Chernobyl Research: Radiological Aftermath

European Commission
and
the Belarus, Russian and Ukrainian
Ministries on Chernobyl Affairs,
Emergency Situations and Health

Foreword

This brochure presents brief summaries of the research activities and results of the sixteen EU-CIS collaborative projects carried out over periods up to five years on the consequences of the Chernobyl accident in 1986. The projects were made possible through a special budget created by the European Parliament and the research collaboration was formalised in an Agreement made between the Commission and the relevant ministries in Belarus, the Russian Federation and the Ukraine.

The different research projects cover the transfer of radioactive material through the environment and into the chain food, a study of decontamination strategies and restoration measures, the investigation of health effects arising from the accident and the development of emergency mangement procedures for improvement of overall emergency preparedness. Each of the research projects has been executed in a cooperative venture between a group of institutes in the European Union and a group of institutes in the three Republics.

The brief summaries of the projects presented here are intended to whet your appetite and you are invited to consult the Final Reports of the projects which interest you most in order to learn of the research work in more detail. The Final Reports are published as an EUR series listed in this brochure and can be obtained from the Scientific Secretariat.

The experience gained was only possible through the scientific collaboration with the CIS, and is thus unique. The overall objectives of the joint programme have been attained and the information obtained is of great value for the development of radiation protection.

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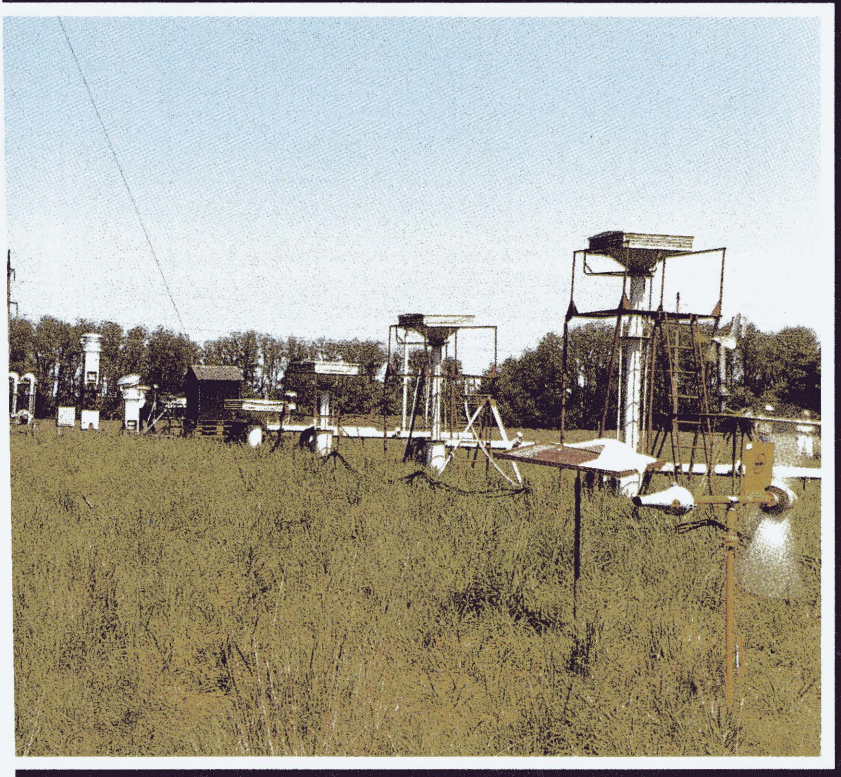
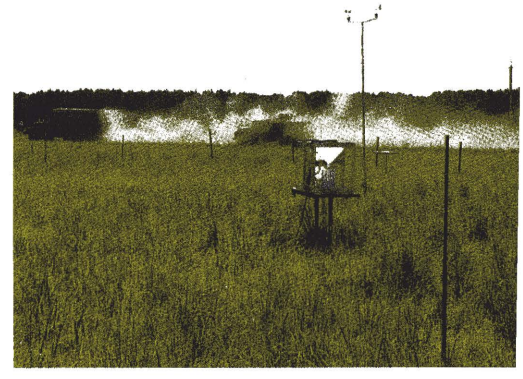


Contamination of surfaces by resuspended material

After the Chernobyl accident, radioactive material was deposited over large areas: resuspension of this material into the air may lead to contamination of neighbouring areas and exposure of the population.

Deposited radioactive material can, by a process called "resuspension", become airborne again. Resuspension is caused by natural phenomena like wind action. Man-made actions are also a major contributor to the resuspension of radioactive material, for example, by agricultural practices such as ploughing, harrowing, and by traffic, especially on unpaved roads, and forest fires.



The main consequences of resuspension are twofold: radioactive material may be transported to uncontaminated areas and it may be inhaled by people thus increasing their radiation exposure. Such transfer processes had not previously been investigated in detail and could be important in the long-term management and control of contaminated areas. In particular, decontamination strategies and policy would be greatly influenced were there to be significant transfer of material from more to less contaminated areas following "clean-up" operations.

This project was concerned with gaining an improved understanding of the mechanisms giving rise to resuspension and assessing its importance as a source of secondary contamination (i.e., transfer of material from more to less contaminated areas) and of exposure of the population through inhalation of airborne material.

There were two major findings of the study: firstly, the current levels of airborne radioactive material from natural and man-made resuspension processes are small and give rise to doses that are, in general, small compared with other exposure pathways (i.e., external radiation and ingestion of foodstuffs); secondly, the transfer of radioactive material by resuspension from more to less contaminated areas is not significant. However, the importance of resuspension in the immediate aftermath of an accident, as opposed to several years later is much greater.

Transfer of radionuclides through the terrestrial environment to agricultural products including the evaluation of agrochemical practices

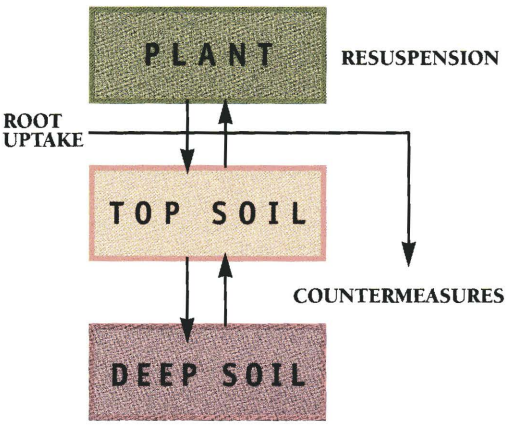
Countermeasure strategies based on field and laboratory studies to reduce radionuclide uptake into agricultural produce.

Transfer of radionuclides through the terrestrial environment to agricultural products including the evaluation of agrochemical practices

In Ukraine, Belarus and Russia, soils have been seriously contaminated by radionuclides deposited via a "condensation pathway" as well as direct deposition of fuel particles. The scope of this research programme was a comprehensive study of the various factors governing the transfer of radionuclides in the agricultural environment. Research was conducted by combining both laboratory and field approaches. **The main objectives were to optimise a countermeasure strategy and to reduce the radiation dose through food chains.**

Field studies were carried out in seven sites located in Ukraine (Kopachy, Poleskoye, Chistogalowska), Belarus (Bragin, Vetka) and Russia (Komsomoletz, Novosibkov).

Physico-chemical properties of the different types of soil and of the nature of the radionuclide deposition have been characterised. The most important contributors to the dose were radiocaesium and radiostrontium. Radionuclide behaviour was studied to predict the mobilisation in contaminated soils using approaches known in soil chemistry including adsorption and desorption experiments. Migration parameters in the soil profile for the different soil types and for different types of deposition were evaluated.



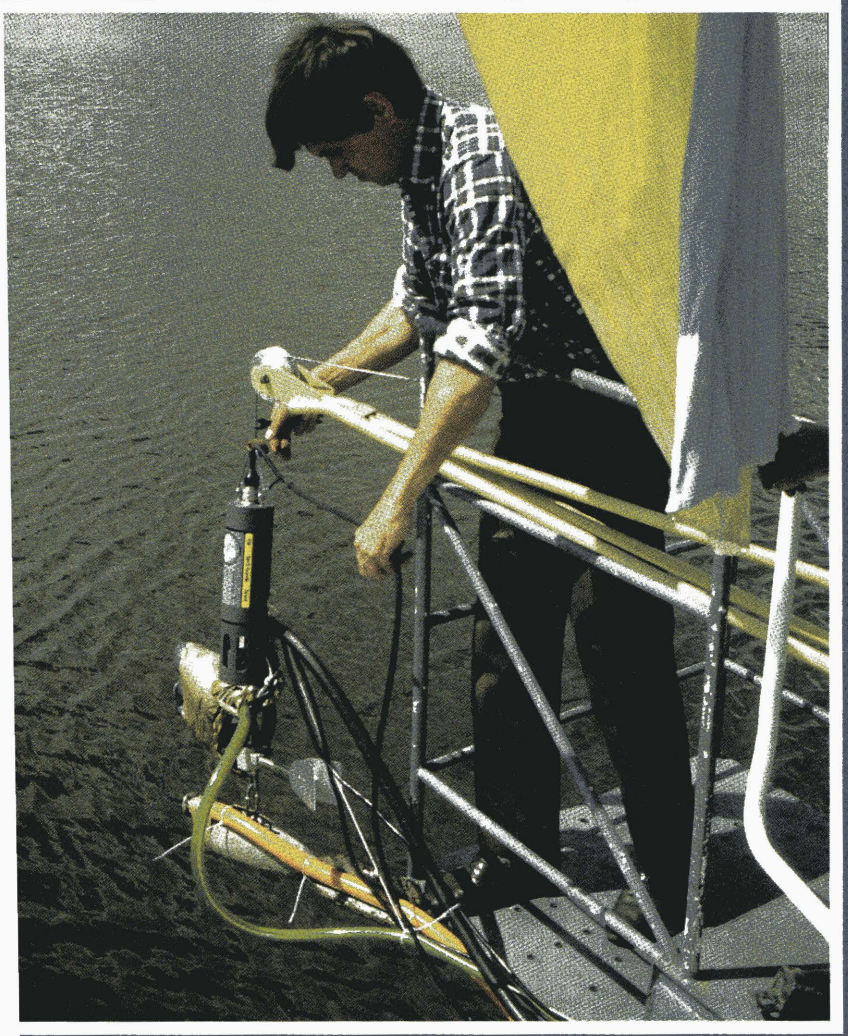
To determine the soil-plant transfer of the radionuclide, the radioactivity content of soil and vegetation samples was measured from the seven sites selected. Uptake of the radionuclides into plants through the soil solution into the root system and then into the aerial part of the plants was analysed. Direct external contamination by deposition, rain splash and resuspension was also assessed.

The countermeasures strategies were based on field and laboratory studies. Experiments were carried out under laboratory conditions to test promising additives and to optimise application rates to reduce the transfer of radionuclides from soil to plants. These studies have relied on techniques and practices divided in two categories:

The first category belongs to the various classical farming practices: mechanical treatments such as ploughing and mulching and the use of fertilisers. The results of the study have demonstrated the efficiency of these types of countermeasures.

The second category consists of some less conventional practices, which have shown a beneficial effect. This contains for instance the use of specific chemicals such as zeolites which may efficiently trap the radionuclides.

The results of the study indicate that more development work on the field application o these chemicals is required.



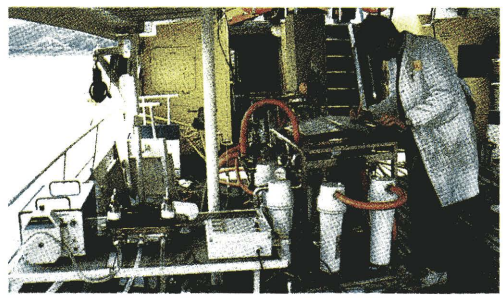
Modelling and study of the mechanisms of the transfer of radioactive material from the terrestrial ecosystem to water bodies around Chernobyl

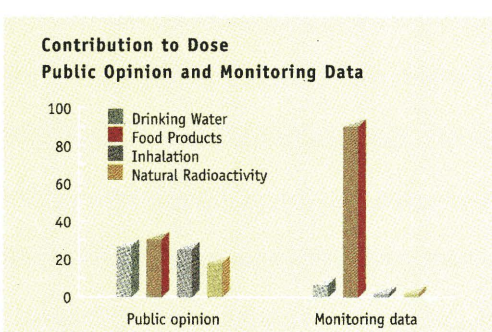
The aquatic system around Chernobyl is a source of water for up to 23 million people. The water pathway seems the most important route for transfer of radionuclides to larger uncontaminated areas, this contamination could affect people throughout Europe.

During the decade following the nuclear accident, the aquatic environment has been contaminated around Chernobyl. The Pripyat river running through the most contaminated zone has fed radioactivity into the cascade of reservoirs on the river Dnieper. **The aquatic system has been the major transporter of radioactivity from the exclusion zone, transferring radionuclides down the 800 km cascade to uncontaminated areas around the Black Sea.** This cascade of reservoirs provide drinking water for about 9 million people living in the Dnieper basin as well as irrigation water and fisheries for a population of up to 23 million. Monitoring of these waters has shown that the dose levels received by direct consumption of the water were relatively low when compared to those received from other sources. However, in the years following the accident, unanticipated levels of contamination were found in water located in the evacuated zone but also in lakes in for example in the UK far away from Chernobyl where radioactive deposition was low.

After the accident, measures were taken by the countries of the former Soviet Union and Western Europe to assess the impact of this catastrophy and to reduce the radioactive dose to the population. However, in some cases, these measures were not only expensive to implement but also ineffective. The main reason for these failures was the lack of understanding of radionuclide behaviour in aquatic systems and an intense programme of research was considered essential.

Scientists from ECP-3 have been studying the effects of radioactive contamination on the freshwater systems of the CIS and Western Europe. **The objective was to understand how the environment influences the mobility of radionuclides from contaminated areas to water bodies and aquatic life.** Computer programmes have been developed in order to describe the long-term movement of radioactivity in the aquatic system and the ways in which the activity is concentrated as it travels through the food chain. Chemical studies about the binding of radionuclides to soils have allowed the identification of those soils which are more likely to release high levels of radioactivity to water bodies following radioactive contamination. **Two main sources of long-term contamination of the water have been emphasised: the annual flooding of the highly contaminated Pripyat flood plain in the 30 km zone, and the release of radioactivity from peat bog soils to the water of the reservoirs on the Dnieper river.**





The radioactivity is concentrated as it moves through the aquatic food chain. This can lead to much higher levels of radioactivity, mainly radiocaesium, in fish than in surrounding water. So, in some waters of Western Europe, where radiocaesium levels were relatively low, the concentration effect was important and some fish became highly contaminated. Previously it was impossible to predict which fish would be most affected because of the great variability in this concentration effect. The studies have shown that this variability is caused by different rates of uptake of radiocaesium in different sized fish, as a result of different feeding patterns and different potassium concentrations in the water. These data permit the identification of those aquatic systems which will lead to high level concentration of radioactivity in fish.

The water pathway is the most important route for the long-term transport of radioactive materials from highly contaminated areas to uncontaminated areas.

Evaluation and development of decontamination strategies for a range of environmental situations and evaluations of their efficacy and other impacts

Case by case strategy instead of generic strategy for decontamination

Evaluation and development of decontamination strategies for a range of environmental situations and evaluations of their efficacy and other impacts

In the aftermath of the Chernobyl accident, measures were taken to develop large scale decontamination actions. Since then, many critical areas had been decontaminated and the residual contamination could be considered as fixed, mainly on urban structures.

The general aim of this project was to assess the availability, costs and efficiency of countermeasures when applied on a practical scale. Of particular interest was whether new decontamination techniques were needed and/or whether further decontamination was justified. **The final goal was to establish a sound basis for developing practical decontamination strategies and policies for use in the event of a future accident.**

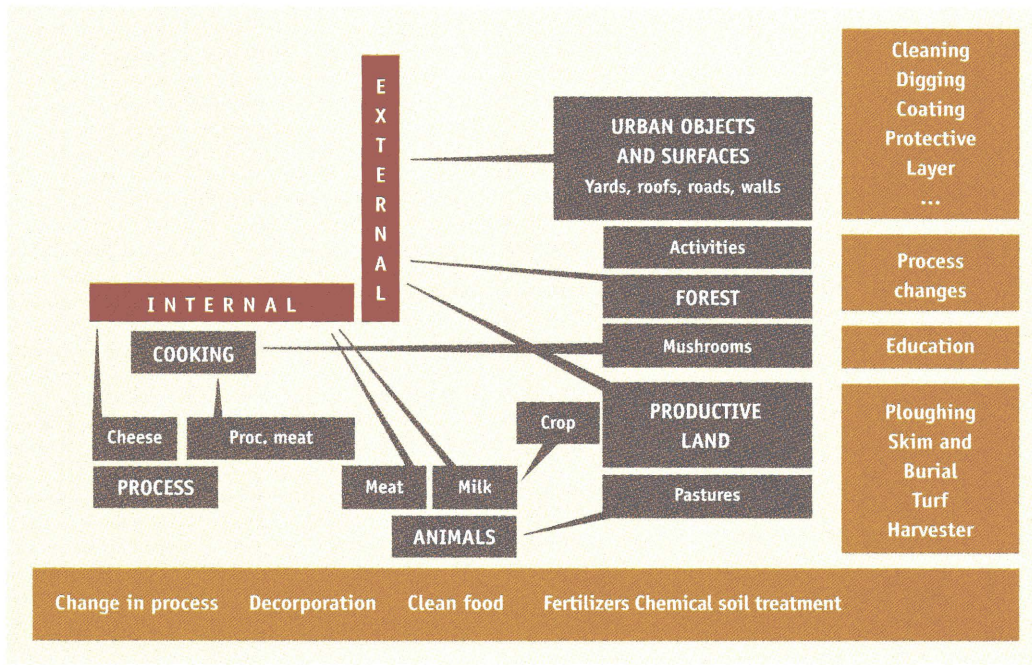
Decontamination of five different environments or products were investigated. These were: soil, forests and processed timber, urban environments (i.e., surfaces like walls, roof, etc.), machines and food products both at a domestic and commercial scale.

Results have shown that some "classical" decontamination techniques remain relevant and it is still possible to remove contamination from walls and rooves, on which radiocaesium has remained for almost 10 years, using water under pressure. The variety of local situations lead to realisation that each situation should be considered separately.

Consequently, a catalogue was prepared which summarises information on different decontamination techniques;this can be used to aid decisions on the introduction of various countermeasures. Comparisons were made of the different strategies on the basis of the characteristics of the techniques, the cost of the established techniques, newly developed techniques and the do-nothing option. **Four case studies were conducted:**

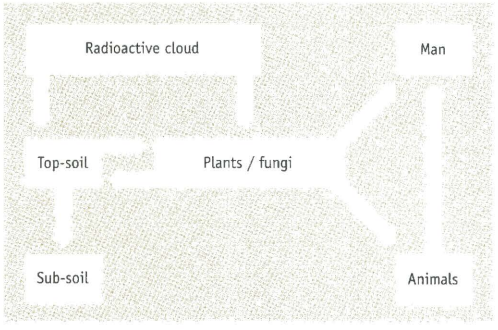
- **rehabilitation of contaminated settlements (Zoborie, Milliachi, Polleskoe, Kirov, Savichi);**
- **dose reduction in the forest industry (a Belarus case);**
- **rehabilitation of a recreational area (Novozikov);**
- **decontamination of a school (Halch).**

The catalogue contains an assessment of some 70 decontamination techniques with information on when, where and how they can be applied and the costs. **The case studies can be used to illustrate the efficiency of the different techniques in the different situations encountered.**



The behaviour of radionuclides in natural and semi-natural ecosystems

Nine years after the Chernobyl event, 70-90% of the radionuclides deposited are still in the superficial soil profiles in meadows and forests of the contaminated areas.



The non-agricultural areas contaminated by radionuclide deposition in the aftermath of Chernobyl include natural and semi-natural environments. Semi-natural ecosystems are those in which the flora and fauna are native but the vegetation is greatly modified by human intervention. These environments includes pastures, hay-meadows, and coniferous and deciduous forests. **After the Chernobyl accident, it became apparent that these contaminated ecosystems are very important potential sources of human exposure.** However, it was difficult to define the dose impact to man and to adopt well justified countermeasures due to the lack of knowledge relating to the consequence of radioactive fallout on forests and semi-natural meadows.

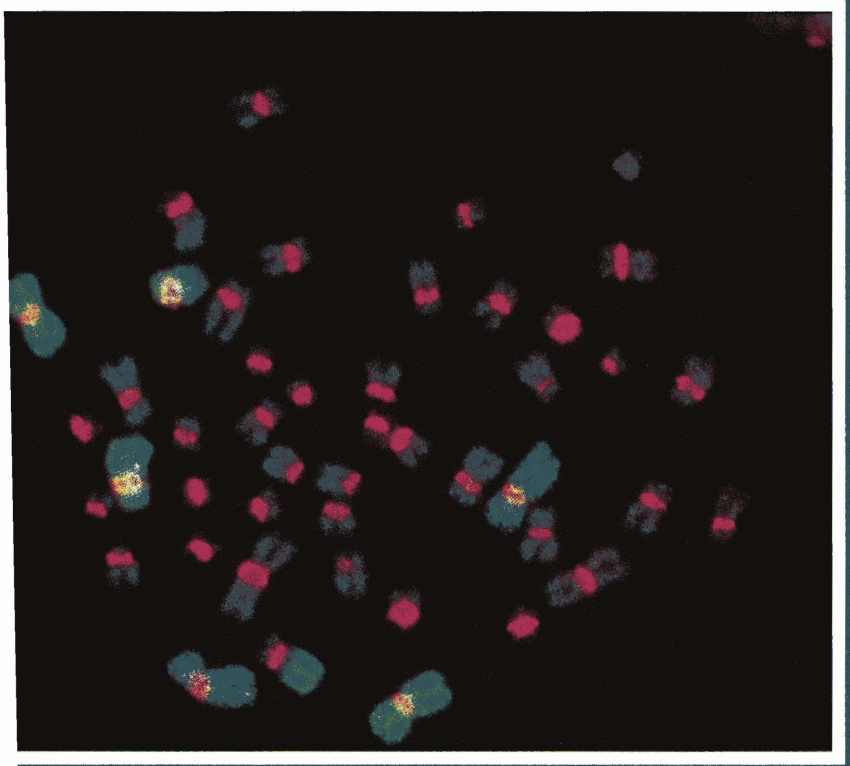
Nine years after the Chernobyl event, the Caesium radionuclide concentrations in plants grown in forest and in meadows had not significantly declined. Restrictions on the use of food products from semi-natural ecosystems are still necessary in some heavily contaminated areas of Ukraine, Belarus and Russia. In addition, wood industries concentrate radionuclides in their waste products. This can be a source of external dose to workers. Furthermore, forests are a potential reservoir of secondary contamination due to resuspension of radioactive material, particularly during forest fires.

Consequently, the central aim of the present project was to assess the long-term behaviour of radionuclides in semi-natural environments in order to assess the dose to man from these environments. Fields studies were carried out in areas with various types of deposition and different characteristics in contaminated fields (30 km zone around Chernobyl) and far fields (other areas of Russia, Ukraine, Belarus and Western European countries).

On the basis of the soil characteristics of meadow soils, a first radioecological classification was developed to identify the soil types that give a higher ingestion dose to the population through the "forage-animal-man" pathway.

The experimental data collected in the near-field and in the far-field were used to develop models to describe the long-term dynamics of contamination in wood and organic layers of forest soil. The model also contributed to the description of the radiocaesium migration in meadows soils and the soil-plant transfer of the radionuclide.

Soil-based countermeasures studied before the Chernobyl accident were originally developed to reduce contamination in agricultural food products. To investigate the applicability of soil-based countermeasures laboratory experiments were set up on different types of soil from semi-natural environments. **The promising laboratory results suggest that the field application of useful countermeasures will be possible in the near future.**



ECP-6

Biological dosimetry for exposed persons

Assessment of a new biological method to measure past radiation exposure of individuals using damaged chromosomes in blood

Immediately after a nuclear accident, there is usually an urgent need to provide estimates of radiation doses of exposed people, especially those exposed to potentially life threatening doses. In some cases the exposed individual will carry a personal dosimeter but in other cases **biological dosimetry has been identified as an alternative approach capable of quantifying the exposure.** The traditional method of biological dosimetry, developed in the 1960's, is to examine peripheral blood cells for damage to the chromosomes due to the radiation exposure. This approach works well when the measurements are made soon after an acute exposure to an external source but less well for internal radiation from intakes of radionuclide in food. As time passes after exposure, the traditional assay becomes less reliable mainly because the blood cells, the lymphocytes, have a finite life-time and the number of chromosomal lesions declines with time, particularly the unstable chromosomal aberrations.

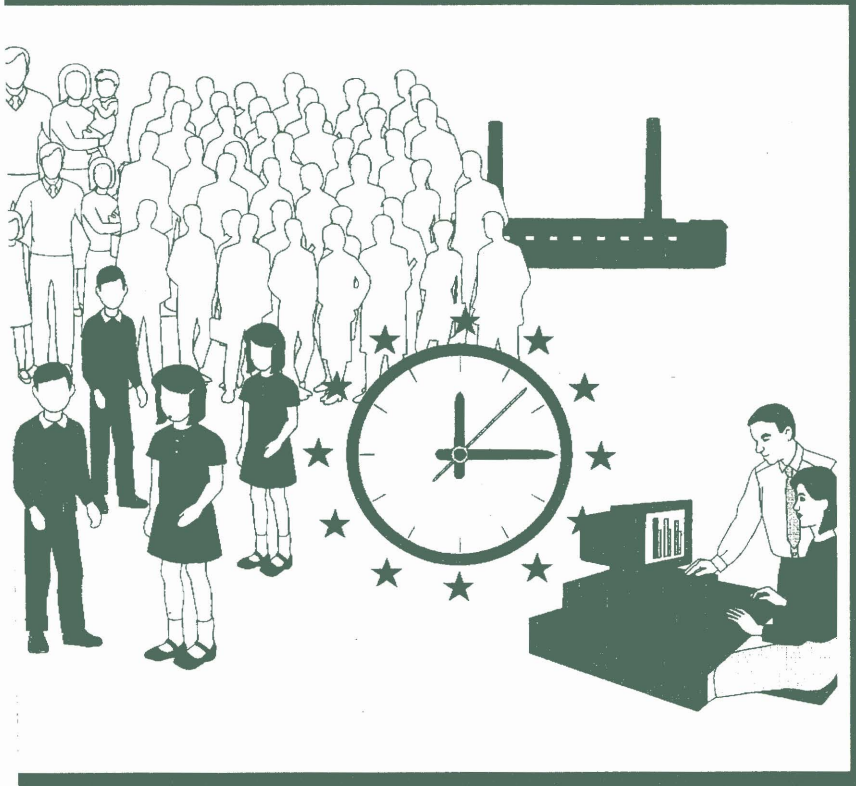
It is clear that, for long term health effect studies, a method of retrospective dosimetry is needed to verify and to extend existing dose information. Some methods of retrospective dosimetry, mainly at the group rather than individual level are described in ECP-10. An alternative biological method for individual dosimetry is based on "fluorescence in-situ hybridisation" (FISH) which permits selected chromosomes to be highlighted or "painted" so that stable aberrations can be detected which are more persistent chromosomal rearrangements.

The objectives of this project were centred on an assessment of the method of analysis for chromosomal damage in blood lymphocytes using the relatively new and untried FISH method. In particular, the reproducibility and the limits of detection of the method are not yet well defined. Retrospective dosimetry was assessed using FISH techniques in a pilot study of blood samples from approximately 60 liquidators. The results were inconclusive and suggest that the FISH method, as applied in this study, was not sufficiently sensitive to determine individual doses in the low range (0-300 mSv).

The study suggests that apart from being used retrospectively to estimate the dose of highly exposed subjects, **this biological dosimetry method requires further development and standardisation before it can be used to estimate the individual dose of the vast majority of exposed subjects.**

Caption to Figure

A human lymphocyte "painted" by the FISH technique to highlight centromeres and chromosomes No 2, 3 and 5. This metaphase shows a reciprocal translocation involving one of the No 5 chromosomes.



Epidemiological investigations including dose assessment and dose reconstruction

Health effects: leukaemia incidence 10 years after the accident: no real increase

ECP-7

In the aftermath of the Chernobyl accident, several hundred thousands of people, either engaged in the clean-up operation (liquidators) or living in the most contaminated areas, were exposed to radiation. In order to assess the health effects arising from the accident it is necessary to be able to trace the exposed population and accurately record the occurrence of health effects especially cancer. This information is also of general interest for public health and radiation protection.

The ECP-7 epidemiological study developed along three main activities: education, training and exchange of scientists; cancer registration and mortality; follow-up and analysis of exposed populations.

Education and training activities included a course in radiation epidemiology and cancer registration, the translation of a basic book in epidemiology and the provision of computer equipment including hardware and software. With regard to monitoring and cancer registration, a project outline was developed using a common data format which included data collection, collaboration between states and allowed linkage to the files of the Chernobyl registries. As a consequence, the existing cancer registry in Belarus was modernised. In the Ukraine, a National Cancer Registry was established by the Ministry of Health. A comprehensive plan of action was developed and implementation started. Finally, in Russia, a regional cancer registration is underway.

The main objectives relating to the follow-up of exposed populations were to assess the feasibility of long-term mortality and cancer incidence of liquidators in Belarus and Russia. It also included the analysis of available mechanisms for tracing individual subjects and collecting relevant data regarding these individuals. The studies covered 500 persons from each of the countries. Follow-up was tested for crucial variables such as vital status, current address, cause of death and cancer diagnosis. Chernobyl registries, medical institutions, ministries were used and data checked against cancer registry.

In order to monitor childhood leukaemia incidence due to the Chernobyl accident, a pan-European descriptive study was launched among cancer registries. **A case-control study of leukaemia among liquidators was conducted in Russia and Belarus, which revealed 18 and 7 leukaemia cases respectively. However, 10 years after the accident no real increase in leukaemia incidence is seen.** An ongoing analysis is investigating the significance of these results.

The blood samples from 62 liquidators were stored for further analysis in the ECP-6 biological dosimetry project.

The results of the project have demonstrated the potential for conducting sound epidemiological follow-up in the CIS. Cancer registration, population monitoring and collaboration between the EU and CIS need some financial support to maintain skill levels, and to stimulate collaboration and the use of data. Cultural differences are expected to be of little importance for the continuation of the project.

ECP-8

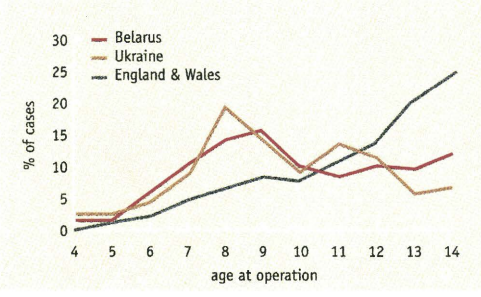
Molecular, cellular, biological characterisation of childhood thyroid cancer

There is a dramatic increase in the incidence of thyroid cancer in children living near Chernobyl

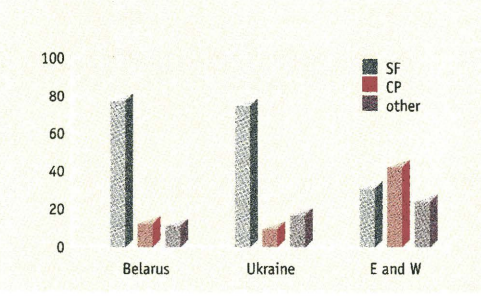
The Chernobyl reactor accident released very large amounts of radioactivity including radioiodine into the atmosphere. Radioactive iodine is known to pose a specific hazard because it is concentrated by the thyroid gland. Increased thyroid cancer incidence has followed exposure to radioactive fallout, adults show no thyroid cancer when radioactive iodine is used in therapy. Urgent action has to be taken to extend our understanding of the cause of the increase in childhood thyroid cancer.

The objectives of this project were a) to verify the pathology of thyroid tumours in children under 15 years in the CIS since the Chernobyl accident, b) to study the morphology and to perform genetic analysis of these tumours to identify any changes that might be related to the cause of the disease and c) to identify any features that might throw light on the relationship between these tumours and exposure to fallout from Chernobyl.

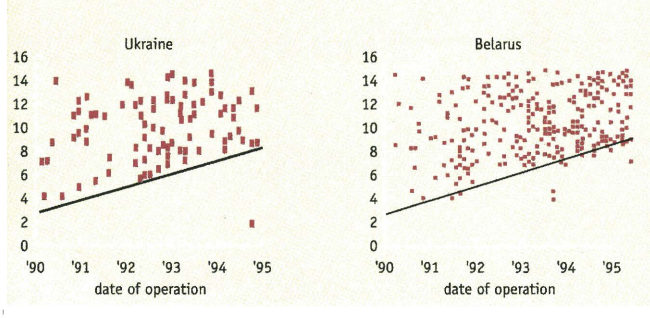
Age distribution of all cases of thyroid carcinoma (expressed as percentage) in children under the age of 15 at time of operation in Belarus and Ukraine (1990-1994) and England and Wales (1963-1992)



The relative proportions of morphological subtypes of papillary carcinoma (PTC) observed in children from Belarus and Ukraine (1990-1994) and England and Wales (1963-1992)



Relationship between age at operation and date of operation for thyroid carcinoma in children from Belarus and Ukraine. The line indicates the age of a child 3 months in utero at the time of the Chernobyl accident.



Age and sex incidence data on 122 cases of thyroid cancer in children under 15 years from Ukraine, and 292 cases from Belarus occurring since 1986 were compared with 154 cases from England and Wales, occurring since 1960 in an area not exposed to significant environmental radiation. The age distribution in England and Wales showed a smooth rise in incidence up to the age of 14. Both the Ukraine and Belarus series showed a bell shape curve with a peak of thyroid cancers in children aged 7-9 at the time of operation.

Microscopic analysis of thyroid cancer tissues from 113 cases from Ukraine, 158 cases from Belarus and 81 cases from England and Wales confirmed the original diagnosis in over 95% of cases from all three series. **The evidence for an increased incidence of childhood thyroid cancer in areas contaminated by the Chernobyl fallout is therefore reliable.** Morphological differences were observed between the tumours from contaminated and from non radiation exposed areas.

Mutation or expression of several specific genes may be involved in the origin of thyroid cancer. However, studies carried out on these factors have not yet shown significant differences between the series from the contaminated areas and the non radioactive exposed areas.

A greatly increased incidence of thyroid cancers has been found in children living near Chernobyl. Analysis of the cases shows a particularly high sensitivity of children who were very young at the time of exposure to the Chernobyl fallout. The incidence drops to normal levels in children who were not conceived at the time of the accident. This suggests that the causative agent is linked to the Chernobyl accident and does not persist in the environment.

The conclusions of the project are therefore that there has been a great increase in childhood thyroid cancer in contaminated zones, this is directly linked to the Chernobyl accident and probably causally related to the release of radioactive iodine. Very young children are much more sensitive to the carcinogenic effect of this exposure than older children. Further studies will be required to ascertain whether the radiation associated thyroid cancer can be differentiated from cancer in a non-exposed population by changes in genes related to the cause of the disease.

Transfer of radionuclides to animals, their comparative importance under different agricultural systems and appropriate countermeasures

Countermeasures to reduce the intake of radioactivity through food produced near Chernobyl

ECP-9

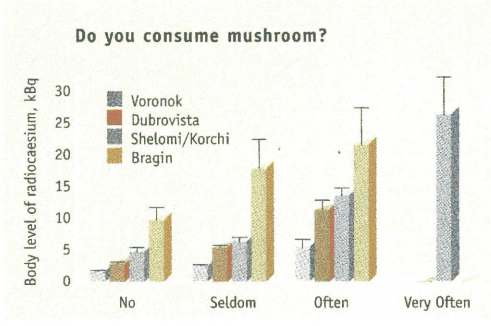
Transfer of radionuclides to animals, their comparative importance under different agricultural systems and appropriate countermeasures

The Chernobyl accident released a cocktail of radionuclides including radiocaesium and radiostrontium. The intake of these radionuclides through food is, in some areas, the greatest contribution to the dose to man. Detailed knowledge about the different pathways for transfer of radioactivity in the food chain is essential to ensure actions to reduce the radioactive content of people's diet.

The programme of research of ECP-9 was aimed at the identification and description of the radiocaesium and radiostrontium transfer pathways to people living in contaminated areas. Field studies were carried out in the three CIS Republics in areas which were affected by contamination from the Chernobyl accident.

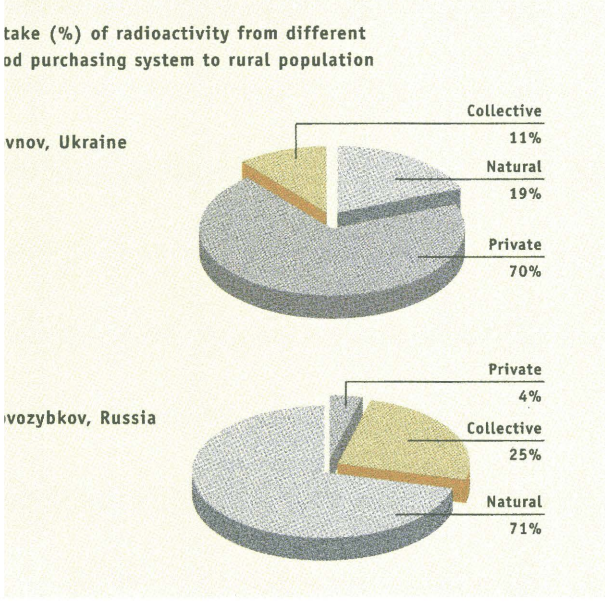
Products from collective farms, state shops, private farms and natural food products (mushrooms, berries and game) were identified as the three major sources of radiocaesium and radiostrontium contributing to the diet of local inhabitants. The radioactivity in village residents will thus depend on what products are consumed and where they originate. In addition, factors influencing radioactivity transfer, such as soil type, management practice and use of countermeasures varied among the study sites.

The countermeasures applied in the collective farms reduced the levels of radiocaesium in food. However, the results suggest that the food produced there is only consumed to a small extent by village residents since they produce their own food. On the other hand, the countermeasures to reduce the radionuclide content in food were less efficiently used in private farming. This led to higher activity in animal products, particularly milk and meat, which then constitute the most important sources of radionuclide intake because of their high consumption rates. At the Russian study area, it was necessary to take cows from private farms to the collective farms to prevent people drinking contaminated milk.



The project has clearly identified that eating natural food products, particularly mushrooms, is an important factor in radiocaesium intake by the population. In mushrooms and game there is considerable variation in radiocaesium levels, both within and between species. Moreover, in the case of game there is also significant seasonal variation partly due to the consumption of highly contaminated mushrooms by game, such as deer, venison, wild boar, etc, in the autumn.

The results obtained in this project allowed the definition of countermeasures that have to be taken. **Effective countermeasures can be applied to the feeding of the cows to reduce transfer of radiocaesium to milk. Dietary advice could be given to inhabitants of contaminated areas, particularly on the consumption of mushrooms which accumulate radiocaesium more readily than most plants.** Adjustment of the hunting season could be an important countermeasure for reducing radiocaesium intake via game.



Retrospective dosimetry and dose reconstruction

Contribution to radiation dose reconstruction for exposed individuals and populations in the Chernobyl accident.

ECP-10

The assessment of the health consequences for groups of people who have lived or are still living in radioactively contaminated settlements, or individuals who were exposed to radiation during clean-up work, requires the retrospective assessment of radiation dose because direct measurements of dose were, in general, not performed.

The general objective of this project which complements that described under ECP 6 was to develop and improve experimental and computational methods to provide estimates of radiation dose based on measurements taken years after the Chernobyl accident. Starting from knowledge gained mainly in studies following the A-bomb detonations in Hiroshima and Nagasaki, this project was based on a comprehensive approach using a variety of methods:

> Determination of long-lived radioactive iodine and caesium in soil samples: for thyroid dose reconstruction.

> "Electron Spin Resonance" (ESR) measurements with teeth: for retrospective dosimetry of individuals

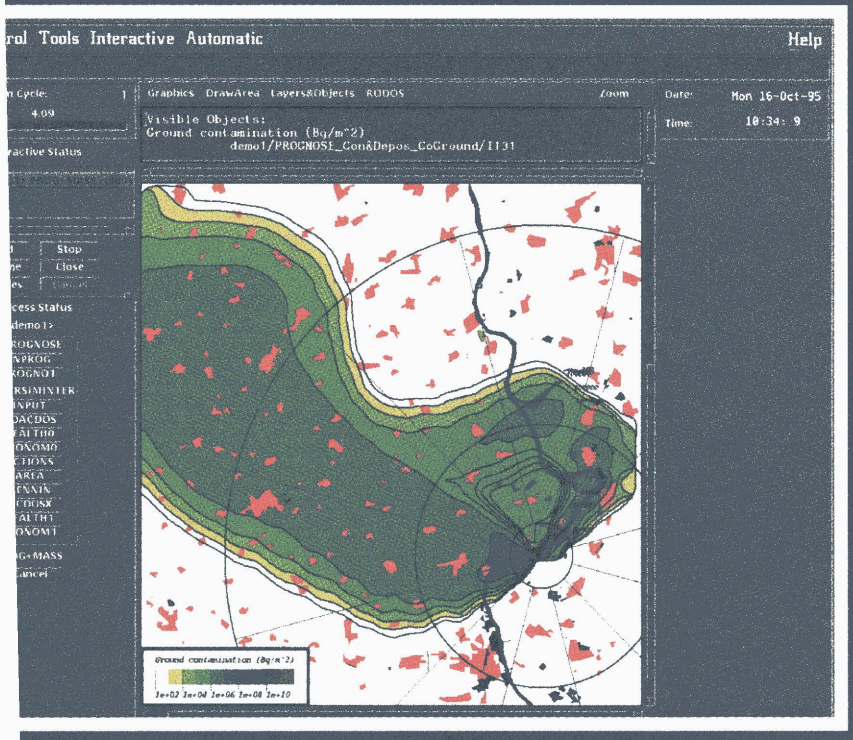
> "Luminescence Dosimetry" using house and household materials (ceramics, tiles) and environmental material: for assessment of population doses accumulated over longer periods

> Mathematical modelling of exposures taking account of exposure pathways, individual living and consumption habits and measurement data.

The study included field work in evacuated and non-evacuated contaminated areas.

The study has shown that reconstruction of organ dose or whole body dose is feasible with accuracies and dose thresholds as required for epidemiological studies, and, in fact, has been carried out for several groups such as the evacuees of Pripyat and thyroid doses for a restricted number of people.

Further work is needed to develop the experimental methods from labour intensive research procedures, requiring expert knowledge, to routine procedures applicable for a large number of people, for example in a large-scale epidemiological study.



Real-time on-line decision support systems for off-site emergency management following a nuclear accident

An east-west scientific co-operation leading to a comprehensive decision support system which can assist the off-site management of any future nuclear accident

JSP-1

Real-time on-line decision support systems for off-site emergency management following a nuclear accident

A Real-time On-line DecisiOn Support system (RODOS) for off-site emergency management of nuclear accidents is being developed by some forty institutes in both Western and Eastern Europe including the three CIS republics most affected by the Chernobyl accident. **The RODOS project represents a common effort to develop a comprehensive decision support system applicable throughout Europe and which is able to support the off-site management and mitigation of the consequences of any future nuclear accident.** Besides application as an emergency management tool, the RODOS system is also designed to be used in training and education in radiation protection and emergency management.

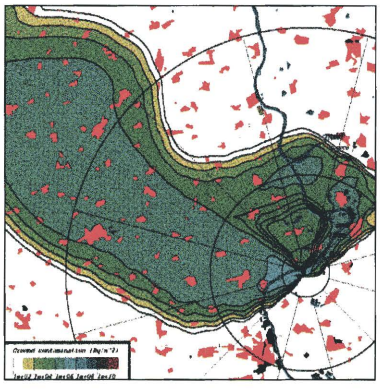


Fig. 1 Ground Contamination (I131) after 12 hours

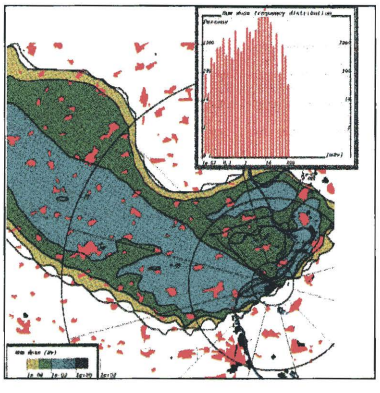


Fig. 2 Effective Dose (7 days) and Dose Frequency Distribution without Action

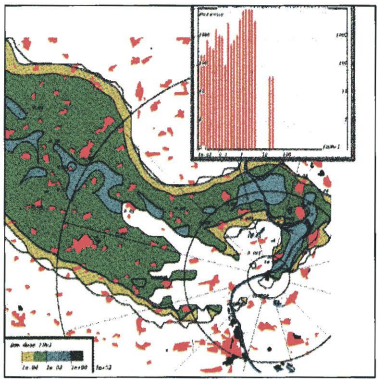


Fig. 3 Effective Dose (7 days) and Dose Frequency Distribution with Action

The work carried out in Joint Study Project, JSP-1, was fully integrated within the broader ongoing RODOS development programme. Major contributions were made by JSP-1 participants to the further development of RODOS and these enhanced the quality of the system and accelerated its completion. Major contributions were made in the following areas: system software, geographical information system, hydrological model chain, data bases for agricultural countermeasures, source term estimation, decision analysis methods and interfaces with meteorological and radiation monitoring networks. **Resources from within the project were made available for the transfer of the RODOS hardware and software to the main participating institutes in Belarus, Russia and Ukraine.**

The first pilot version of RODOS was completed at the end of 1995 with functionality limited to the early and intermediate stages of an accident. Pre-operational testing of the system will be carried out at emergency centres in 1996, in particular, interfaces will be established with meteorological and radiological monitoring networks and with the decision process itself. Based on experience obtained this version of the system will be brought to maturity for operational use in 1997.

Decisions have been taken to integrate RODOS within national emergency arrangements in Belarus, Russia and Ukraine and practical steps are being taken to achieve this. The establishment of a network of RODOS centres will contribute greatly to improved management of any future accident that might affect Europe. In particular it will promote a more coherent and consistent response between countries, which is important for public confidence.

Further development of the system continues with the objective of completing a fully comprehensive version (i.e., functionality extended to the late stages of an accident, in particular the management of contaminated land and the return to "normality") in 1999

Decision aiding system for the management of post-accidental situations

Decision makers have to evaluate new strategies to better optimise health protection taking account of social and psychological factors as well as radiation protection considerations

JSP-2

Decisions on the introduction of countermeasures are often complex. The basic principles are that their introduction should do more good than harm. Besides the beneficial effect of reducing radiation exposure, countermeasure could have detrimental effects including cost, disruption of lifestyle, anxiety and other social considerations.

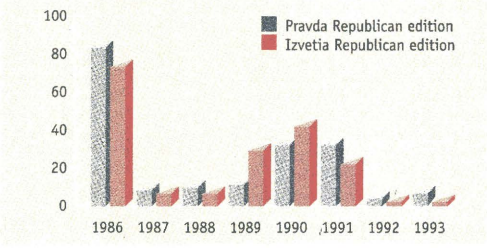
In assessing the effectiveness of countermeasures introduced in the longer term following the Chernobyl accident, the influence of non radiological factors was not performed in adequate scope or detail. The political, social, economic and regulatory situation in the country both before and after the accident considerably influenced the effectiveness, credibility and efficiency of the countermeasures taken.

The purpose of the JSP-2 project was to analyze these factors in order to reach more well founded conclusions in future on the justification and effectiveness of post-accident countermeasures.

The historical evolution of the policy on countermeasures clearly shows that the major political changes occurring in the former Soviet Union in 1989-1992 greatly influenced post-Chernobyl actions and countermeasures. Decisions were taken against the background of the political break-up of the USSR and there was much confusion between political and scientific aims.

This political context, combined with a declining standard of living, led to the development of social and psychological side-effects (uncertainty, vulnerability, distrust in official information, widespread dissatisfaction). Significant differences were found in the psychological status of people (stress, anxiety, etc.) in affected and non-affected areas.

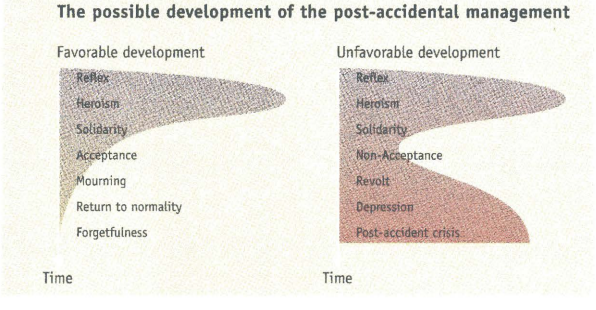
Number of publications related to the Chernobyl accident in two Russian newspapers all months from 1986 to 1993

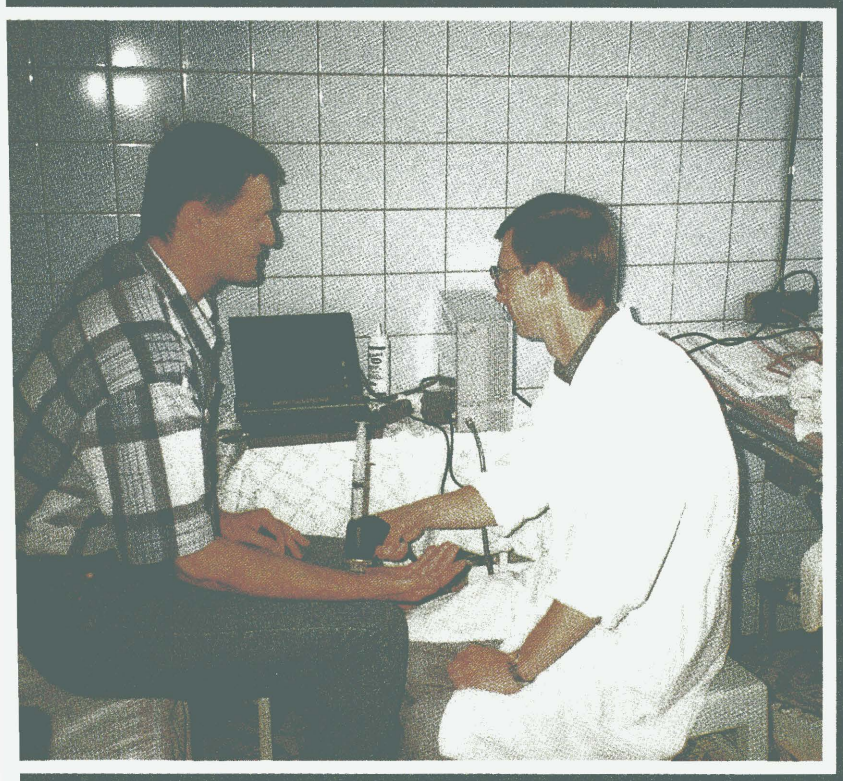


Taking account of this experience, a more coherent and rational framework can be developed for establishing a "countermeasure's policy" in future. In this context, various computer systems were developed within the project. These systems provide easy access to the wide range of information relevant to making well founded decisions on intervention following an accident; moreover, they provide a framework within which due account can be taken of social and psychological considerations in the decision making process.

The main conclusion to emerge from the project is that new strategies need to be defined for the effective long term management of territories contaminated as a result of an accident. A new approach, beginning to take shape, is to restructure the social infrastructure and economic life of the affected regions. The complexity of the situation calls for a decentralised and pragmatic approach of public action to allow the population to actively participate in the rehabilitation of the affected areas. **New psychological and social conditions have to be established to restore trust among the affected population to enable greater "normality" to return to every day life notwithstanding the residual contamination of their environment.**

The possible development of the post-accidental management

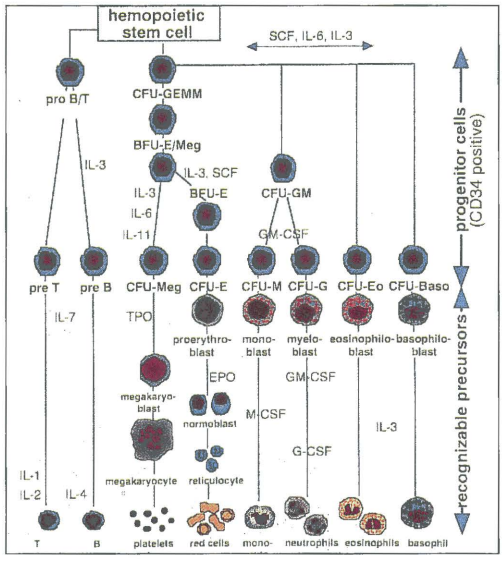




Treatment of accident victims

Blood growth factors restoring host defence: a new perspective for radiation sickness treatment

JSP-3



The steam explosion that resulted in the Chernobyl accident initially caused 31 deaths, mainly due to exposure to radiation. Some one hundred people, mostly rescue workers, were treated for acute radiation sickness. Due to the widespread application of radiation in clinical cancer treatment, the effects of radiation on the human body are well-known and the course of events can easily be predicted. In addition, radiation exposure can be quantified, allowing in this way the estimation of the dose received, even in accident situations. However, the emergency situation made it difficult to reach an early diagnosis and provide appropriate treatment for radiation sickness. It is therefore important to develop diagnostic tools that can be applied immediately to determine the extent of radiation damage.

The most sensitive parts of the body to radiation exposure are the blood forming cell system and the mucous membrane that lines our oesophagus, stomach and gut. A patient exposed to a lethal radiation dose rapidly looses almost all of the white blood cells, which protect the body against micro-organism invasion, the blood platelets, which prevent bleeding, and also suffers from nausea and diarrhoea. In addition, there can be other injuries, for instance to the skin damaged by radiation and a life-threatening condition may occur within a few days after an accidental radiation exposure.

This project aims primarily to improve diagnosis and treatment of the high dose accidental irradiation injury to the blood cell system and to the skin. In addition, it was directed to an evaluation of the 110 patients that have survived acute radiation sickness contracted in the aftermath of the Chernobyl accident. From these patients, it is hoped to learn how to improve the initial treatment and how to anticipate and prevent so-called late radiation effects. For this purpose, a programme has been developed to store the numerous medical data and to make these accessible to specialists in the fields.

The radiation effects on the blood cell system and skin were analyzed by experimental studies. Blood cells need to be permanently produced as their life-span is short. This process originates in the bone marrow from a small number of so called stem cells which have large regeneration capacity but are also highly sensitive to radiation. **The project study has discovered the reason why bone marrow transplantation, considered previously as the logical treatment of choice, does not work for accidental radiation exposures.** Optimally, remaining radiation resistant cells are allowed to regenerate and repopulate the bone marrow. Other improvements can be achieved using stem cells from another source than bone marrow and by new developments in stem cell transplantation technology.

Growth factors have also been identified which are involved in the activity of the stem cells and the turnover of blood cells. The ability of these growth stimulating agents to accelerate the regeneration of stem cells and blood cell production quickly after an accident and to restore the host defence were tested. Similarly, the modern molecular approaches to the diagnosis of radiation damage of the skin as well as new imaging techniques to assess residual skin damage enables direct monitoring of the effectiveness of new agents which alleviate skin damage. **Such studies were successful and are now dramatically changing approaches to the treatment of radiation accident victims by the use of newly designed therapeutic intervention that were simply not available in 1986.**

Development of optimal treatment and preventive measures for radiation-induced childhood thyroid cancer

Clinical investigations of the post-Chernobyl childhood thyroid cancer lead to improvements in diagnosis, treatment and follow-up of the disease

JSP-4

Since the Chernobyl accident, there has been a substantial increase in the incidence of thyroid cancer in children in Southern Belarus and later in Ukraine. **The unique nature of the Chernobyl accident, the numbers of thyroid cancers registered to this date and the assumption that many more will be diagnosed in the years to come demands an investigation of the relationship between thyroid cancer and the causal event.** Moreover, the affected countries should be provided with the most useful information, equipment and knowledge in order to allow effective treatment of the affected population and possibly should carry out a prevention campaign on iodine prophylaxis in those not yet affected.

With the intention of fulfilling these requirements, the project has developed appropriate protocols for diagnosis, treatment and follow-up of radiation-induced childhood thyroid cancer in the CIS. They contain principles for the diagnosis of thyroid cancer, particularly, with regard to the differential diagnosis of benign thyroid nodules. Treatment of both primary tumour and metastases by surgery and radioiodine was also assessed. A large part of the protocol is dedicated to the post-surgical medical treatment with L-thyroxine and with vitamin D to prevent post-surgical hypoparathyroidism.

Several exchanges of scientists have taken place between the Western and the CIS participating institutions. The aim was to train CIS medical specialists and technicians in the management of childhood thyroid cancer and other radiation-induced thyroid diseases. They performed an extensive number of endocrine and immunological assays in children with and without thyroid disorders, from areas exposed or unexposed to radiation. **The results obtained so far, suggest that there is a significant increase in autoimmune phenomena both in children with thyroid cancer and in unaffected children.**

Clinical and molecular aspects of childhood thyroid cancer in Belarus and Ukraine have been investigated. A control database of thyroid cancer occurring in unirradiated children of Western countries as a control group was organised. The fraction of ingested radioiodine taken up by the thyroid of a normal individual is inversely related to the dietary iodine supply of this individual. Increasing iodine supply in a country could therefore reduce the radiation load after a nuclear accident. The impact of iodine deficiency on the development of thyroid cancer after the Chernobyl accident was analyzed and is still under evaluation.

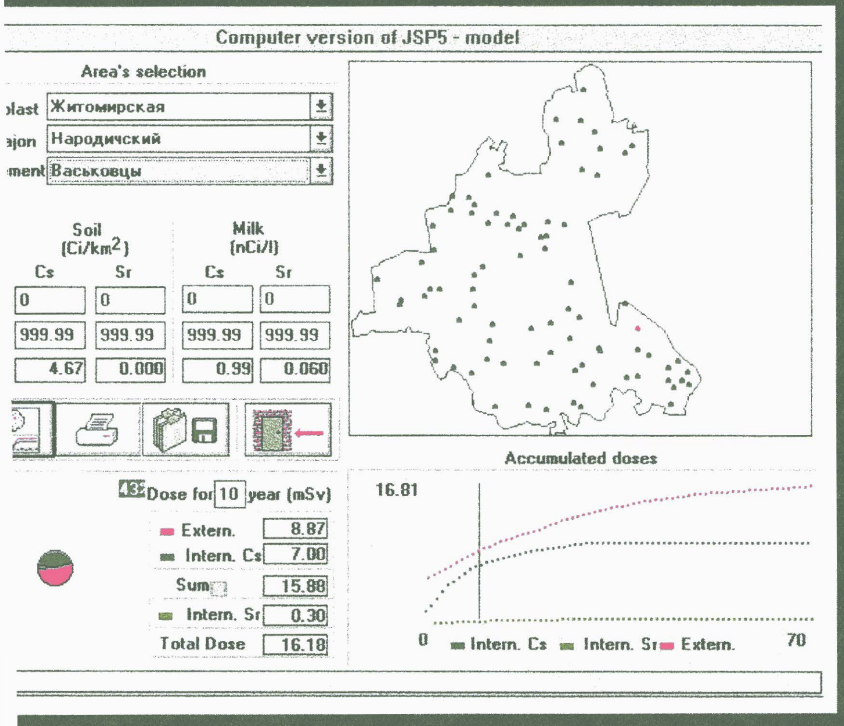
Results achieved in this study will greatly facilitate optimisation in the management of thyroid cancer. Information obtained from the training program will certainly contribute to the amelioration of the diagnostic and therapeutic procedures as well as the standardisation of laboratory procedures. **Finally, it is expected that the information obtained from studies on iodine deficiency should provide relevant information on the prophylactic use of stable iodine for the prevention of radiation induced thyroid disorders.**

Thyroid cancer in children after the Chernobyl accident
0-14 years old

BELARUS	1986-1995*	390 cases
UKRAINE	1986-1994	220 cases
Total		610 cases

**January to July 1995*

Before the accident in 1986, only 3 to 5 cases/year were observed.

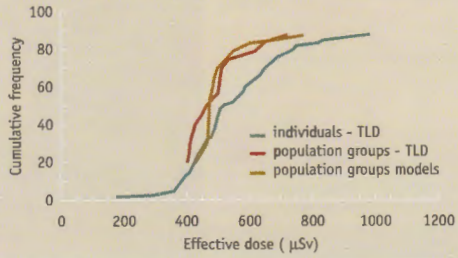


Pathway analysis and dose distributions

Models for estimating radiation exposures of the population in the contaminated settlements

The radiation exposure of people living in areas contaminated after the Chernobyl accident has been investigated. **The main objective was to improve the methods used to estimate doses taking account of current knowledge of radioecology. The methods developed enable external and internal doses to be estimated for various population groups and the identification of those who are most exposed.** Figure 1 shows distributions of external doses in a settlement.

Fig.1 - Effective doses to external exposures of individuals and of population groups living during April 1989 in the village Kozhany in the Briansk region



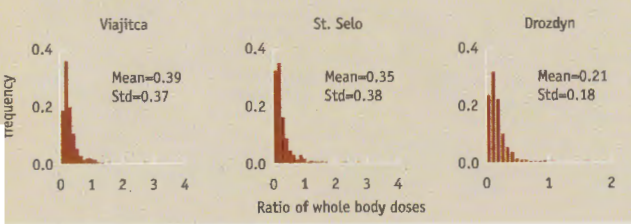
In general, external exposure contributes more than 50% to the current and future doses. External exposures are determined by the locations where people live and work. Five population groups, with different behaviourial patterns have been considered in the model, namely, pre-school children, school children, outdoor workers, indoors workers and pensioners. The model differentiates between rural environments, small towns and urban environments. **The most exposed groups in the population were found to be outdoor workers, in particular forestry workers, living in wood frame houses.**

In those settlements where there is high caesium uptake by plants from the soil (especially in areas with peaty soils), the consumption of foodstuffs (ingestion pathway) dominates the total exposure of the population. The model takes account of caesium transfer from soil to the foodstuffs, the influence of food processing and consumption rates. The transfer of caesium to milk, beef, pork, and potatoes has been derived for four soil types (peat, sandy, podzol, loamy podzol and chernozem) and for soils with very high transfer that are present in some of the contaminated areas. Culinary preparation may significantly influence the intake of caesium from the consumption of mushrooms. **Measurements of caesium in people showed that the highest levels were found in those with a high consumption of local food products (particularly, milk and mushrooms).**

Comparisons of model predictions with measurements of caesium in people have shown the importance of foodstuffs imported from other regions. For example of the three settlements in the Rovno oblast (a region with a very high caesium transfer from the soil to grass) shown in Figure 2, the measured levels of caesium in people are a factor of three to five lower than predicted by models which assume only consumption of locally produced foodstuffs. In the JSP-5 model account is taken of food obtained from elsewhere and of its level of contamination.

Computer software has been developed for the JSP-5 model (Figure 3). Potential applications include calculations of dose distributions in the affected areas and as an input to evaluations of remedial actions.

Fig.2 - Ratios of whole body cesium contents measured and whole body cesium contents calculated under the assumption that only locally produced foodstuffs are consumed



Caption to Figure 3 *(previous page)*

A picture of the computer screen produced by the JSP 5 model. The upper right window shows the settlement Vas'kortsy (red point) in the raion Narodichy. The lower left part gives information about the average dose during the first ten years after the accident due to external exposure (55%), cesium incorporation (43%), and strontium incorporation (2%).

Atlas of caesium contamination across Europe after the Chernobyl accident

Detailed maps for the radiocaesium deposition in Europe

JSP-6

Following the Chernobyl accident, maps were produced of caesium contamination of particular countries or regions. Prior to this project, however, **no attempt had been made to compile a comprehensive presentation of the contamination over the whole territory of Europe**, the continent on which by far the majority of released material was deposited. The compilation of a European map of caesium contamination has both scientific and wider public interest. **The extent and scale of contamination can be readily visualised from the Atlas which also provides useful and much needed perspective on the significance of the contamination.** The Atlas has been compiled from data provided by the competent authorities in more than thirty European countries. This compilation of data is unique and represents a valuable resource for further scientific research and investigation.

The maps were produced electronically from the data using a geographic information system. The data on caesium deposition are spatially very heterogeneous and geostatistical techniques were used for interpolation and the derivation of isolines of contamination. **Based on the deposition patterns, an estimate has been made of the amount of caesium released to the environment during the accident.**

The atlas content is subdivided into five sections.

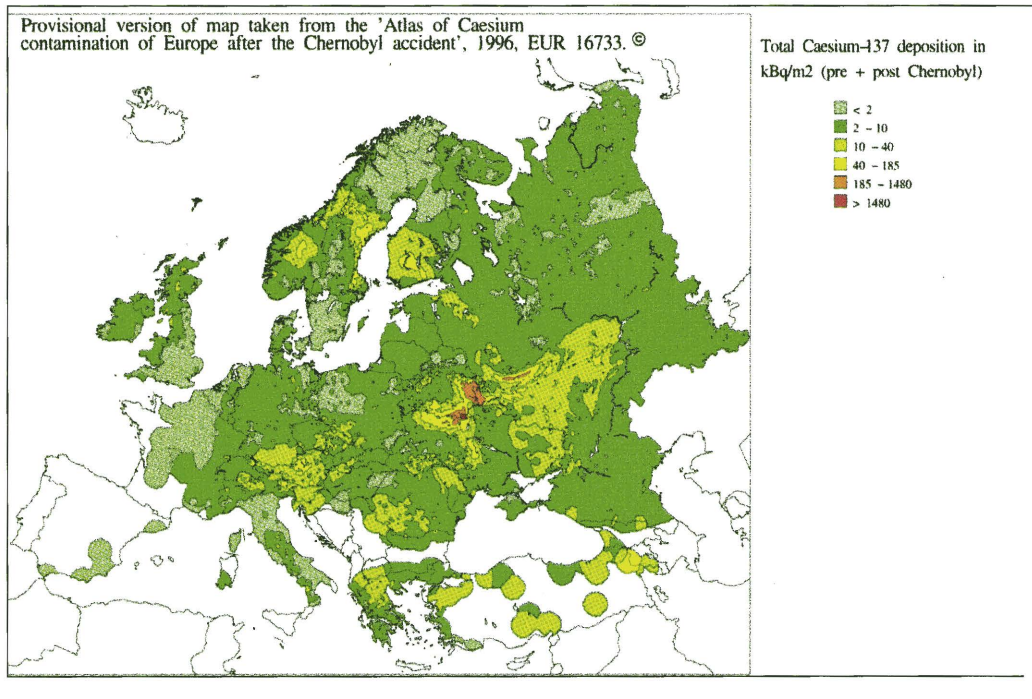
The Introductory section is an overview of the phenomena of radioactivity and its consequences for man. This section also contains a summary of the risks of radiation exposure and a description of the Chernobyl accident.

The Data section contains maps of caesium deposition across Europe. **Some 60 full colour maps are presented in differing scales ranging from one map for the whole of Europe to very detailed maps of those areas which experienced particularly enhanced levels of contamination.**

The Reference section contains supporting information (elevation, vegetation, soil...)

The Meteorological section presents a series of maps which illustrates daily precipitation and wind fields during the period of the accident.

The Annexes contain all technical information associated with the atlas, the sampling and measuring techniques used by each country and summaries of the data compilation and interpolation methods.



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List of Final Reports

ECP 1	Contamination of surfaces by resuspended material	EUR16527
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ECP 4	Evaluation and Development of decontamination strategies for a range of environmental situations and evaluations of their efficacy and other impacts	EUR16530
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ECP 6	Biological dosimetry for irradiated persons	EUR16532
ECP 7	Epidemiological investigations including dose assessment and dose reconstruction	EUR16537
ECP 8	Molecular, cellular, biological characterisation of childhood thyroid cancer	EUR16538
ECP 9	Transfer of radionuclides to animals, their comparative importance under different agricultural systems and appropriate countermeasures	EUR16539
ECP10	Retrospective dosimetry and dose reconstruction	EUR16540
JSP 1	Real-time on-line decision support systems for off-site emergency management following a nuclear accident	EUR16533
JSP 2	Decision aiding system for the management of post accidental situations	EUR16534
JSP 3	Treatment of accident victims	EUR16535
JSP 4	Development of optimal treatment and preventive measures for childhood cancer	EUR16536
JSP 5	Pathway analysis and dose distribution	EUR16541
JSP 6	European atlas of radioactive contamination and external exposure resulting from the Chernobyl accident	EUR16542

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