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Risø-R-1318(EN)

Nuclear Safety Research Department Annual Report 2001

Edited by B. Majborn, A. Damkjær, S.P. Nielsen and E. Nonbøl

Risø National Laboratory, Roskilde, Denmark
June 2002

Abstract This report presents a summary of the work of the Nuclear Safety Research Department in 2001. The department's research and development activities were organized in two research programmes: "Radiation Protection and Reactor Safety" and "Radioecology and Tracer Studies". In addition the department was responsible for the tasks "Dosimetry" and "Irradiation and Isotope Services". Lists of publications**,** committee memberships and staff members are included.

Cover illustration:
During 2001 the department moved to new renovated premises on the western part of the Risø peninsula

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Contents

1 Introduction

From January 1, 2002, the name of the department was changed from “Nuclear Safety Research” to “Radiation Research”, so this is the last annual report from the Nuclear Safety Research Department. The reason for the change is that the new name better encompasses the work of the department, which is primarily concerned with research related to radiation protection, environmental radioactivity and applications of nuclear methods in research, industry and medicine.

2001 was the last year of the second performance management contract between Risø and what is now called the Ministry of Science, Technology and Innovation. A new contract has been signed covering the period 2002-2005. In the beginning of 2001 Risø went through an international evaluation, which was very positive for Risø as well as for the department.

From April 2001 the Applied Health Physics section was transferred from the Nuclear Safety Research Department to a new department called Risø Decommissioning, which includes the former Nuclear Facilities Department. Hence the work of the Applied Health Physics section in 2001 is not described in this report. Risø Decommissioning has the task of preparing for the decommissioning of Risø’s nuclear facilities and take care of the management of radioactive waste. It is planned that Risø Decommissioning shall be transferred to a new state company, called Danish Decommissioning, probably in 2003.

During the spring of 2001 the department moved to new renovated premises on the western part of the Risø peninsula.

In 2001 the research of the Nuclear Safety Reseach Department was organised in two research programmes: “Radiation Protection and Reactor Safety” and “Radioecology and Tracer Studies”. In addition the work of the department included two tasks: “Dosimetry” (including personnel dosimetry and industrial dosimetry) and “Irradiation and Isotope Services”.

The research and development work of the department is carried out in close co-operation with Danish and foreign universities and research institutes and also with the Danish nuclear and radiation protection authorities. The department participates in national and international research programmes including the European Commission research programmes and the Nordic Nuclear Safety Research Programme.

This report presents a summary of the work of the department in 2001 with an emphasis on the results of the research and development activities. Lists of publications, committee memberships and staff members are included.

2 Radiation protection and reactor safety

The Radiation Protection and Reactor Safety Programme carries out research and development in the fields of radiation protection, dosimetry, and reactor safety. The aim is to contribute to the protection against the harmful effects of ionising radiation through co-operation with the Danish nuclear and radiation protection authorities and to develop new methods and new applications of nuclear methods in research and industry.

2.1 Luminescence dosimetry

Single-grain OSL techniques

In the assessment of the radiation dose received as a result of a nuclear accident, considerable attention has been paid to retrospective dosimetry using heated materials such as household ceramics and bricks. However, unheated materials such as mortar and concrete are more commonly found in industrial sites and particularly in nuclear installations. These materials contain natural dosimeters such as quartz grains, which are usually much less sensitive compared to those found in heated materials. The potential of quartz extracted from mortar in a wall of a low-level radioactive-waste storage facility at Risø containing distributed sources of ^{60}Co and ^{137}Cs has been investigated using the single-grain OSL apparatus recently developed at Risø. The wall has been exposed to radiation from the stored radioactive materials for 11 years. We have measured the dose distributions in small aliquots (~ 75-100 grains) and individual grains of quartz extracted from this mortar, and from these derived a dose-depth curve into the wall (see Figure 2.1). These results compare very well with those obtained from heated quartz and polymineral fine grains extracted from an adjacent brick, and the integrated dose recorded by environmental TLDs (also seen in Figure 2.1).

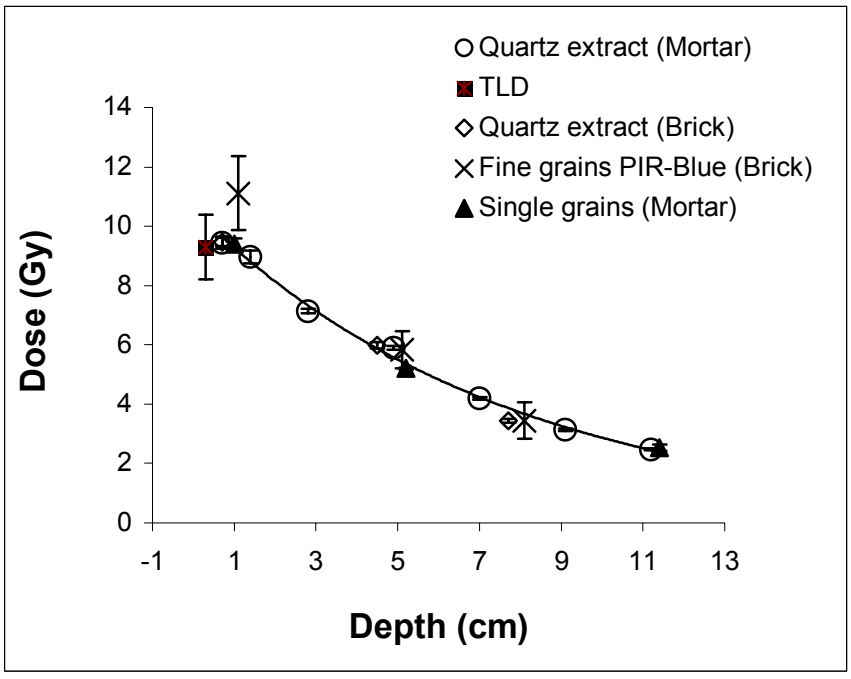


Figure 2.1. OSL dose-depth profiles measured using different materials extracted from the outer wall of a radioactive-waste storage facility.

Household and workplace chemicals as retrospective accident dosimeters

Other unheated crystalline materials found in the domestic and industrial environments, may also act as potential retrospective dosimeters with high sensitivity. We have surveyed the thermoluminescence (TL) and optically stimulated luminescence (OSL) characteristics of several household and workplace chemicals. These chemicals are often held in light-tight packaging, which is important for keeping the TL and OSL signals stable. Also these materials are likely to have been manufactured recently, which limits the size of the likely background dose.

We found that common salt, washing powder, dishwashing powder, and water softener in solid form have strong OSL sensitivity. Fading was detected to be negligible for short-term dosimetry, which always would be likely for this class of materials. A general lower detection limit of less than 20 mGy was derived from the experiments and we conclude that household chemicals should be seriously considered as potential dosimeters in the event of an accident involving ionising radiation.

Clinical dosimetry
The optical fibre dosimetry system for real-time in-vivo dosimetry in radiotherapy recently developed at Risø has been further tested in real clinical environments. The system measures the optically stimulated luminescence (OSL) and radioluminescence (RL) signals from solid-state dosimeters made of carbon doped aluminium oxide (Al_2O_3:C). Several Al_2O_3:C fibre dosimeters have been tested using experimental ^{90}Sr/Y, ^{137}Cs and ^{60}Co radiation sources and in clinical beams of 6 MV and 18 MV photons and 20 MeV electrons at various dose rates. The experiments showed that the OSL and RL signals increased linearly with absorbed dose and dose rate in the ranges 0.1 mGy to 100 Gy and 0.6 mGy/min to at least 3 Gy/min, respectively, which well matches the clinical ranges. The overall precision was in the order of 1 %. Figure 2.2 shows the optical probe mounted on a water phantom in an experimental gamma irradiation facility.

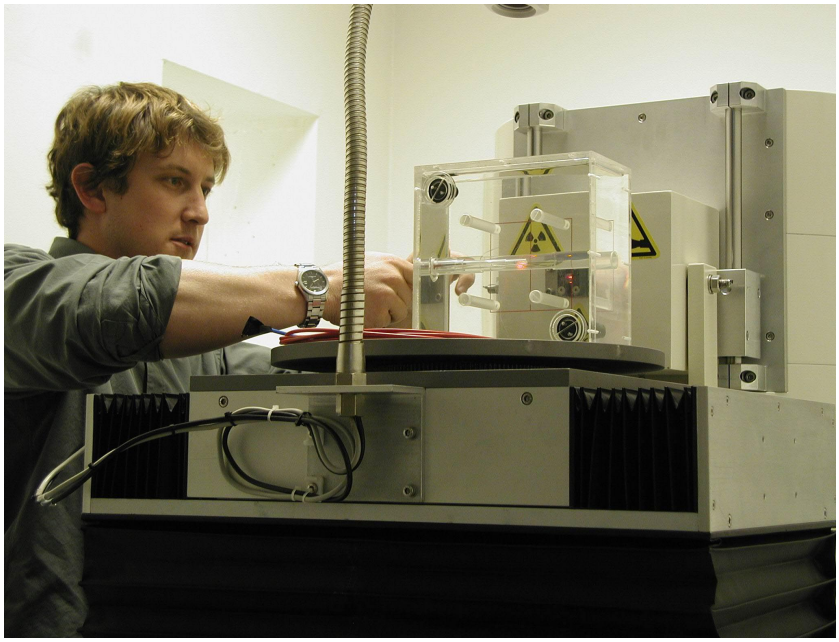


Figure 2.2. The optical probe mounted on a water phantom in an experimental gamma irradiation facility.

2.2 Natural radioactivity

Radon in houses and the risk of childhood cancer
In 2001, an epidemiological study was initiated to investigate if radon in Danish houses is correlated with the occurrence of childhood cancer. Denmark has about 150 such cases every year, the cause of which is unknown. The study is motivated by results from the latest national radon survey (published in 2001)

that showed a considerable variability in radon level from house to house, and that a significant part of this variability can be explained by factors relating to house construction and geology. The epidemiological study uses a database from the Danish Cancer Register with 2400 leukaemia and other cancers diagnosed from 1968 to 1994 among Danish children. Included in the study are also about 6700 matched control children. The project is lead by the Danish Cancer Society. Other participants are: the National Institute of Radiation Hygiene, the National Survey and Cadastre (KMS), and the Geological Survey of Denmark and Greenland (GEUS). The Danish Research Centre for Environmental Health (ISMF) finances the project.

Radon as a tracer of sub-marine groundwater
Two naturally occurring radioactive isotopes, radon-222 and radium-226, have been measured in Eckernförde Bay as part of the EU project called "Sub-Gate". The purpose has been to identify and quantify submarine groundwater discharge. The study is based on the hypothesis that submarine groundwater is enriched in radon and radium such that sufficient discharge will increase the level of these isotopes in the vicinity of the point of discharge. To this end, a relatively detailed mapping study has been carried out with five cruises to the bay and more than 200 samples of seawater, groundwater and sediments. The study showed that the groundwater 6 m below the seafloor has a radon-222 concentration about three orders of magnitude larger than that of the seawater, and that submarine groundwater discharge probably creates the steep gradients of both radon-222 and radium-226 observed at some of the sampling stations in the central part of the bay. From the measured data and a simple inventory model, we assess that the total discharge of submarine groundwater to the bay is less than 0.14 m^3/s per km^2.

2.3 Emergency preparedness

Nordic project: Nordic Nuclear Safety Research (NKS)
Risø has been leading the NKS project on nuclear emergency preparedness, BOK-1, which was carried out in 1998-2001. The BOK-1 project comprises a number of activities aimed at developing and improving nuclear emergency preparedness. The activities supported by the project include surveys of techniques and equipment, workshops and exercises aimed at developing and testing emergency response plans and people, techniques and equipment, as well as research activities aimed at improving ways to monitor and model the radiological impact of nuclear accidents and develop response plans.

The project consists of six sub-projects: Laboratory measurements and quality assurance (BOK-1.1); Mobile measurements and measurement strategies (BOK-1.2); Field measurements and data assimilation (BOK-1.3); Countermeasures in agriculture and forestry (BOK-1.4); Emergency monitoring in the Nordic and Baltic Sea countries (BOK-1.5); and Nuclear exercises (BOK-1.6). The BOK-1 project has arranged 8 seminars or workshops, four intercomparison exercises and three field exercises and has produced 20 technical reports. Project results have been summarized in the BOK-1 Final report, March 2002.

Atmospheric dispersion experiment
An atmospheric dispersion experiment was conducted using a visible tracer along with the routine releases of argon-41 from the BR1 air-cooled research reactor in Mol, Belgium. In the experiment, simultaneous measurements of the radiation field from the ^{41}Ar decay, the meteorology, and the ^{41}Ar source term and plume geometry were performed. The visible tracer was injected into the

reactor emission stack, and the plume cross section determined by Lidar scanning of the released aerosols. The data collected in the exercise provide a valuable resource for atmospheric dispersion and dose rate modelling. The dispersion experiment has been a central part of a Ph.D. project on data assimilation in atmospheric dispersion of radioactive materials.

The Danish early warning stations

The Danish Emergency Management Agency operates a nation-wide early warning system (PMS) consisting of 11 measuring stations. Risø is a parallel operator of the system and maintains its measuring equipment. The system has been in continuous operation during 2001 except for short-term interruptions of some of the stations due to technical changes. These changes included the movement of the PMS computer to the new premises for the department in building 201 and the replacement of the GK communication network with standard telephone lines. A further modernisation of the system is planned for 2002.

The Danish early warning system is attached to the EU Radioactivity Data Exchange Platform (EURODEP) based at Ispra in Italy. 22 countries exchange measurements under this system. In 2001, 18 new measuring stations were started, increasing the number of early warning stations in the European system from 1605 to 1623.

2.4 Contamination physics

Making sense of Chernobyl

In the years 1999 – 2001 Risø together with SPAN Consultants in the Netherlands and STUK in Finland have conducted an EU Tacis project entitled: *Addressing the clean-up and the secondary medical effects of the Chernobyl disaster*. Risø had the role of 'team-leader' in the project. The scope of the project was:

"*To contribute to minimising the environmental and secondary medical effects resulting from the Chernobyl disaster by improving the public perception and awareness of these effects*". The outputs hoped for were clear: "*Preparation and delivery of information and services to the local population, including training of trainers and grass-root interlocutors*".

The project was defined as a communication project consisting of 15 pilot projects, 5 in each of the 3 republics: Belarus, Russia, and Ukraine. It is evident that the identification of topics and audiences, assigning priorities and translating the results into discrete projects was not easy, however, in the end, a master list of 15 projects was completed along the following lines, beginning with the major research themes:

- Dose reduction techniques in agriculture, to be developed in Svetilovichi State Farm, near Heinicke in the Gomel Region of Belarus.
- The behaviour of both residents and visitors to the forests near Vulka 2, in the Luninets District of the Brest Region in Belarus.
- A technical, pre-investment survey, conducted in Ukraine. In the search for alternative fuels and energy sources: is it possible to make use of contaminated wood for energy production?
- An analysis of the impact of the Chernobyl accident on the water systems of the affected zone, including the Pripyat and Dnieper rivers.

- The Living conditions from both a health- and a socio-psychological viewpoint, in the Savichi village in the Bragin District, of the Gomel Region of Belarus.
- Decontamination techniques, including self-help techniques, as demonstrated in two villages, Svetilovichy and Dubovy Log, in the Vetka District of the Gomel Region.

The remaining pilots were devoted to special interest groups, particularly those in a position to validate and extend information on Chernobyl:

- Updating and practical orientation for doctors and nurses was piloted in the Klintsy District, in the Bryansk Region of Russia.
- Training and materials for teachers in the Tula Region in Russia were piloted, designed to tie in with the national school curriculum.
- In Korosten, a town in the Zhitomir Region, Ukraine, work in the local community involved social and community workers from a newly established Centre.
- A special training programme in radiation issues was mounted in Belarus, for specialists in the SES (the sanitary-epidemiological service) drawn from the regions of Gomel and Mogilev.
- Work with local administrators from seven districts in the Bryansk region in Russia was based on a special needs assessments survey.
- Regional planners often lack detailed information on which to base their decisions – both scientific and normative. This was to be rectified in Ukraine, initially in two regions – Zhitomir and Rivne – by providing them with an interactive CD-ROM.
- Information is also often lacking at the national level, for parliamentarians and their specialist advisers. A second CD-ROM was directed towards this influential audience.
- Ecologists – and especially teachers and students – need to evaluate many different perspectives of the Chernobyl accident and to integrate their findings. This was promised in an experimental CD-ROM looking at Chernobyl through the three dimensions of nature, the individual and society.
- Finally, the most directly affected audience: the liquidators. They have a special need for expert, credible advice on the Chernobyl aftermath.

The lesson learnt from this large project is that timely communication with key groups in the affected areas is crucial in handling the aftermath of a nuclear accident. It is also clear that there is no all-purpose strategy for communication applicable to all situations and problems; each new case needs to be contextualised and independently analysed.

This has to be borne in mind when extending the pilot projects or constructing new designs. At the present stage, however, the most immediate concern is for the future of the pilot projects themselves. They have been designed in a limited, flexible and experimental way so that the experience acquired can be put to greater use in the future. At the present stage of the Chernobyl accident follow-up, intensive communication and socio-psychological consideration will be the basis for the success of any future countermeasure project launched in the Former Soviet Union.

2.5 Reactor safety

The DR-2-project

Work on the DR-2-project has continued during the year. The remaining movable components in the reactor tank, in particular the beryllium reflector elements, were taken out, deposited in containers and sent to the waste treatment plant of Risø. The total activity of all removed components was measured and the radionuclides identified. The dominating activity was due to ^{60}Co. For longer components the activity distribution along the components was measured too. The total activity of all components removed from the reactor tank was 28 GBq. After the removal the radiation level at a number of points in the reactor tank was measured by use of dosimeters and a number of construction components were inspected and their activity measured. The work was carried out as planned without any unexpected events.

To allow activation calculations for the DR-2 to be carried out, a compilation of geometric and material data for the reactor was prepared. By use of these data some preliminary neutron flux calculations were performed with a Monte Carlo code. A subsequent activity calculation on the DR-2 concrete shield was made and it showed reasonable agreement with activity measurements from two radial bore samples of the concrete.

The Nuclear Knowledge Preparedness Group

The group, whose members come from Risø National Laboratory, the Nuclear Office of the Emergency Management Agency and the Technical University of Denmark, published its annual report on the international status of nuclear power and held two half-day seminars.

Co-operation with Latvia on Research Reactor Decommissioning

A study of the Salaspils reactor data available at Risø was carried out. It was found that more data had to be obtained to perform activation calculations on this reactor. The manual with geometry and material data prepared for the DR-2 was translated into English to demonstrate to the Salaspils project what data was needed.

Nordic Project on Nuclear Risks from Areas close to the Nordic Countries

A status report containing available information on the nuclear vessels of the Northern Fleet and the Russian icebreaker fleet was prepared. The report discusses the nuclear vessels and their reactors, the decommissioning of nuclear vessels, spent fuel handling, accidents with Russian nuclear vessels, submarines with damaged cores and the threats posed by these vessels to the Nordic countries. The report will be published as a NKS document.

Nordic Reactor Physics Conference

Risø National Laboratory was organiser of the 10th Conference on Reactor Physics Calculations in the Nordic countries. The conference took place in Roskilde, May 14-15, and had 30 participants and 15 papers. A new topic, reactor physics aspects of decommissioning, was included in the program.

Calculation of heat dissipation in the moderator tank of Forsmark 1

The moderator tank at Forsmark 1 was planned to be replaced in 2001 due to irradiation damage from fast neutrons after being in operation for 20 years. One of the dimensioning parameters is the maximal wall temperature during operation, which has to be below 300^{o} C to minimise stress build up. The heat dissipation in the moderator tank is due to the absorption of gamma radiation

Calculation of the gamma dose was made with a Monte Carlo code MCNP similar to a normal neutron flux calculation, with focus on energy tally in each MCNP-cell instead of flux tally. A so-called (n p) (neutron photon) calculation is made with MCNP, taking both neutron and gamma processes into account. The heat deposition is shown in table 2.1.

Table 2.1. Heat deposition in the moderator tank wall at the centre of the core. The left column is closest to the core

1.32 w/cm^3	1.02 w/cm^3	0.82 w/cm^3	0.64 w/cm^3	0.52 w/cm^3
0-8 mm	8-16 mm	16-24 mm	24-32 mm	32-40 mm

In Figure 2.3 is shown the temperature distribution in the moderator tank wall assuming a surface temperature of 286°C (saturation temperature at 70 bar) at both the inner wall and at the outer wall (down comer). The temperature 286°C at the outer wall is conservative because it corresponds to a feed water temperature of similar size. In practice the feed water temperature is 180°C and the outer wall temperature about 274°C.

It is seen, that the max temperature of the new moderator tank at Forsmark 1 (292.5°C) is well below 300°C even in the most conservative case. It is also clear, that the max temperature of the old moderator tank, with a wall thickness of 25 mm, was also safely below 300°C.

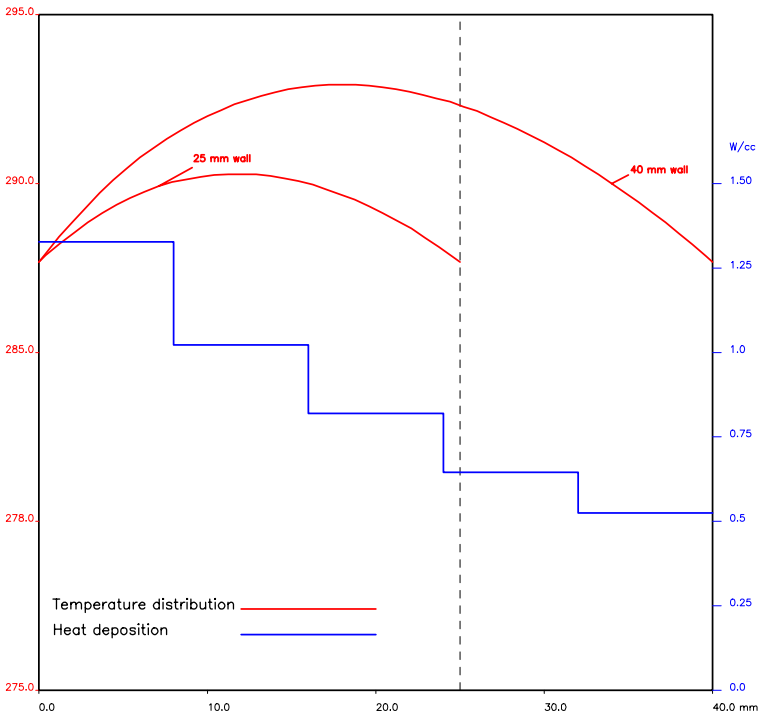


Figure 2.3. The temperature distribution in radial direction in the moderator tank at the core central plane level.

Assumptions:Inner surface=286° C, Outer surface=286° C
Heat capacity=0.51 J/gr/° C; Heat conductance=0.25 J/cm/sec/° C.

3 Radioecology and tracer studies

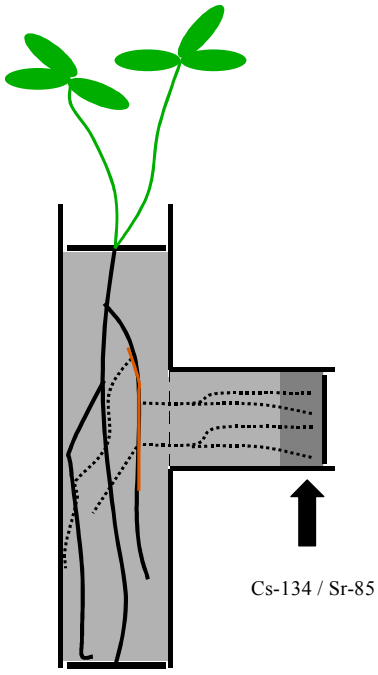
The research programme on radioecology and tracer studies focuses on the occurrence and transport of man-made and naturally occurring radioactivity in the environment and the radiological impact on man. The programme participates in a number of international projects supported by the European Commission concerning studies of radionuclides in terrestrial and marine environments. Investigations of environmental radioactivity in Denmark, the Faroe Islands and Greenland are carried out and the results reported to national authorities and international organisations.

3.1 The role of mycorrhizal fungi in uptake of radionuclides in plants

Risø participates in an EU-funded project with the aim of focusing on the role of micro-organisms, in particular mycorrhizal fungi, which probably play an important part in the soil-to-plant transfer because they have the possibility to act on solubilization/immobilisation and complexation processes in the soil. Their role in the general radioisotope cycling in soils are however practically unknown.

In order to study the influence of mycorrhizae on the plant uptake an *in vivo* experimental system has been developed and tested to study the impact of mycorrhizae on the bioavailability of caesium. It was shown that the transport of Cs by mycelia from a root-free soil compartment could be directly measured independent from the uptake by roots.

The experimental system was of the cross-pot type and was constructed from 50-mm diameter PVC tubing. It consisted of a soil-filled main root compartment and a soil-filled side compartment separated from the main compartment by a nylon mesh. A mesh size of 37 µm was chosen to prevent roots from growing into the side compartment. The side arm was first filled with a 25 mm layer of non-contaminated soil, such that radionuclides were not readily available to root uptake. This was followed by a 15-mm layer of ^{134}Cs contaminated soil. *Medicago truncatula*, a common test plant in mycorrhizal research, was grown in all pots. Mycorrhizal and non-mycorrhizal plants of radionuclide treatments were harvested after 27, 37 and 47 days.



The measured levels of ^{134}Cs in the plants at the three harvest times are shown in Figure 3.1.1. Mycorrhizal plants clearly contained more ^{134}Cs than the non-mycorrhizal plants. However, mycorrhizal plants were also larger than the non-mycorrhizal.

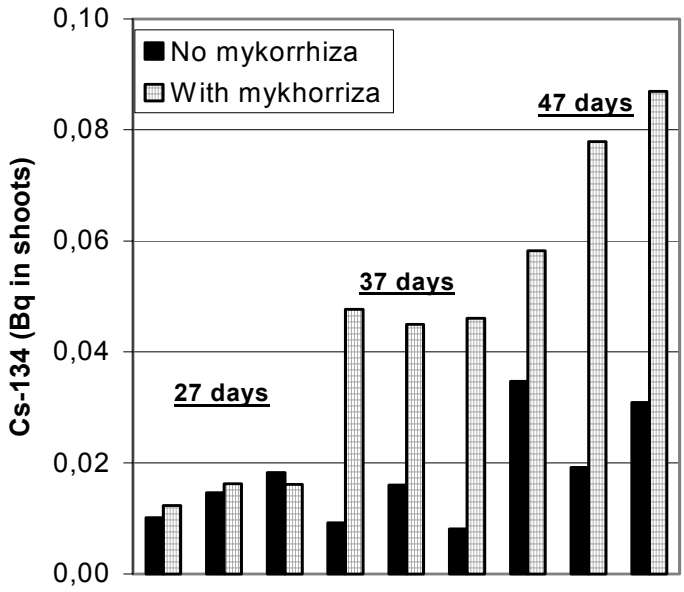


Figure 3.1.1. Caesium-134 activity in M. truncatula shoots from individual AMF- inoculated and non-inoculated pots harvested 27, 37 or 47 days after planting (AMF = Arbuscular Mycorrhizal Fungi).

3.2 Outflow of Chernobyl derived ^{137}Cs from the Baltic Sea through the Danish Straits

Three main sources have influenced the anthropogenic radioactivity in the Danish Straits: fallout from the atmospheric nuclear tests in the 1950´s and 1960's, discharges from the European nuclear fuel reprocessing plants Sellafield and La Hague and the Chernobyl accident. The latter contaminated the Baltic Sea with around 5 PBq of ^{137}Cs in 1986. This Chernobyl contamination is still the dominant source of ^{137}Cs in the Baltic and the Danish Straits 15 years after the accident whereas the present levels of ^{99}Tc originate mainly from Sellafield.

The exchange of water between the Baltic Sea and the North Sea is slow. The connection to the North Atlantic is restricted through the Danish straits with two shallow sills determining the border between the Baltic and the transition zone: Flinterenden in Øresund with a sill depth of 8 m and the Dars sill between Gedser and Darsser Ort with a maximum depth of 18 m (Fig. 3.2.1). A driving force in the Baltic water exchange is the fresh water surplus from river run-off estimated as 473 km^3 yr^{-1}. This amount of water constitutes the net outflow leaving the Baltic through the surface layer in the Danish Straits. Based on this and on knowledge of the salinity conditions in the Danish straits obtained since the beginning of the last century, the mean Baltic outflow has been estimated as 1107 km^3 yr^{-1} with a salinity of 8.6 ‰, and the inflow as 634 km^3 yr^{-1} with a salinity of 15 ‰. The inflowing North Sea water is gradually entrained in the outflowing surface water leaving the Baltic Sea. Therefore the surface water salinity is gradually increasing from the Baltic to the North Sea. Using the above data and setting pure Baltic surface water to 7 ‰ and pure North Sea Water to 34 ‰, a mean residence time for the 21580 km^3 Baltic water volume may be calculated as 29 years equivalent to a half-life for the water of 20 years.

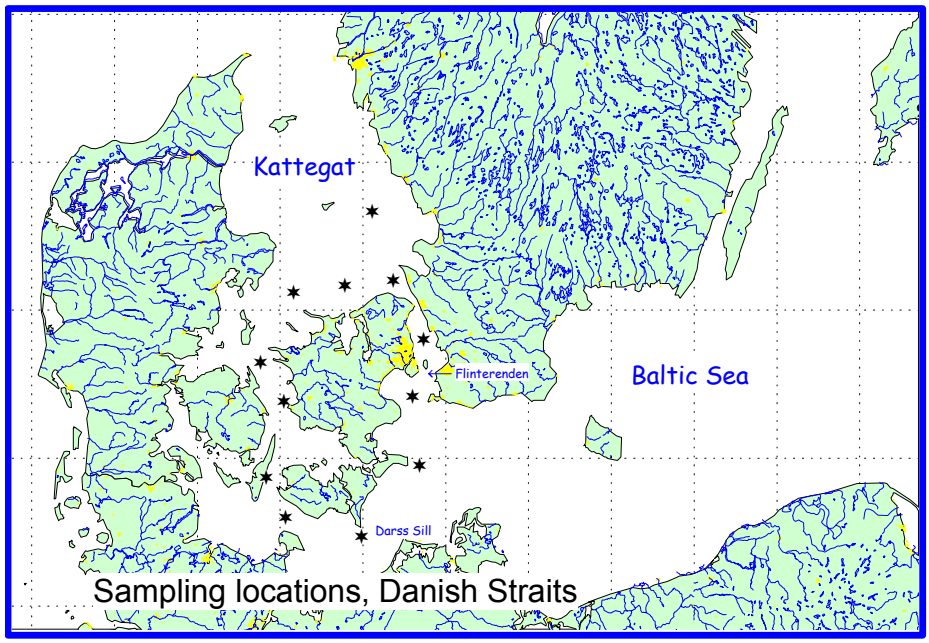


Figure 3.2.1. Sampling locations in the Danish straits.

Data on ^{137}Cs in Danish waters have been collected semi-annually since 1972. Linear regressions of radionuclide concentrations versus salinity are used to estimate the time-trend in the different water masses characterised above. ^{137}Cs is dominated by the low-saline Baltic outflow whereas ^{99}Tc is linked to the inflowing North Sea salt water. The linear trends for the two radionuclides depicted as a function of salinity (Fig. 3.2.2) show a conservative mixing of the low-salinity Baltic water with the high-salinity Atlantic water through the Danish straits. Based on 1991 – 2000 ^{137}Cs data and the flow rates described above, a net outflow from the Baltic can be calculated as 39 TBq in year 2000. This value shows an exponential decrease 1991 – 2000 with an observed halflife of 13.4 years. When the physical half-life of ^{137}Cs (30.17 yr) is subtracted, the "stable" caesium net outflow may be described by an exponential decrease with a halflife of 24 years. This may be compared with the Baltic water half-life calculated above as 20 years. In the calculation above, no account has been taken of sedimentation of ^{137}Cs. Caesium is known to show a significant sedimentation – especially in the brackish, particle rich Baltic Sea. Thus before the Chernobyl accident, sedimentation of ^{137}Cs was a significant parameter for inventory calculations. If the indication of no net sedimentation is valid, the explanation may be that the current sedimentation is counterbalanced by remobilization of earlier sedimented ^{137}Cs and of the ^{137}Cs content in the river inflow.

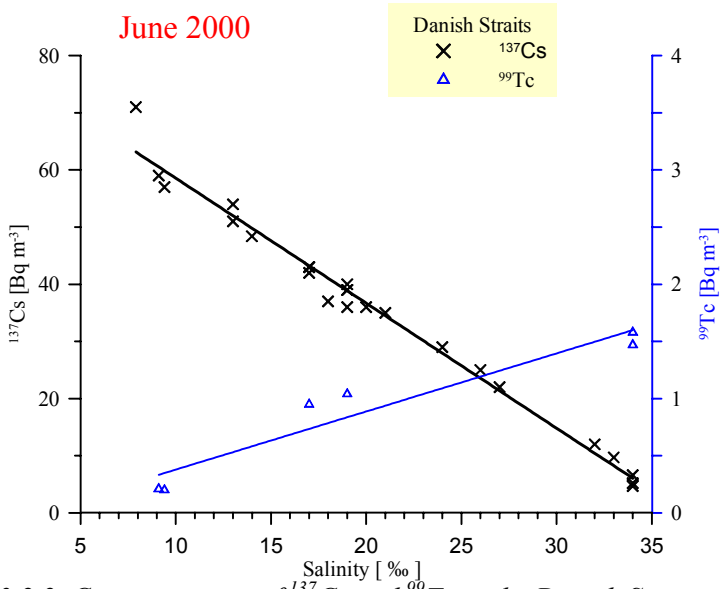


Figure 3.2.2. Concentrations of ^{137}Cs and ^{99}Tc in the Danish Straits as a function of salinity.

3.3 Seminar on detector and measurement techniques

A Nordic seminar on detectors and radionuclide measurement techniques was held in Lund, Sweden, May 3-4, 2001. The objective was to highlight recent progress and problems for techniques to study environmental radioactivity. It covered the aspect of detector-sample geometry and methods for evaluation of gamma-pulse-height distributions. Alpha-spectrometric techniques, gridded ionisation chambers, semiconductor detectors and a general description for analysis of alpha-particle-spectra were presented. Recent development in mass spectrometric techniques, AMS (Accelerator Mass Spectrometry) and ICPMS (Inductively Coupled Plasma Mass Spectrometry) for long-lived radionuclides were described. Principles for analysis of beta particle emitters, especially by liquid scintillation were presented. The seminar also covered radiochemistry such as advantages and disadvantages between ion exchange, solvent extraction and extraction chromatography. The use of controlled laboratory conditions for discerning the dynamics of radionuclide accumulation in organisms was demonstrated. Other techniques such as neutron activation were also shown to be useful analytical tools for certain long-lived radionuclides. The results of the intercalibration exercises within the Nordic countries showed the importance of analytical quality control.

3.4 Iodine-129 and caesium-137 in Chernobyl contaminated soil and their chemical fractionation

Several investigations show a strong dependence of childhood thyroid cancer incidence on thyroid exposure from short-lived radioiodine isotopes, such as ^{131}I and ^{133}I released from the Chernobyl accident. Many children's thyroids were measured for ^{131}I by local authorities in some of the contaminated areas, and these data have been used to calculate thyroid doses. Chernobyl ^{137}Cs has been used as a surrogate to infer to the thyroid dose from ^{131}I in areas where ^{131}I ac-

tivity in the thyroid was not measured at that time. It was based on an assumption that the $^{131}I/^{137}Cs$-deposition ratio was constant and known. Long-lived ^{129}I (1.57×10^{7} years) was also released from the Chernobyl accident. Due to identical chemical properties, the ratio of $^{129}I/^{131}I$ from the Chernobyl accident is constant and has been measured to be in the range 12-19. The ^{129}I concentration can be used to accurately reconstruct the ^{131}I dose to thyroids. In addition, determination of ^{129}I and ^{137}Cs in different locations contaminated by Chernobyl deposition can also be used to check the assumption of constant $^{137}Cs/^{131}I$ ratio from Chernobyl. Soil samples from areas in Belarus, Russia and Sweden contaminated by the Chernobyl accident were collected and analysed for ^{129}I and ^{137}Cs. The atomic ratio of $^{129}I/^{137}Cs$ in the upper layer of the examined soil cores ranges from 0.10 to 0.30, with an average of 0.18 (Fig. 3.4.1), and no correlation between the $^{129}I/^{137}Cs$ ratio and the distance from Chernobyl reactor to sampling location was observed. It seems feasible to use the $^{129}I/^{137}Cs$ ratio to reconstruct the deposition pattern of ^{131}I in these areas. The Chernobyl release is one of the main anthropogenic sources of ^{129}I in the environment, especially in the areas that were most affected by the Chernobyl accident. Due to the long half-life and continuous production and release of ^{129}I from nuclear fuel reprocessing plants, the environmental fate and geochemical cycle of ^{129}I are becoming of increasing concern. In this context, the chemical speciation of ^{129}I in environmental samples is a key factor. A strongly Chernobyl-contaminated soil was sampled, and the association of ^{129}I and ^{137}Cs with different soil components was investigated by sequential extraction combined with neutron activation analysis and gamma spectrometry. About 70% of ^{129}I is bound to oxides and organic matter, and 10-20% is in the readily available phase, while most of the ^{137}Cs (73%) in Chernobyl soil remains in the extraction residue (Fig. 3.4.2).

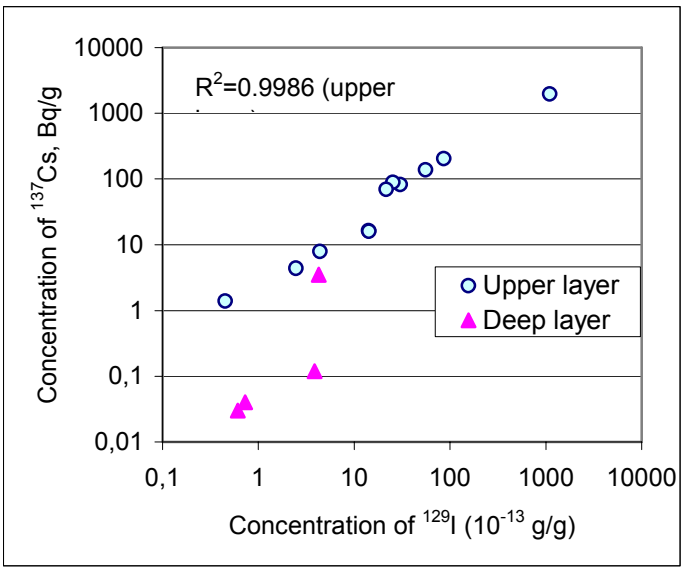


Figure 3.4.1 Correlation between ^{129}I and ^{137}Cs in soils from Russia, Belarus and Gävle.

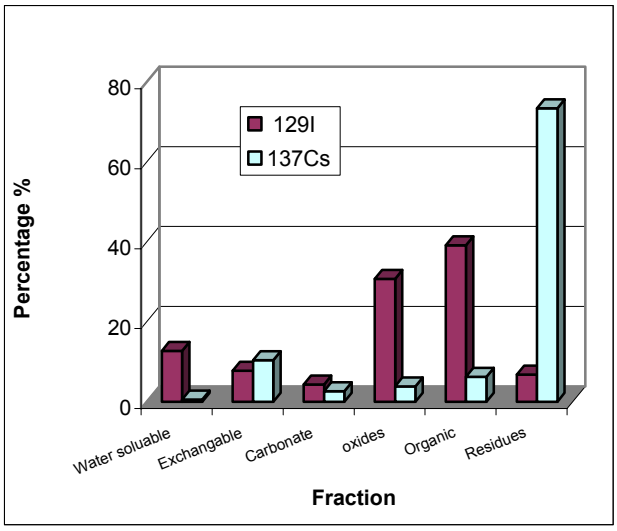


Figure 3.4.2 Distribution of ^{129}I and ^{137}Cs in different fractions of soil components from the Chernobyl region.

4 Dosimetry

Risø High Dose Reference Laboratory

Risø High Dose Reference Laboratory (HDRL) is accredited by DANAK and the accreditation was renewed for a 5-year period in 2001. The new approval was given in accordance with the new standard ISO/EN 17025, and the laboratory's quality manual was thoroughly revised in order to meet the requirements of this new standard.

The activity of HDRL was – when measured as number of issued reports (total 75) and certificates (total 75) - reduced relative to last year, but its financial turnover increased.

Two courses on "Validation and Process Control for Electron Beam Sterilization" were arranged with 18 participants from 9 countries, and one course was arranged "Introduction to Radiation Sterilization" (in Danish).

The laboratory moved to new localities in building 201. Normal operation was maintained during this period. The new offices and laboratories meant significantly improved working conditions. The cobalt-60 gamma cells were also moved to building 201 from building 313. The dose rates of these irradiation facilities were recalibrated after the move, and showed no difference compared to the calibrations prior to the move.

RisoeScan

RisoeScan is a software that uses an image of an irradiated dosimeter film obtained at an ordinary PC scanner to measure dose and dose distribution. The software is written in LabView, and can run at a standard PC.

RisoeScan is developed by Risø HDRL, and it is based on a previous collaboration with Institute of Isotopes, Hungary, and on a collaboration with AECL, Canada. The dosimeter system based on RisoeScan and a PC scanner is designed to work with Risø B3 Dosimeter films.

An example of a measurement is shown in Figs 4.1 and 4.2

Low energy project

There is a growing interest in the industrial use of electron irradiation in the energy range of 50 – 200 keV. When this process is used for sterilization of surfaces, it is required to be able to demonstrate traceability to national standards. Presently such standards only exist at higher electron energy (MeV-range) or for gamma radiation (Cobalt-60).

The response of several dosimeters is known to change as the radiation energy is approaching values below approximately 200 keV, due to changes in stopping power and to changes in the yield of the radiation-induced species being measured. It is therefore needed to establish a standard for low energy electron irradiation that can be used for calibration of dosimeters in that range.

We have started a project in collaboration with National Physical Laboratory, UK, and two firms to develop such a standard based on calorimetry.

Standards

The international standards for radiation sterilization (EN 552 and ISO 11137) are currently being revised, and we participate in European and international working groups that are preparing the drafts to be considered by the international community.

The International Committee for Radiation Units and Measurements (ICRU) has appointed a report committee to write on "Dosimetry systems for Radiation Processing". Risø HDRL is a member of this committee.

Personnel Dosimetry

Risø Personnel Dosimetry Laboratory measures doses for personnel within the Risø grounds. The laboratory was recently approved by the State Institute of Radiation Hygiene in accordance with the Danish rules for Personnel Dose Monitoring.

Gamma calibration facility

A new gamma calibration facility was installed in building 201 and commissioned in November 2001. A movable table allows irradiations to be carried out at distances from the source ranging from 0.6 to 4 m. The facility is equipped with three Cs-137 sources and one Co-60 source which combined with the movable irradiation table allows for dose rates from 20 μGy/h to more than 0.6 Gy/h.

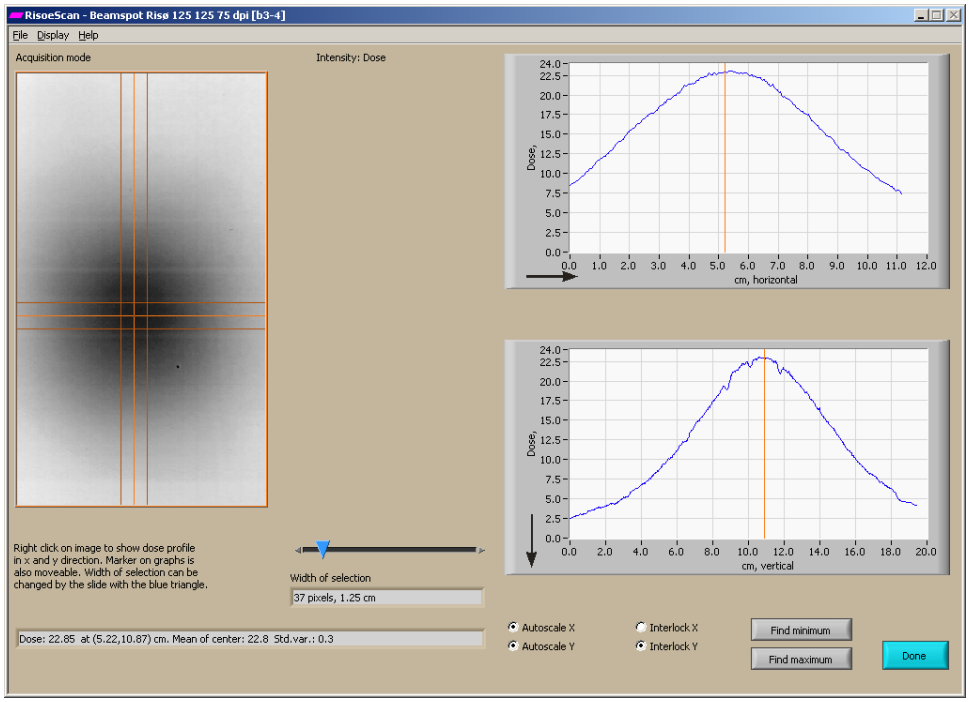


Figure 4.1 RisoeScan measurement of the beam spot at the Risø 10-MeV electron accelerator made with Risø B3 dosimeter film and recorded at a PC-scanner. The dose distribution in the X (horizontal) and Y (vertical) directions are shown.

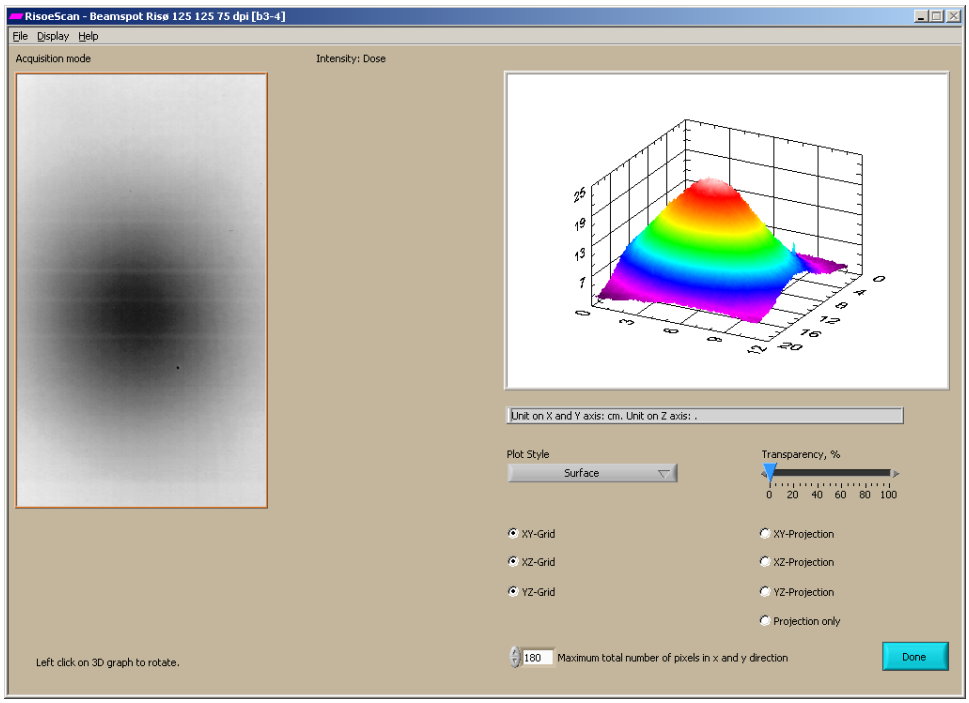


Figure 4.2 RisoeScan measurement of the beam spot at the Risø 10-MeV electron accelerator made with Risø B3 dosimeter film and recorded at a PC-scanner. The dose distribution is shown as a 3-D plot with dose at the Z-axis.

5 Isotope and irradiation services

The Isotope Laboratory has continued its operations to supply radioactive material but at a reduced scale as a consequence of the permanent closure of the DR3 reactor in September 2000. Instead irradiation services at Swedish and Norwegian research reactors have been used to provide radioisotopes to customers and to maintain a production of ^{203}Hg, ^{75}Se and ^{110m}Ag.

A total of 284 irradiations of ^{82}Br were supplied to 16 Danish leak detection companies and 23 for production of radiochemicals for use at Risø. Altogether 64 shipments of other radioactive products were sent to domestic and foreign institutes, industry and hospitals. For educational purposes 473 solid radioactive sources were supplied to the Nordic countries. For research applications at Risø 47 deliveries of specially prepared radioisotopes were made.

In collaboration with the J. F. Kennedy Institute and the University Hospital in Copenhagen investigations were carried out in order to develop a method to produce ^{64}Cu radiochemicals based on irradiation of ^{64}Ni at the hospital cyclotron. The isotope is used for medical diagnostic purposes.

6 Education

The department is involved in educational activities at Risø as well as at the universities.

In 2001 four Ph.D. students have carried out projects at Risø in co-operation with the University of Copenhagen, the Technical University of Denmark, and Lund University in Sweden.

Staff from the department contributes to a course in isotope techniques at the University of Copenhagen, a course in nuclear instrumentation and health physics at the Technical University of Denmark, and a course in health physics at Risø conducted by the Applied Health Physics section of Risø Decommissioning.

In 2001 two international courses on “Validation and Process Control for Electron Beam Sterilization” were arranged in the department, and one national course was arranged on “Introduction to Radiation Sterilization”.

Staff from the department has been external examiners in physics at the University of Copenhagen and at the University of Odense, and in isotope techniques at the Technical University of Denmark.

7 Committee memberships

7.1 National

The advisory committee on protection measures in the case of accidents in nuclear facilities (§ 9 stk 2)
B. Majborn and E. Nonbøl

The coordination committee of the Emergency Management Agency and Risø National Laboratory

B. Majborn and A. Damkjær

The coordination committee for nuclear safety in Central and Eastern Europe (Ministry of Foreign Affairs)
B. Majborn

The advisory coordination committee for research in environmental medicine (Ministry of Health)
B. Majborn

The Board of the Danish Nuclear Society
B. Majborn (chairman)

Danish National Council for Oceanology
H. Dahlgaard

7.2 International

European Union

Consultative Committee Euratom - Fission
B. Majborn

External Advisory Group Euratom – Fission
S.P. Nielsen

Articles 35 and 36 of the European Treaty (Environmental Monitoring)
S.P. Nielsen

Article 37 Group of Experts
S.P. Nielsen

National Correspondents on Assistance and Emergency Planning in the Event of a Nuclear Accident or Radiological Emergency
F. Nielsen

Group for Nuclear Safety Research Index, NSRI
E. Nonbøl

OECD/NEA

CSNI (NEA) Committee on the Safety of Nuclear Installations
P.B. Fynbo

Editorial Advisory Boards

Radiation Measurements
L. Bøtter-Jensen

Radiation Physics and Chemistry
A. Miller (Editor-in-Chief)

Radiation Protection Dosimetry
L. Bøtter-Jensen

Analytical Letters
B. Rietz

Other Committees

The Board of the Nordic Nuclear Safety Research Programme, NKS
B. Majborn

Baltic Marine Environment Protection Commission Helsinki Commission (HELCOM), Group of Experts on Monitoring of Radioactive Substances in the Baltic Sea (MORS)
S. P. Nielsen

International Solid State Dosimetry Organization
L. Bøtter-Jensen

Standing Committee for the International Solid Sate Dosimetry Conferences
L. Bøtter-Jensen

European Atomic Energy Society (EAES) Working Group
B. Majborn

Evaluation panel concerning SSI's future needs for laboratory resources regarding radiation and radioactivity
A. Damkjær

8 Publications

8.1 International publications

Andersen, C.E., Numerical modelling of radon-222 entry into houses: An outline of techniques and results. *Sci. Total Environ.* (2001) v. 272 p. 33-42

Andersen, C.E.; Ulbak, K.; Damkjær, A.; Kirkegaard, P.; Gravesen, P., Mapping indoor radon-222 in Denmark: Design and test of the statistical model used in the second nationwide survey. *Sci. Total Environ.* (2001) v. 272 p. 231-241

Andersson, K.G., Danish national contribution. In: Lauritzen, B. (ed.), HUGINN. A late-phase nuclear emergency exercise. NKS-23 (2001) p. 17-30

Andersson, K.G.; Antsipov, G.V.; Astashko, G.A.; Balonov, M.I.; Barkovsky, A.N.; Bogachev, O.M.; Golikov, V.Y.; Kenik, I.A.; Kovgan, L.N.; Matveenko, S.A.; Mirkhairdarov, A.K.; Roed, J.; Zombori, P., Guide on decontamination of rural settlements in the late period after radioactive contamination with long-lived radionuclides. (2001) (IAEA Working Document: TC Project RER/9/059) 84 p.

Banerjee, D.; Murray, A.S.; Bøtter-Jensen, L.; Lang, A., Equivalent dose estimation using a single aliquot of polymineral fine grains. *Radiat. Meas.* (2001) v. 33 p. 73-94

Bartlett, D.T.; Ambrosi, P.; Back, C.; Bordy, J.M.; Christensen, P.; Colgan, P.A.; Carvalho, A.F. de; Delgado, A.; Dijk, J.W.E. van; Fantuzzi, E.; Hyvonen, H.; Lindborg, L.; Stadtmann, H.; Vanhavere, F.; Wernli, C.; Zamani-Valasiadou, M., Harmonisation and dosimetric quality assurance in individual monitoring for external radiation. *Radiat. Prot. Dosim.* (2001) v. 96 p. 27-33

Bordy, J.M.; Stadtmann, H.; Ambrosi, P.; Bartlett, D.T.; Christensen, P.; Colgan, T.; Hyvonen, H., Eurados trial performance test for neutron personal dosimetry. *Radiat. Prot. Dosim.* (2001) v. 96 p. 167-173

Brodén, K.; Carugati, S.; Brodersen, K.; Ruokola, E.; Ramsøy, T., Experiences of storage of radioactive waste packages in the Nordic countries. NKS-32 (2001) 28 p.

Bulur, E.; Bøtter-Jensen, L.; Murray, A.S., Frequency modulated pulsed stimulation in optically stimulated luminescence. *Nucl. Instrum. Methods Phys. Res. B* (2001) v. 179 p. 151-159

Bulur, E.; Bøtter-Jensen, L.; Murray, A.S., LM-OSL signals from some insulators: an analysis of the dependency of the detrapping probability on stimulation light intensity. *Radiat. Meas.* (2001) v. 33 p. 715-719

Bøtter-Jensen, L.; Murray, A.S., Optically stimulated luminescence techniques in retrospective dosimetry. *Radiat. Phys. Chem.* (2001) v. 61 p. 181-190

Chen, Q.J.; Dahlgaard, H.; Nielsen, S.P.; Aarkrog, A.; Christensen, I.; Jensen, A., Determination of ^{237}Np in marine sediment and seawater. *J. Radioanal. Nucl. Chem.* (2001) v. 249 p. 527-533

Chen, Q.J.; Hou, X.L.; Dahlgaard, H.; Nielsen, S.P.; Aarkrog, A., A rapid method for the separation of ^{210}Po from ^{210}Pb by TIOA extraction. *J. Radioanal. Nucl. Chem.* (2001) v. 249 p. 587-593

Christensen, P.; Bordy, J.M.; Ambrosi, P.; Bartlett, D.T.; Colgan, T.; Hyvonen, H.; Stadtmann, H., Eurados trial performance test for personal dosemeters for external beta radiation. *Radiat. Prot. Dosim.* (2001) v. 96 p. 175-182

Damkjær, A.; Saxebøl, G.; Tillander, M., Evaluation of the laboratory resources of the Swedish Radiation Protection Institute. SSI-2001-24 (2001) 46 p.

Devell, L.; Lauritzen, B. (eds.), Radiological emergency monitoring systems in the Nordic and Baltic Sea countries. NKS-28 (2001) 128 p. www.nks.org/Publikationer/nks-28.doc

Fogh, C.L., NKS 1999 intercomparison of measurements of radioactivity. NKS-19 (2000) vp.

Fogh, C.L.; Andersson, K.G., Dynamic behaviour of Cs-137 contamination in trees of the Briansk region, Russia. *Sci. Total Environ.* (2001) v. 269 p. 105-115

Frid, W.; Højerup, C.F.; Lindholm, I.; Miettinen, J.; Nilsson, L.; Puska, E.K.; Sjövall, H., Severe accident recriticality analyses (SARA). *Nucl. Eng. Des.* (2001) v. 209 p. 97-106

Gustafsson, O.; Axelman, J.; Broman, D.; Eriksson, M.; Dahlgaard, H., Process-diagnostic patterns of chlorobiphenyl congeners in two radiochronologically characterized sediment cores from the northern Baffin Bay. *Chemosphere* (2001) v. 45 p. 759-766

Hedemann Jensen, P., Comment on Are public dose limits necessary? response. *Health Phys.* (2001) v. 80 p. 286

Hou, X.L.; Dahlgaard, H.; Nielsen, S.P., Chemical speciation analysis of I-129 in seawater and a preliminary investigation to use it as a tracer for geochemical cycle study of stable iodine. *Mar. Chem.* (2001) v. 74 p. 145-155

Jain, M.; Singhvi, A.K., Limits to depletion of blue-green light stimulated luminescence in feldspars: Implications for quartz dating. *Radiat. Meas.* (2001) v. 33 p. 883-892

Keith-Roach, M.J.; Day, J.P.; Fifield, L.K.; Livens, F.R., Measurement of Np-237 in environmental mater samples by accelerator mass spectrometry. *Analyst* (2001) v. 126 p. 58-61

Lauritzen, B. (ed.), Huginn. A late-phase nuclear emergency exercise. NKS-23 (2001) 103 p.

Majborn, B., The Risø National Laboratory, Denmark. In: Nuclear research centres in the 21st Century. Final report. (International Atomic Energy Agency, Vienna, 2001) p. 73-77

Moring, M.; Ikäheimonen, T.K.; Pöllänen, R.; Ilus, E.; Klemola, S.; Juhanoja, J.; Eriksson, M., Uranium and plutonium containing particles in a sea sediment sample from Thule, Greenland. *J. Radioanal. Nucl. Chem.* (2001) v. 248 p. 623-627

Nielsen, S.P.; Dahlgaard, H., Radionuclides in sediment cores from Thule, Greenland. In: Pálsson, S.E. (ed.), Marine radioecology. Final reports from subprojects within the Nordic Nuclear Safety Research Project EKO-1. NKS-8 (2001) p. 118-124

Poolton, N.R.J.; Bulur, E.; Wallinga, J.; Bøtter-Jensen, L.; Murray, A.S.; Willumsen, F., An automated system for the analysis of variable temperature radioluminescence. *Nucl. Instrum. Methods Phys. Res. B* (2001) v. 179 p. 575-584

Poolton, N.R.J.; Nicholis, J.E.; Bøtter-Jensen, L.; Smith, G.M.; Riedi, P.C., Observation of free electron cyclotron resonance in $NaAlSi_3O_8$ feldspar: Direct determination of the effective electron mass. *Phys. Stat. Sol. B* (2001) v. 225 p. 467-475

Probst, T.U.; Rietz, B.; Alfassi, Z.B., Platinum concentrations in Danish air samples determined by instrumental neutron activation analysis. *J. Environ. Monit.* (2001) v. 3 p. 217-219

Rietz, B.; Krarup-Hansen, A.; Rorth, M., Determination of platinum by radiochemical neutron activation analysis in neural tissues from rats, monkeys and patients treated with cisplatin. *Anal. Chim. Acta* (2001) v. 426 p. 119-126

Roos, P., Radioecology. In: Radiation at home, outdoors and in the workplace. Brune, D.; Hellborg, R.; Persson, B.R.R.; Pääkkönen, R. (eds.), (Scandinavian Science Publishers, Oslo, 2001) p. 204-230

Schilles, T.; Poolton, N.R.J.; Bulur, E.; Bøtter-Jensen, L.; Murray, A.S.; Smith, G.; Riedi, P.C.; Wagner, G.A., A multi-spectroscopic study of luminescence sensitivity changes in natural quartz induced by high-temperature annealing. *J. Phys. D* (2001) v. 34 p. 722-731

Shtangeeva, I.V.; Vuorinen, A.; Rietz, B.; Christiansen, G.; Carlson, L., Decontamination of polluted urban soils by plants. Our possibilities to enhance the uptake of heavy metals. *J. Radioanal. Nucl. Chem.* (2001) v. 249 p. 369-374

Stadtmann, H.; Bordy, J.M.; Ambrosi, P.; Bartlett, D.T.; Christensen, P.; Colgan, T.; Hyvonen, H., Eurados trial performance test for photon dosimetry. *Radiat. Prot. Dosim.* (2001) v. 96 p. 159-165

Trinkler, L.; Bøtter-Jensen, L.; Christensen, P.; Berzina, B., Stimulated luminescence of AlN ceramics induced by ultraviolet radiation. *Radiat. Meas.* (2001) v. 33 p. 731-735

Vandenhove, H.; Thiry, Y.; Gommers, A.; Goor, F.; Jossart, J.M.; Holm, E.; Gäufert, T.; Roed, J.; Grebenkov, A.; Timofeyev, S., Short rotation coppice for revaluation of contaminated land. *J. Environ. Radioact.* (2001) v. 56 p. 157-184

Zeevaert, T.; Bousher, A.; Brendler, V.; Hedemann Jensen, P.; Nordlinder, S., Evaluation and ranking of restoration strategies for radioactively contaminated sites. *J. Environ. Radioact.* (2001) v. 56 p. 33-50

8.2 Risø-R Reports

Aarkrog, A.; Simmonds, J.; Strand, P.; Christensen, G.; Salbu, B., Radiological assessment of past, present and potential sources to environmental contamination in the Southern Urals and strategies for remedial measures (SUCON). Risø-R-1243(EN) (2000) 71 p. www.risoe.dk/rispubl/NUK/ris-r-1243.htm

Andersen, C.E., Radon som sporgas for jordluftindtrængning til hus ved forurenet renserigrund. Risø-R-1279(DA) (2001) 37 p. www.risoe.dk/rispubl/NUK/ris-r-1279_dk.htm

Chen, Q.J.; Aarkrog, A.; Nielsen, S.P.; Dahlgaard, H.; Lind, B.; Kolstad, A.K.; Yu, Yixuan, Procedures for determination of ^{239,240}Pu, ^{241}Am, ^{237}Np, ^{234,238}U, ^{228,230,232}Th, ^{99}Tc and ^{210}Pb-^{210}Po in environmental materials. Risø-R-1263(EN) (2001) 33 p. www.risoe.dk/rispubl/NUK/ris-r-1263.htm

Lauritzen, B.; Majborn, B.; Nonbøl, E.; Ølgaard, P.L. (eds.), International kernekraftstatus 2000. Risø-R-1248(DA) (2001) 86 p. www.risoe.dk/rispubl/NUK/ris-r-1248_dk.htm

Majborn, B.; Nielsen, S.P.; Damkjær, A.; Nonbøl, E. (eds.), Nuclear Safety Research Department annual report 2000. Risø-R-1232(EN) (2001) 37 p. www.risoe.dk/rispubl/NUK/ris-r-1232.htm

8.3 Publications in proceedings

Andersen, C.E., Numerisk modellering af radonindtrængning til enfamiliehuse. In: Truslen mod indeklimaet fra jordforureninger. ATV-møde, Gentofte (DK), 3 May 2001. (ATV-Fonden for Jord og Grundvand, Lyngby, 2001) p. 45-54 www.risoe.dk/rispubl/NUK/nukartikler/radonatv.htm

Dahlgaard, H.; Eriksson, M.; Ilus, E.; Ryan, T.; McMahon, C.A.; Nielsen, S.P., Plutonium in the marine environment at Thule, NW-Greenland after a nuclear weapons accident. In: Plutonium in the environment. Edited proceedings. 2. Invited international symposium, Osaka (JP), 9-12 Nov 1999. Kudo, A. (ed.), (Elsevier Science Ltd., Oxford, 2001) (Radioactivity in the environment, vol. 1) p. 15-30

Eriksson, M.; Holm, E.; Roos, P.; Dahlgaard, H., Plutonium in temperate and Arctic lakes. In: Plutonium in the environment. Edited proceedings. 2. Invited international symposium, Osaka (JP), 9-12 Nov 1999. Kudo, A. (ed.), (Elsevier Science Ltd., Oxford, 2001) (Radioactivity in the environment, vol. 1) p. 293-303

Hedemann Jensen, P., The system of radiological protection revisited - Protection of the public against prolonged exposures. In: Stralingshygiëne aan het begin van de 21ste eeuw. Wetenschappelijke Lustrumvergadering, Carlton de Brug te Mierlo (NL), 30-31 Mar 2000. Vermeer, B.R. (ed.), (Nederlandse Vereniging voor Stralingshygiëne, Arnhem, 2001) (NVS-Publicatie nr. 31) p. 69-91

Hedemann Jensen, P., Countermeasures in the late phase. In: Training course on off-site emergency planning and response to nuclear accidents. European Radiation Protection Education and Training (ERPET), Sofia (BG), 5-9 Nov 2001. (2001) 16 p.

Hedemann Jensen, P., Principles for intervention. In: Training course on off-site emergency planning and response to nuclear accidents. European Radiation Protection Education and Training (ERPET), Sofia (BG), 5-9 Nov 2001. (2001) 17 p.

Miller, A.; Sharpe, P.H.G., Dose intercomparisons among European radiation sterilization facilities. In: Conference proceedings (CD-ROM). Medical plastics 2001, Lyngby (DK), 17-20 Sep 2001. (Hexagon Holding ApS, Copenhagen, 2001) (Collected Papers of the Annual Conference and Seminar, Vol. 15) vp.

Rietz, B.; Andersen, C.E.; Stürup, S.; Gundersen, V., Comparison of paired INAA and ICP-MS measurements: Trace elements in vegetables. In: New perspectives in the research of hardly known trace elements and the importance of the interdisciplinary cooperation. 9. International trace element symposium 2000, Budapest (HU), 30 Aug - 2 Sep 2000. Pais, I. (ed.), (Szt Istvan University, Budapest, 2001) p. 201-219

8.4 Unpublished lectures

Andersen, C.E., Metoder til reduktion af radonkoncentrationen i danske enfamiliehuse. ATV vintermøde om jord- og grundvandsforurening, Vingsted (DK), 6-7 Mar 2001. Unpublished.

Andersen, C.E., Ny viden om radon i danske boliger. Faggruppemøde i Dansk Kerneteknisk Selskab, Ingeniørforeningen i Danmark, København (DK), 26 Apr 2001. Unpublished.

Andersen, C.E., Radon i boliger: Mekanismer, reduktion og kortlægning. Faggruppemøde i Byggeteknisk Gruppe, Ingeniørforeningen i Danmark, Hillerød (DK), 20 Sep 2001. Unpublished.

Andersen, C.E.; Dahlgaard, H., Radon-222 and radium-226 as tracers for submarine groundwater discharge into Eckernförde Bay: Contribution to the subgate project. In: Book of abstracts. 4. Open science meeting on European land-ocean interaction studies (ELOISE), Rende (IT), 5-7 Sep 2001. Pirrone, N.; Fragakis, C.; Barth, H. (eds.), (CNR-Institute for Atmospheric Pollution, Rende, 2001) p. 67-68

Dahlgaard, H.; Chen, Q.J.; Stürup, S.; Keith-Roach, M.J.; Nielsen, S.P., On neptunium-237 in Nordic waters. 8. Nordiska radioekologiseminariet, Rovaniemi (FI), 25-28 Feb 2001. Unpublished. Abstract available

Hedemann Jensen, P., Udarmet uran - Helsefysiske og biologiske forhold ved brug af udarmet uran til militære formål. Møde i Militærteknisk Forening, København (DK), 14 Mar 2001. Unpublished.

Hedemann Jensen, P., Cleanup of areas contaminated by past activities and accidents to resolve the issues raised previously by RASSC/WASSC concerning the draft requirement (DS162) and safety guide (DS172). 2. Joint meeting of the Radiation Safety Standards Committee (RASSC) and Radioactive Waste Safety Standards Committee (WASSC), Vienna (AT), 2-4 Apr 2001. Unpublished. PowerPoint presentation available

Hedemann Jensen, P., Radiation protection and decision-making in existing exposure situations. Radiation protection in the 21. Century: Ethical, philosophical and environmental issues. Consensus conference on protection on the environment, Oslo (NO), 22-25 Oct 2001. Unpublished.

Hedemann Jensen, P., Integrated framework of emergency response system. Technical Committee meeting (TCM), Vienna (AT), 19-23 Nov 2001. Unpublished. Discussion paper and PowerPoint presentation available

Hou, X.L., Activation analysis for the determination of long-lived radionuclides. NKS-seminar, Lund (SE), 3-4 May 2001. Unpublished.

Hou, X.L., Chemical speciation analysis of iodine in biological and environmental samples. 1. International FESTEM congress on trace elements and minerals in medicine and biology, Venice (IT), 16-19 May 2001. Unpublished. Abstract available

Hou, X.L.; Dahlgaard, H.; Nielsen, S.P., French and British emissions of radioactive Iodine-129 in the Baltic Sea. 8. Nordiska radioekologiseminariet, Rovaniemi (FI), 25-28 Feb 2001. Unpublished. Abstract available

Højerup, C.F.; Nonbøl, E., Methods used at Risø for calculation of neutron and gamma fluxes in materials surrounding the core and for calculation of activities and heat deposition rates in these materials. Nordic reactor physics conference, Roskilde (DK), 14-15 May 2001. Unpublished. Paper available

Keith-Roach, M.J.; Roos, P., Technetium reduction and removal in a stratified fjord. 8. Nordiska radioekologiseminariet, Rovaniemi (FI), 25-28 Feb 2001. Unpublished. Paper available

Keith-Roach, M.J.; Roos, P., The transport of Tc to the sediments of a stratified fjord. In: Abstracts. 8. International conference on chemistry and migration behaviour of actinides and fission products in the geosphere (Migration '01), Bregenz (AT), 16-21 Sep 2001. (Forschungszentrum Karlsruhe, Karlsruhe, 2001) p. 47-48 (PA5-05)

Miller, A., Validation and process control. Meeting on novel sterilization techniques in food industry: The use of E-beam, gamma and X-ray radiations, Pavia (IT), 19-20 Nov 2001. Unpublished.

Miller, A., Radiation dosimetry for food irradiation. Meeting on novel sterilization techniques in food industry: The use of E-beam, gamma and X-ray radiations, Pavia (IT), 19-20 Nov 2001. Unpublished.

Miller, A.; Hansen, J., Revision of the international radiation sterilization standards. 12. International meeting on radiation processing, Avignon (FR), 25-30 Mar 2001. Unpublished.

Miller, A.; Kovacs, A.; Kuntz, F., Development of polystyrene calorimeter for application at electron energies down to 1.5 Mev. 12. International meeting on radiation processing, Avignon (FR), 25-30 Mar 2001. Unpublished.

Morris, K.; Keith-Roach, M.J.; Butterworth, J.C.; Livens, F.R., Behaviour of plutonium and technetium in sediments. In: Abstracts. 8. International conference on chemistry and migration behaviour of actinides and fission products in the geosphere (Migration '01), Bregenz (AT), 16-21 Sep 2001. (Forschungszentrum Karlsruhe, Karlsruhe, 2001) p. 156 (PB5-04)

Nonbøl, E., Validation of the Risø system for ex-core flux calculations. Nordic reactor physics conference, Roskilde (DK), 14-15 May 2001. Unpublished. Paper available

Nonbøl, E., Models and methodology used at Risoe for activation calculations. Meeting on inventarization of activated material and spent fuel, Davos (CH), 22-23 Oct 2001. Unpublished. Paper available

Zeevaert, T.; Hedemann Jensen, P.; Bousher, A.; Brendler, V.; Nordlinder, S., RESTRAT, a decision-aiding methodology for restoration of radioactively contaminated sites (poster). ECORAD 2001, Aix en Provence (FR), 3-7 Sep 2001. Unpublished. Manuscript available

Ølgaard, P.L., Nuclear risks in submarine decommissioning. In: Ecological problems in nuclear decommissioning. Abstract volume. International seminar, Severodvinsk (RU), 4-9 Jul 2001. ([s.n.], [s.l.], 2001) p. 149-150

Ølgaard, P.L., Dekommissioneringsseminaret i Severodvinsk. Videnberedskabsseminar, Risø (DK), 19 Nov 2001. Unpublished. Abstract available

Ølgaard, P.L., Tendenser i kernekraftudviklingen. Videnberedskabsseminar, Risø (DK), 19 Apr 2001. Unpublished. Abstract available

Ølgaard, P.L., Nuclear decommissioning at Risø and the DR-2-project. Nordic reactor physics conference, Roskilde (DK), 14-15 May 2001. Unpublished. Paper available

8.5 Internal reports

Hedemann Jensen, P., Uheldsscenarier for Risøs nukleare anlæg. Risø-Dok-670 (2001) 12 p.

Hedemann Jensen, P. (ed.), Annual report 2000. Applied health physics and emergency response preparedness. Risø-I-1629(EN) (2001) 35 p.

Højerup, C.F.; Nonbøl, E., Monte Carlo calculations of neutron doses to and activations of components of the Forsmark 1 BWR with improved neutron source distribution. Risø-I-1815(EN) (2001) 163 p.

Nielsen, S.P.; Clausen, J.; Miller, A., Radioactivity in the Risø District July-December 2000. (Radioaktiviteten i Risø-området juli-december 2000). Risø-I-1733(EN) (2001) 24 p.

Nielsen, S.P.; Clausen, J.; Miller, A., Radioactivity in the Risø District January-June 2001. (Radioaktiviteten i Risø-området januar-juni 2001). Risø-I-1791(EN) (2001) 24 p.

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The report presents a summary of the work of the Nuclear Safety Research Department in 2001. The department's research and development activities were organized in two research programmes: "Radiation Protection and Reactor Safety" and "Radioecology and Tracer Studies". In addtion the department was responsible for the tasks "Dosimetry" and "Irradiation and Isotope Services". Lists of publications, committee memberships and staff members are included.

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