine	3c
Matveenko Ivan	RCRCM	Belarus	0 , 1
Nasvit Oleg	IGB	Ukraine	3,d
Orlov Mark	SPA Typhoon	Russia	4
Ossipiants Igor	IBRAE	Russia	0,1
Ostapenya Alexander	BSU	Belarus	3d
Ovsyannikova Svetlana	BSU	Belarus	3a
Panchenko Serguey	IBRAE	Russia	2, 4
Panov Alexander	RIARAE	Russia	3a
Perepelyatnikova Ludmila.	UIAR	Ukraine	3a, 5
Podgaiskaya Marina	RCRCM	Belarus	0 , 3c

Name	Institute	Country	Sub-project
Prister Boris	UIAR	Ukraine	3a, 5
Rolevitch Ivan	IREP	Belarus	4
Sanzharova Natalia	RIARAE	Russia	3a, 5
Savchuk Olga	ISGeo	Ukraine	0, 1
Sazykina Tatiana	SPA Typhoon	Russia	3d
Shmigelskaya Inna	BRIISA	Belarus	3a, 5
Skurat Vladimir	IREP	Belarus	2
Skvortsov Valentin	IEG	Ukraine	2
Sobotovitch Emlen	IEG	Ukraine	2, 4
Sokolik Anatoly	BSU	Belarus	3a
Sokolik Galina	BSU	Belarus	5, Co-ordination
Spiridonov Serguey	RIARAE	Russia	3a
Spirin Yevgeni	RIARAE	Russia	3b
Tabachny Leonid	MECA	Ukraine	0, 1
Tarasiuk Siarhei	BRISSA	Belarus	5
Timofeev Serguei	RIR	Belarus	4
Todosienko Seguey	UHMI	Ukraine	3c, 5
Vynogradskaja Victorija	UIAR	Ukraine	5
Voitsekhovitch Oleg	UHMI	Ukraine	3c, 3d, 5
Zhukova Olga	RCRCM	Belarus	3c
Zhurba Marina	UIAR	Ukraine	3a
Zlobenko Boris	IEG	Ukraine	4