

The conclusions presented in the STUK report series are those of the authors and do not necessarily represent the official position of STUK.

ISBN 951-712-405-8
ISSN 0781-1705

Oy Edita Ab, Helsinki 2000

Sold by:
STUK • Radiation and Nuclear Safety Authority
P.O. Box 14 FIN-00881 HELSINKI Finland
Tel. +358 9 759 881

SALOMAA, Sisko (ed.). *Research projects of STUK 2000-2002. STUK-A179. Helsinki 2000, 116 pp.*

ISBN 951-712-405-8

ISSN 0781-1705

Keywords radiation protection, ionising radiation, non-ionising radiation, health effects, radioecology, emergency preparedness

FOREWORD

The primary goal of STUK, the Finnish Radiation and Nuclear Safety Authority, is to prevent and limit the harmful effects of radiation. The research conducted by STUK yields new information related to the use, occurrence and effects of radiation. STUK research projects 2000 - 2002 summarizes STUK's own research activities on radiation protection. In addition to these, STUK also supervises and funds research projects related to safety of nuclear energy and nuclear waste and materials that are carried out in other research institutes. Information on the research projects and related publications is also available on STUK's WWW pages at www.stuk.fi.

STUK's research focuses on radiation protection and the health effects of radiation. During 2000 – 2002, the main emphasis will be on projects supporting the Finnish national environmental health action plan, the health risks of radiation, emergency preparedness and cooperation with neighbouring CEE areas. EU directives on radiation protection and medical exposure to radiation also influence the course taken by research carried out at STUK. New research priorities also include studies on non-ionising radiation, especially the effects of mobile phone frequency radiation. STUK's research activities are now more international than ever; the institute is involved in about 20 research projects funded by EC. Apart from the European Union and the Nordic countries, STUK's main partners are to be found in Russia, Estonia and the USA.

SALOMAA, Sisko (toim.). *Säteilyturvakeskuksen tutkimushankkeet 2000-2002. STUK-A179. Helsinki 2000, 116 s.*

ISBN 951-721-405-8

ISSN 078-1705

Avainsanat säteilysuojelu, ionisoiva säteily, ionisoimaton säteily, terveyshaitat, radioekologia, onnettomuusvalmius

ALKUSANAT

Säteilyturvakeskuksen (STUK) tehtävänä on säteilyn vahingollisten vaikutusten estäminen ja rajoittaminen. Tutkimus tuottaa säteilyn käyttöön, esiintymiseen ja vaikutuksiin liittyvää uutta tietoa ja tukee viranomaisvalvontaa. Tutkimushankkeet 2000 – 2002 on yhteenveto Säteilyturvakeskuksen omasta säteilysuojeluun liittyvästä tutkimustoiminnasta Näiden lisäksi Säteilyturvakeskus ohjaa ja rahoittaa ydinenergian käyttöä ja ydinjätehuollon turvallisuutta koskevia, viranomaistarpeista lähteviä tilaustutkimuksia, joita tehdään muissa tutkimuslaitoksissa. Tutkimushankkeet ja niistä kertyvät julkaisut ovat nähtävissä myös Säteilyturvakeskuksen [www-sivuilla \(www.stuk.fi\)](http://www.stuk.fi).

Säteilyturvakeskuksen oma tutkimustoiminta keskittyy säteilysuojeluun ja säteilyn terveyshaittoihin. Vuosina 2000 – 2002 tutkimuksen painopisteinä ovat Suomen kansallista ympäristöterveysohjelmaa tukevat hankkeet, säteilyn terveysriskit, ydinonnettomuusvalmius ja lähialueyhteistyö. EU:n säteilysuojelua ja lääketieteellistä säteilyaltistusta koskevat direktiivit suuntaavat osaltaan Säteilyturvakeskuksessa tehtävää tutkimusta. Myös ionisoimattomaan säteilyyn, erityisesti matkapuhelintaajuuksiin liittyvä tutkimus on noussut esiin vahvana painopistealueena. Säteilyturvakeskuksen tutkimustoiminta on entistä kansainvälisempää. STUK on mukana noin kahdessakymmenessä EU:n rahoittamassa tutkimushankkeessa. EU-maiden ja Pohjoismaiden lisäksi tärkeimmät yhteistyökumppanit löytyvät Venäjältä, Virosta ja Yhdysvalloista.

CONTENTS

	Page
FOREWORD	3
ALKUSANAT	4
CONTENTS	5
1 MEDICAL RADIATION	10
Development of a method to follow up X-ray examination frequencies and patient doses	10
Measures of optimising radiological information and dose in digital imaging and interventional radiology (DIMOND III)	11
Further development and application of the PCXMC - patient dose calculation program	13
Computer program for radiation risk assesment	14
Performance measurements of X-ray diagnostic units	15
Objective methods for measuring the image quality of radiographs	15
The relationship between measured and visual image quality	16
Development of measurement techniques for Quality Audit in radiotherapy	17
Dosimetry of boron neutron capture therapy (BNCT)	18
Quality assurance of Electronic Portal Imaging Devices (EPID) in radiotherapy	20
2 NATURAL RADIATION	21
2.1 Indoor radon	21
Indoor radon mapping	21
Radon in indoor air	22
Total radon exposure of Finns (RATVA)	24
Radon remedies at workplaces	25
Radonsafe foundation, moisture prevention and air exchange in a healthy building, phase 2	26
Validation of the retrospective radon measurement method	

(RETRO)	28
2.2 Natural radioactivity in household water	29
Radioactivity in household water	29
Safe operation of domestic equipment for removing radionuclides from drinking water	31
Household water as a source of radiation to Finnish people - the random-sampling survey (TAVES)	32
²¹⁰ Pb in humans	34
2.3 Other sources of natural radiation exposure	35
Exposure to natural radiation in industry (NORMA)	35
Impacts of natural stone production to radiation exposure	36
3 ENVIRONMENTAL TRANSFER OF RADIOACTIVE SUBSTANCES AND NUCLEAR EMERGENCY PREPAREDNESS	38
3.1 Environmental transfer of radioactive substances	38
Framework of Assessment of Environmental Impact (FASSET)	38
3.1.1 Forests	
Forest radioecology and distributions of ¹³⁷ Cs	40
Radioactivity of timber	41
Radiological consequences of the use of wood energy	42
Plutonium in forests (NKS- BOK-2.1.1. b)	43
Forest ecosystem study in the environs of Finnish nuclear power plants	44
3.1.2 Freshwater ecosystems	45
Behaviour of long-lived radionuclides in lake ecosystems and their storage in the bottom sediments of the lakes	45
¹³⁷ Cs and ⁹⁰ Sr in freshwater fish	47
Radionuclides in sludge in waterworks and wastewater treatment plants	48
Amounts of ¹³⁷ Cs and ⁹⁰ Sr discharged by river runoff from Finland into the Baltic Sea	49
3.1.3 Baltic and Nordic Sea	50
Study of coastal ecosystems in the environs of Finnish nuclear power plants	50
Radiation surveillance and studies in the Baltic Sea	52
Radioactive tracers in Nordic sea areas (NKS/BOK-2.2)	53
Sedimentation, transport and fate of organic pollutants in the	

	Gulf of Finland/sediment timing by radioactivity measurements	55
	The history of cyanobacterial blooms in the Baltic Sea: A multidisciplinary study/sediment timing by radioactivity measurements	56
3.1.4	Arctic and subarctic regions	57
	Radioecological assessment of the consequences of radioactive contamination of Arctic marine areas (ARCTICMAR)	57
	Arctic Monitoring and Assessment Programme, Phase II - Trends and Effects Programme (AMAP)	58
	The Thule sediments	60
3.1.5	Methodology and measurement techniques	62
	Analysis of fission-bomb particles detected in marine sediments in Thule	62
	Determination of several alpha and beta emitting radionuclides from one sample	63
	Optimising the size of environmental samples	64
3.2	Internal exposure to man-made radioactivity	66
	Foodstuffs research	66
	¹⁴ Cs in foodstuffs	67
	¹³⁷ Cs content and internal radiation doses to the population	67
	Development of dietary surveillance	68
	The dependence of the biological half-life of cesium on age	69
	Indirect methods of analyses for internal contamination and estimated doses	70
	The Nordic (NKS) projects on assessment of internal doses	71
	Radiation doses to the population from depositions of nuclear weapon tests and the Chernobyl accident (NKS-BOK-2.1.1 a)	72
	Optimisation of monitoring for internal exposure (OMINEX)	74
3.3	Decision support systems for emergency preparedness	75
	RODOS Users' Group (RUG)	75
	Improvement, extension and integration of operational decision support for nuclear emergency management (DSSNET)	77
	Finnish Decision Conferences: Protective Actions in Urban and Rural Environment	79
	Migration of RODOS to practical applicability for supporting decisions in operational emergency response to nuclear accidents (RODOS Migration)	82
	Food and agriculture restoration management involving	

networked groups (FARMING)	83
Radiation surveillance by unmanned aerial vehicle (UAV)	84
4 HEALTH EFFECTS OF RADIATION	86
4.1 Radiation biology	86
Genomic instability and radiation-induced cancer (RADINSTAB)	86
The use of FISH techniques for retrospective biological dosimetry (COD)	87
The significance of individual radiation sensitivity to secondary cancer	88
Inter-individual differences in the yield of radiation-induced chromosome aberrations	89
Radiation-induced changes in gene expression	90
4.2 Epidemiology	91
Minisatellite mutations and biodosimetry of the population around the Semipalatinsk nuclear test site (SEMIPALATINSK)	91
Radiation-induced heritable mutations in humans	92
Mobile phones and the risk of brain tumours (INTERPHONE)	93
Pooled analysis of European case-control studies of radon and lung cancer (RADON EPIDEMIOLOGY)	94
Cancer risk among nuclear workers (LOWDOSERISK)	95
Cancer risk among airline personnel	96
Cancer among Saami people (Lapps)	97
Kidney toxicity of uranium in drinking water (JURMU)	97
Radioisotopes in drinking water and cancer risk (JUORAAS)	98
Chernobyl fallout and adult leukemia	99
Brain tumors and X-ray examinations	100
Leukemia incidence in the vicinity of nuclear facilities	101
Radon and lung cancer: an analysis using additive generalised linear models (RALMA)	101
5 NON-IONISING RADIATION	103
5.1 Radiation metrology and dosimetry	103
Development of exposure systems for animal and cell culture studies	103
Improving the accuracy of ultraviolet radiation measurement	104
New antennas and measurement methods for 3 rd generation	

cellular systems (NAMS)	106
The ASTE project: EMC & Safety of Multimedia Terminals	107
The combined effects of electromagnetic fields with environmental carcinogens (CEMFEC)	108
5.2 Biological effects and radiation protection	110
Development of in Vitro Dosimetry and Bio-Markers (LaVita)	110
Potential health hazards of mobile telephones (REFLEX)	111
Effects of mobile-telephone-emitted microwave radiation on the functioning of cells	112
UV effects on melanoma metastasis (SYTTY)	113
Use of sunbeds in Finland	114
Restricting exposure to broadband and pulsed electric and magnetic fields	115

1 MEDICAL RADIATION

Development of a method to follow up X-ray examination frequencies and patient doses

Objectives:

The European MED directive (97/43/Euratom) stipulates that the radiation doses to patients in diagnostic X-ray examinations should be assessed in all hospitals, and the patient doses should be compared with national reference levels. The mean patient doses and examination frequencies should also be used for the estimation of population dose. The goal of the project is to develop a method to follow up nationally the frequencies and patient doses in X-ray examinations. The national reference levels based on international recommendations and measured patient doses will be set up for optimisation purposes. The collective dose to the population from X-ray examinations will be estimated.

Description of the work:

The project will be realised in 6 phases:

1. Literature review concerning patient doses
2. Development of a method to follow up the frequencies of X-ray examinations
3. Development of methods of measuring the patient dose
4. Development of methods for the assessment of the effective dose and collective dose
5. A pilot study of patient dose measurements in some hospitals
6. Publication of a dosimetry report based on the measurements

Exploitation of results:

The project will be finalised by the end of 2000. The results of the study will be applied in the implementation of the MED directive in the health care systems in Finland. The national reference levels will be set up based on the patient dose measurements.

Publication plan:

The results will be reported in national and international journals and conferences.

Timetable:

2000

Responsible scientist:

Antti Servomaa

Measures for optimising radiological information and dose in digital imaging and interventional radiology (DIMOND III)*Objectives:*

The project DIMOND 3 contributes to many objectives of the European Commission's radiation protection research programme in the medical use of radiation. The European MED directive identifies interventional radiology and mammography as areas that require particular attention. A number of studies into the benefit/risk ratio of interventional procedures and mammography will be performed. It will directly address the issue of justification given prominence in the MED directive. In addition, technical and clinical approaches will be developed for the optimisation of medical exposures for digital, interventional radiology and mammography.

Studies on the optimisation of X-ray facilities and procedures are especially important in digital and interventional radiology and digital mammography because of the rapid development in these branches of medical imaging and minimally invasive medicine. Interventional radiology has a large social dimension, in that individuals who would have required expensive operative procedures and long stays in hospital can now be treated as outpatients. Patients' confidence in the outcome of these procedures should not be undermined because of potential adverse radiation effects. A very high dose rate is at some intervals needed to reach sufficient image quality and the duration of all exposures cannot always be foreseen. Carefully optimised technical and clinical protocols are therefore important in interventional radiology.

Description of the work:

The project contains six work packages, each comprising of a series of sub-projects. The first three packages concern the basis underlying scientific and clinical research: Clinical Quality Criteria and Technical Parameters (WP1), Physical Aspects of Image Quality (WP2) and Reference Values and Justification (WP3). The other three work packages aim to bring the basic research

into clinical practice: Clinical evaluation projects of the special radiology procedures of interventional radiology (WP4) and cardiology (WP5) and digital mammography (WP6). STUK has taken the initiative to participate in the work of WP2 and of the clinical evaluation in projects WP4 to WP6.

The study is supported by EC Nuclear Energy programme.

Exploitation of results:

According to the work plan:

- WP2 will establish a linkage between technical parameters which are easy to measure with purely clinical indices of image quality.
- WP4 to WP6 cover the application of quality assurance and the use of reference values in the three above-mentioned specific clinical areas, demonstration projects and the implementation of the methodologies developed in work packages 1 to 3. The three clinical evaluation projects ensure that the results of scientific and clinical research will be implemented in radiology departments. They will also enable industry to improve its medical equipment to meet the demands of clinical protocols and to facilitate the widespread introduction of the digital techniques in European health systems.

Publication plan:

The results will be published in the progress reports and in scientific journals.

Collaborators:

Quality Assurance Reference Centre, Newcastle, K. Faulkner (co-ordinator) UK; Haughton Institute, Dublin, J. F. Malone, IRL; Brudder Krankenhaus, Trier, H. P. Busch, D; Compluteuse University, Madrid, E. Vano, S; University Zikenhaus, Leuven,B; University Hospital, Innsbruck, W. Jaschke, AUS; S.Maria della Misericordia Hospital, Udine, G. Back; I; Centre Hospitalier de Luxembourg, B. Schreiner, L; IRI, Delft, J. Zoetelife, NL; Athens General Hospital, Athens, V. Neofotiston, GR; Regional Medical Physics Department, Newcastle, UK, Diakonissenkrauhenhaus, Karlesruke, S. C. Vetter, D.

Timetable:

2000-2003

Responsible scientist:

Matti Toivonen

Further development and application of the PCXMC - patient dose calculation program

Objectives:

In medical radiology, the air kerma at the patient entrance surface (ESD) and the kerma-area product (DAP) in the X-ray beam are common patient dose descriptors that can be readily measured. However, they are not sufficient for evaluating the radiation risk from the X-ray examination or for comparing the radiation detriment from different examinations. Therefore, methods are needed for the calculation of conversion factors from ESD or DAP to the effective dose and doses in various organs. The dose calculation program PCXMC of STUK is capable of providing such data. It is intended to develop the program further, and to use it for calculating conversion factors for various X-ray examinations of interest.

Description of the work:

The user interface of the program will be modified for easier applicability in complex examinations, and methods for reducing the calculation time will be studied. The program will be applied to specific questions of patient dose that will emerge from other projects.

Exploitation of results:

The new version of the program will replace the old version (1.4) that is being used (and sold) presently. Calculation of effective doses and organ doses will be used in the assessment of the collective effective dose, the effective doses in the X-ray examinations in the focus of the MED directive (paediatric X-ray examinations, fluoroscopic examinations) and for the estimation of the fetal dose of pregnant patients.

Publication plan:

Calculation results will be used in other projects concerning medical radiology. The new version of the program will be described in the web pages of the program (<http://www.stuk.fi/pcxmc>).

Timetable:

2002

Responsible scientist:

Markku Tapiovaara

Computer program for radiation risk assessment

Objectives:

A computer program used for radiation risk assessment will be updated and developed further, and applied for the estimation of cancer risk from various X-ray examinations.

Description of the work:

A radiation risk assessment system based on the modified relative risk model published in the BEIR V report (1990) has been coded in a PC program together with Finnish demographic and cancer statistics. Now the method needs to be supplemented by new published estimates of the incidence and mortality of radiation-induced cancer. It also needs updating with new statistical data, and re-programming to make it more suitable for common use.

Exploitation of results:

The program can be used to calculate lifetime risk estimates, such as the *risk of exposure-induced death* and the *loss of life expectancy*, when the radiation doses to specified organs and organ groups are known. The risk estimates are calculated as a function of the age at exposure, and an average risk of the exposed population is calculated according to the age distribution. The primary task will be the assessment of risks from various X-ray examinations, in order to complement the collected information of measured patient doses. The program is also applicable to any other types of radiation exposure if the organ doses can be estimated.

Publication plan:

The results will be published in STUK report series and in scientific journals.

Timetable:

2002

Responsible scientist:

Tuomo Komppa

Performance measurements of X-ray diagnostic units

Objectives:

This project is composed of several studies of patient dose measurement for diagnostic procedures that are emphasized in the MED directive, development of measurement and calculation methods, and optimisation of X-ray examination techniques. The purpose in this project is to measure the performance of the computed tomography, mammography, fluoroscopy and digital imaging plate units.

Description of the work:

In computed tomography and fluoroscopy units the performance measurements focus on the technical performance, image quality and patient dose of the newest unit types. In mammography the study focuses on the performance of the newest unit types and digital image receptors. The performance measurements are made in connection with the inspections for radiation protection.

Exploitation of results:

The results are used in quality assurance programs and in optimisation of the performance of the units.

Publication plan:

The results will be reported in national and international journals and conferences.

Timetable:

2002

Responsible scientists:

Juhani Karppinen, Teuvo Parviainen

Objective methods for measuring the image quality of radiographs

Objectives:

We have previously developed methods for the measurement of image quality in fluoroscopy. These methods use a frame-grabber board and programming environment that are presently outdated. Our aim is to employ a new state-of-the-art frame-grabber and rewrite the computer programs fully to utilize the 32-bit architecture of modern PC systems. Another part of the work will explore possibilities to modify the methods to be useful for static X-ray images (radiographs) also.

Description of the work:

The computer programs will be rewritten for a new frame-grabber card (Matrox Genesis LC) and 32-bit PC operating systems (Windows NT/95/98). Measurement methods for static radiographs will be studied.

Exploitation of results:

The new measurement system will be used in other studies where measurement of image quality is needed.

Publication plan:

We have already published the details of the measurement method. If new measurement methods or procedures are found during the study, these will be reported in the proper publications.

Timetable:

2000 - 2003

Responsible scientist:

Markku Tapiovaara

The relationship between measured and visual image quality*Objectives:*

We have previously developed a system for the measurement of the accumulation rate of SNR^2 in fluoroscopic imaging, and studied the relationship between the measurement result and visual performance in simple imaging tasks with homogeneous phantoms. The objective of this study is to extend these studies to more clinically relevant imaging tasks and anatomic phantoms and, additionally, see whether the results can be understood on the basis of Monte Carlo calculations of image quality.

Description of the work:

Visual performance will be studied by using the MAFC (multiple alternative forced choice) or ROC (receiver operating characteristic) paradigm, supplemented with more simple observations of contrast-detail performance. The test phantoms and details will be chosen in order to mimic clinically important features as closely as is possible. Measures of visual performance will be compared with objective physical measurements and Monte Carlo calculations.

Exploitation of results:

The project will provide information about the optimization and evaluation methodology of X-ray examination techniques. If the results support the present understanding of the problem, Monte Carlo simulation and the measurement methodology will provide excellent tools for minimising patient dose in fluoroscopic imaging.

Publication plan:

The results of the study will be submitted for publication in a scientific journal.

This study will be made in collaboration with the Radiation Physics Department of Linköping University (Sweden), which will be the main contributor to the project.

Collaborator:

Linköping University, M. Sandborg, S.

Timetable:

2000 - 2003.

Responsible scientist:

Markku Tapiovaara

Development of measurement techniques for Quality Audit in radiotherapy*Objectives:*

The aim is to develop techniques of measurement which can be used for independent verification of the accuracy of CT imaging, treatment simulation

and dose planning in radiotherapy. A supplementary aim is to develop independent techniques for verification of dose distributions of treatment units, for both traditional and dynamic radiation fields.

Description of the work:

At first, imaging characteristics of CT equipment for radiotherapy dose planning are investigated, and a simple homogeneous phantom is developed for the verification of the correctness of input data of the dose planning systems. Second, a more comprehensive technique is to be developed, in order to verify the accuracy of the entire treatment process. This involves a more complex phantom, provided with non-homogeneities and the possibility of carrying out dose measurements close to the phantom edge. The technique is tested with a number of dose planning systems under practical conditions. For the supplementary aim, available commercial equipment is evaluated against a planned homemade system based on the use of multiple-detectors.

Exploitation of results:

The techniques and equipment developed will be applied in routine quality audits of the Finnish radiotherapy departments.

Publication plan:

The interim results will be reported at international meetings of radiotherapy societies (e.g. ESTRO). The final results will be published as a paper in a scientific journal.

Timetable:

2000-2002

Responsible scientist:

Petri Sipilä

Dosimetry of boron neutron capture therapy (BNCT)

Objectives:

The objective is to develop methods of measurement for the verification of correctness and accuracy of absorbed dose determination in the BNCT.

Description of the work:

The feasibility and accuracy of the following methods are studied by comparative measurements and theoretical calculations:

- twin ionization chamber technique for the determination of absorbed dose from gamma and neutron radiation
- boron fluoride counter for the determination of thermal neutron fluence
- microdosimetric methods for the determination of absorbed dose from gamma and neutron radiation

The comparative measurements are carried out in a few available European neutron beams.

The research is part of an EC funded shared-cost project, under the Measurements and Standards research programme of the EC. The aim of this project is to prepare an European Code of Practice for dosimetry of the BNCT. The responsibilities of STUK in the project are to coordinate the work for developing basic methods of calibration of epithermal neutron beams, and to co-ordinate the drafting of the entire Code of Practice for publication.

Exploitation of results:

The recommended methods of measurements and other recommendation to be presented in the Code of Practice will be adapted in Quality Audits of the Finnish BNCT facility. The European Code of Practice will be of great importance in harmonizing the dosimetry at all European BNCT facilities.

Publication plan:

An interim report on the results is to be prepared annually for the EU. The most essential results are to be published in international scientific journals (1-3 papers). The final results are to be summarized through the publication of a Code of Practice for the BNCT dosimetry.

Collaborators:

The Netherlands Energy Research Foundation, F. Shecher-Rasmussen, NL; The Netherlands Cancer Institute, B. Mijnheer, NL; The Institute for Advanced Materials of the Joint Research Centre of the Commission of the European Communities, R. Moss, NL; University of Helsinki, S. Savolainen, FI; The University of Birmingham, S. Green, UK; The Nuclear and Technological Institute, Sacavém, I. Concalves, PT; The Technical University of Budapest, E. Zsolnay; The Nuclear Research Institute, Rez, M. Marek, CZ; VTT, Espoo, I. Auterinen, FI; Universitätsklinikum Essen, J. Rasson, D.

Timetable:

2000-2003

Responsible scientist:

Antti Kosunen

Quality assurance of Electronic Portal Imaging Devices (EPID) in radiotherapy

Objectives:

The objectives are to settle the characteristics of EPID which are important for the verification of treatment accuracy and for the use of these devices as a dosimetric tool, and to develop quality control requirements of EPID in respect of these characteristics.

Description of the work:

The technical characteristics of EPID and the parameters, problems and possible solutions related to image handling and to various applications of EPID, are reviewed on the basis of published studies. A series of patients (prostate cancer and cancer in the head and neck region) are imaged at certain intervals with given fields, and the results are used to study the factors affecting the accuracy of patient positioning. The use of EPID for dosimetric and quality control measurements of the treatment unit, and the characteristics of associated computer programs are studied by comparative measurements with other dosimetric techniques. The results are used to develop the required quality control programme of the EPID.

Exploitation of results:

The quality control programme of EPID will be used as the basis of quality control requirements for the EPID in Finnish radiotherapy departments.

Publication plan:

The results are to be published as a paper in an international scientific journal.

Collaborator:

Tampere University Hospital, Radiotherapy department, J. Vanhanen, FI.

Timetable:

2000-2001

Responsible scientist:

Ritva Parkkinen

2 NATURAL RADIATION

2.1 Indoor radon

Indoor radon mapping

Objectives:

STUK's systematic indoor radon mapping has two purposes: first to help the local health authorities to locate homes exceeding the action level of 400 Bq/m³ and second to prevent the building of new houses exceeding the indoor radon level of 200 Bq/m³. The Ministry of Social Affairs and Health advised the municipalities to continue the radon investigations in co-operation with STUK in the Guidebook on Indoor Air (1997).

The correlation between predicted and actual indoor radon concentrations in different areas, soil types and construction types will be investigated.

Description of the work:

- STUK performs nationwide and regional maps and statistical summaries concerning indoor radon.
- STUK co-operates with health authorities in municipalities and provinces and with the Ministry of Social Affairs and Health.
- STUK performs training on radon issues.
- The radon prognosis method used in STUK will be validated. In this radon prognosis method, indoor radon concentrations in houses are adjusted for different substructure types. Classification of the substructures is made according to the probability of radon leaks. The soil types

are classified according to the permeability, and the prognosis area is divided into homogenous sub-areas within each soil type class. The probability of exceeding 200 Bq/m³ is then calculated for the house type at the highest risk in each sub-area and soil type. For the validation, new indoor radon data from STUK's representative surveys in the area of the prognosis map will be utilised. This data will be classified using the same method as described above. The predictions of the prognosis map will be compared with the new data. Houses built radon-safe will be dealt with separately.

- STUK maintains the indoor radon database utilised in research and information. The database includes information on radon measurements, building techniques, and location of houses and the geology of building sites.

Exploitation of results:

Radon maps and statistical summaries show areas where the most active measures should be taken and will be used in municipal decision making. The validation of the radon prognosis method aims at development of the method.

Publication plan:

- Municipal statistical summaries of indoor radon and radon in drilled wells according to postcodes.
- Updated nationwide and regional radon maps for media and municipal authorities and on STUK's Internet pages.
- Radon mapping strategy in Finland. Presentation for the conference of natural radiation in Munich.
- The evaluation of radon prognosis method. STUK's report and an article for an international journal.

Timetable:

Collaboration with municipal authorities is a continuous project, validation 2000-2001.

Responsible scientists:

Anne Voutilainen, Ilona Mäkeläinen (validation)

Radon in indoor air

Objectives:

1. To explore the structural and geological factors that have an effect on radon concentration in the indoor air.
2. To establish the temporal variations in the radon concentration of single family houses using a previous representative survey data in 300 houses.
3. In order to estimate the accretion of the radon concentration in the indoor air due to the gravel used in the foundations of Finnish small-houses, the uranium content and the rate of radon production of the gravel are investigated.
4. To develop and improve the techniques for measuring human exposure to radon.

*Description of the work:*Structural and geological factors

The study is based on a previous random-sampling survey in 3800 houses in an area with high indoor radon concentrations. The test houses are classified according to the house construction, foundation type and building soil. Factors affecting the radon concentration in indoor air are investigated. The trend of the radon concentration in new dwellings is studied, with a special focus on the effect of foundation type.

Radon sources and temporal variation

1. The results of the study commenced in 1997 on the rate of radon production and the emanation factor of the gravel used in the foundations will be published. The results concerning the concentration of radium have already been published. Implications to the radon concentration in the new stock of dwellings will be estimated.
2. The measurement data acquired in 300 small-houses between 1996 and 1997 concerning temporal variations in the radon concentration will be analysed. The results of the measurements will be compared to the estimates that are based on modelling studies.

Development of the measurement techniques

The feasibility of new methods of determining air-borne radon retrospectively will be studied (surface-trap or volume-trap) in connection of other ongoing projects (RETRO, Radon epidemiology /EC).

Exploitation of results:

Expertise on the structural and geological factors and the effects of the gravel will be utilised when planning the national radon policy.

Knowledge of temporal variations benefits studies on the health effects of radon. This knowledge is also essential when estimating the annual average of the radon concentration based on short-term measurements (duration less than one year), e.g. in epidemiological studies.

Publication plan:

Structural and geological factors: analysis 2001, publication 2002.

Temporal variations: analysis 2000-2001, publication 2001.

Timetable:

2000-2002

Responsible scientists:

Tuukka Turtiainen, Ilona Mäkeläinen, Hannu Arvela

Total radon exposure of Finns (RATVA)

Objectives:

The study aims at determining the total exposure from inhaled radon in Finland. Indoor radon both at home and at the workplace, and the time spent outdoors and elsewhere is taken into account.

Description of the work:

The survey will be performed as a random sampling study. At the first stage a questionnaire will be sent to 4,000 Finns randomly selected from the central population register of Finland. If an under-aged person is selected, her/his guardian will be the addressee, but the questions refer to the person selected.

Using a questionnaire, willingness to have an indoor radon measurement at home and/or at the workplace, and willingness to carry a personal radon monitor is asked. Other questions will concern the hours spent at work or at school, at home, outdoors, etc. Seasonal variation in these hours, and the time spent at a summer residence will be asked. The site and type of the office or work place (underground/first floor/upper floor, mobile, etc.) and other related questions will be asked as well.

At the second stage, all study subjects working in underground work places will be selected for radon measurements at home and at work. 500 subjects

working at sites located on the first floor and 500 subjects at sites located on upper floors will be selected as well. 150 persons, mostly among those selected for radon measurements, will be selected to carry a personal radon monitor. Those who will be selected for radon measurements will receive radon dosimeters for home and the work place, and a letter to be handed to the employer. Questionnaires concerning the dwelling and the work place (especially the ventilation) will be filled in by the study subjects. Those carrying the personal monitors are asked to account for their stay at home, outdoors, at work, and elsewhere.

The radon concentration at an individual work place will be obtained using the measurement results in this study. Corrections due to different air exchange rates during working days, and at nights and weekends will be made by utilising additional one-week measurements using continuous radon monitors, and data from previous measurements in other workplaces. The distribution of different work place types will be used to assess the mean radon concentration at work places in Finland.

The proportion of time spent at home, at the workplace and outdoors will be obtained from the survey. The indoor and outdoor radon concentrations are known from previous studies, and the mean concentration at work places will be obtained from this study. Using these figures, the total radon exposure for males and females of different ages will be calculated. The data from the personal radon monitors will be compared with these results.

Exploitation of results:

The results of this study will help us to expand our knowledge of the radon exposure of Finns. This kind of information is useful when interpreting the risk estimates from epidemiological studies and applying them to the Finnish population.

Publication plan:

An article in a scientific journal

Timetable:

Measurements 2000, final analysis and report 2001.

Responsible scientists:

Project manager: Ilona Mäkeläinen (project manager), Tuukka Turtiainen (dwellings), Heikki Reisbacka (work places), Hannu Arvela

Radon remedies at workplaces

Objectives :

Gathering of information of radon remediation at workplaces, aiming at production of new guidance material.

Description of the work:

The workplaces to be studied will be found in the radon register of STUK. A questionnaire will be sent to these workplaces.

Exploitation of results:

Through new guidance material and authority information.

Publication plan:

Report by end of 2000. Guidance 2001- 2002.

Timetable:

2000 - 2002

Responsible scientists:

Heikki Reisbacka, Hannu Arvela, Mika Markkanen

Radonsafe foundation, moisture prevention and air exchange in a healthy building, phase 2

Objectives:

- To develop the methods of radon-safe construction, guidance published by the authorities and the markets of enterprises
- Developing of the regulations and practices of building companies
- Combination of the implementation of qualified moisture prevention and radonsafe structures in Finnish housing
- To explore the effect of sub-floor ventilation on the moisture of the floor slab and sub-floor aggregate layer
- To evaluate the effect of different ventilation strategies on indoor radon reduction and to develop air inlet vents for this purpose and to study the effect of vents on indoor air quality

- To promote utilisation of radon-safe constructions and qualified air exchange strategies
- To do basic research aiming at providing guidance on radon-safe construction of blocks of flats

Description of the work:

Radonsafe structures will be studied in 10-15 houses with slab-on-grade or hill-side constructions. As a precaution sub-slab piping will be installed in all houses.

The construction documents and the practices on building site including the experiences of responsible building groups will be controlled and documented by the researchers of the project. Different approaches will be tested in order to find easy to use and reliable practices.

The tests started in 1999, aiming at exploring the feasibility of sub-slab-ventilation on the acceleration of the slab drying process and will be continued. In test houses humidity probes are installed in the floor slab and sub-floor gravel layer.

The effect of depressure control to indoor radon concentration will be studied in both single family houses and ground floor flats.

The study is supported by TEKES, Finnish Technology Agency.

Exploitation of results:

Wide introduction of radon safe building practices prevent the harmful effects of high indoor radon concentrations. Simultaneously these practices improve the quality of Finnish housing, decrease problems caused by soil-borne moisture and improve the quality of indoor air. The project delivers guidance material for authorities, builders and building companies. The studies of slab-drying aim at savings and reliability of the building process.

Collaborators:

Helsinki University of Technology, Laboratory of Structural Engineering and Building Physics, A.V. Kettunen; Laboratory of Heating Ventilating and Air Conditioning, J. Kurnitski, K. Jokiranta; Katepal Oy, Skanska Oy; Optiroc Oy; Pyhännän Rakennustuote Oy; Kastelli Oy.

Publication plan:

Reports of the responsible organisations and publications 2000 - 2002.

Timetable:

2000-2001

Responsible scientists:

Hannu Arvela, Tuukka Turtiainen

Validation of the retrospective radon measurement method (RETRO)

Objectives:

The aim of the study is to evaluate the feasibility of the retrospective radon exposure assessment method in epidemiological studies. The method utilises glass specimens owned by residents.

Description of work:

The study will be a co-financed project of STUK and Battelle Memorial Institute, Columbus, Ohio. Four different detectors will be validated.

Alpha activity from polonium 210 accumulated on the surfaces in a room, e.g. mirrors and other glass objects, is proportional to the cumulative in-planted radon decay products. The activity may be used as a measure of the indoor radon exposure during the period the resident had the glass specimen in his/her possession. The alpha activity is measured using a passive radon detector attached to a glass object. The objects have to have been owned by the resident for at least ten years.

About 1,000 dwellings with at least two previous radon measurements within at least one year were selected from the indoor radon database of STUK, and letters requesting volunteers to take part in the survey were sent. Questions about suitable glass objects and smoking indoors were asked as well. From the respondents having lived in the house at for least 10 years, 80 dwellings with the most stable indoor radon concentration were selected. Both smokers and non-smokers were selected for the study group.

During the fieldwork, the detectors will be placed by a qualified field technician. He/she will question the residents about the dwelling and the glass ob-

jects selected. The detectors will be returned after two months, and sent back to the laboratories responsible for the analysis. STUK will assess the radon history for all dwellings.

Exploitation of results:

If the validation is successful, the method will be used in future epidemiological studies.

Publication plan:

An article in a scientific journal.

Collaborators:

National Cancer Institute, NCI, M. Alavanja, US; St John's University, D. Steek, US.

Timetable:

1999-2001

Responsible scientists:

Ilona Mäkeläinen, Hannu Arvela

2.2 Natural radioactivity in household water

Radioactivity in household water

Objectives:

The primary goals of the research are:

- To determine occurrence of radioactivity (^{222}Rn , $^{234,238}\text{U}$, ^{226}Ra , ^{210}Pb and ^{210}Po) in Finnish ground waters and the influence of bedrock on radionuclides concentration
- To explore the transfer factor of radon from household water to the indoor air
- To study the influence on sampling and plumping of the concentration of lead (^{210}Pb) and polonium (^{210}Po)
- To clarify the proportion of particle bound lead (^{210}Pb) and polonium (^{210}Po) in various ground waters
- To develop new time-saving analytical methods for lead (^{210}Pb) and radium (^{226}Ra and ^{228}Ra)

- To study the basis for an upper limit for radionuclides in household water, which the Ministry of Social Affairs and Health will probably issue during the year 2000. The upper limits are based on health hazards in Finland and on costs avoiding health hazard
- To develop and maintain the water database.

Description of the work:

Radon atlas of drilled wells will be published during the year 2000. The same kind of atlas will be composed for the other radionuclides. STUK is responsible on radioactivity chapter in New Geochemical atlas of Finland will be produced by Geological Survey of Finland. Dependence of radionuclide concentrations and rock types will be explored.

Ministry of Social Affairs and Health will issue upper limits for radionuclides in drinking water. The basis for these limits will studied by comparing the effects of different limits on health hazards and the costs of averting these hazards.

The amount of radon released from water to indoor air will be studied in test locations where water contains high radon concentration. Radon concentration in indoor air is measured before and after radon is removed from water or after people have changed they water source e.g. public water supply.

Influence of sampling on lead and polonium concentrations will be studied by taking water samples in different water consumptions. The portion of particle bound lead and polonium will be studied using filtering experiments.

Eichroms new selective resins will be used in new analytical methods for lead and radium. Liquid scintillation with alpha-beta discrimination will be used in measurement of isotopic uranium. The database of water laboratory will be maintained and developed to provide better laboratory's needs.

Exploitation of results:

The results of the studies are utilized by the Ministry of Social Affairs and Health in their decision making. The local health authorities use them in planning of public water supply and in guidance of people living outside it. Results from the transfer factor study as well as results from studies of lead and polonium are utilized in dose estimations in connection of epidemiological studies.

Collaborators:

Geological Survey of Finland , K. Backman, T. Tarvainen, FI.

Timetable:

2000-2001

Responsible scientists:

Pia Huikuri, Laina Salonen, Anne Voutilainen, Ilona Mäkeläinen, Tuukka Turtiainen

Safe operation of domestic equipment for removing radionuclides from drinking water

Objectives:

The study aims at exploring the reliability of the granular activated carbon filters (GAC) and ion exchangers used for radionuclide removal, in domestic use under various circumstances and for ground waters whose qualities differ from those presently tested. Further studies are required before a consumer guide can be prepared. The capability of commercial aerators to remove radon and of nanofiltration to remove long-lived radionuclides (uranium, radium, ^{210}Pb and ^{210}Po) will also be studied.

*Description of the work:*Radon removal with granular activated carbon (GAC) filtration:

- A number of the GAC filters (10-20) having been in service for years and representing various water types will be selected for the study. E.g. iron, particles, humus can impede the filter performance and reduce radon reduction. Another aim of this study is to find means to reduce their effect e.g. by equipping the GAC with a backwash unit or a pre-filter. Their effect on the radionuclide removals, on the technical operation of the filter and on the behaviour of iron will be studied.
- The operation of the GAC filters will be tested with high water flow rates in order to ensure that radionuclides will not be released into water under such a situation.
- The ^{210}Pb content of the spent carbon will be determined and its amount compared to the amount of ^{210}Pb calculated on the basis of the amount of radon in the water. This comparison will possibly ascertain whether all of the ^{210}Pb generated in the decay of radon is retained in GAC and will not be released into the treated water.

Radon removal by aeration

- The radon removal capacity of a few types of aeration equipment (3 - 6) recently come onto the Finnish market will be tested under various water consumption circumstances

Removal of uranium, radium, ^{210}Pb and ^{210}Po with ion exchangers

- The performance of ion exchangers having been in service for years will be studied, as well as the effect of water qualities on the removal efficiencies. The capability of new ion exchange resins (not presently tested) will also be studied.
- The effect of other filters (e.g. prefilters or GAC installed to operate with an ion exchange unit) on the removal efficiencies and on the service life of the ion exchangers will be studied.
- Laboratory experiments will be carried out in order to find which unexpected conditions in water supply systems (pH, mineral contents, pressure etc.) have effect on the performance of the ion exchangers. The aim of these tests is to ensure that radionuclides will not be released into the water under such circumstances.

Removal of uranium, radium, ^{210}Pb and ^{210}Po by nanofiltration

- The suitability of various nanofiltration membranes to remove these nuclides from a few type of ground waters will be studied. Radon removal will also be measured.

The study is supported by TEKES, Finnish Technology Agency.

Exploitation of results:

The information gained is needed to prepare a consumer guide, which is necessary also for the companies. The guide will increase the sale of the water treatment equipment both in Finland and also in other Nordic countries, which have not yet carried out any experimental study on water treatment methods for removal of uranium, radium, ^{210}Pb and ^{210}Po from drinking water.

Collaborators:

Vartiainen Oy, WatMan Oy, Well Rock (WRO), Dosfil Oy (DFI), Callidus Oy, Akva Filter Oy, Alvitek Oy

Timetable:

2000-2001

Responsible scientist:

Laina Salonen, Pia Huikuri, Tuukka Turtiainen, Hannu Arvela

Household water as a source of radiation to Finnish people - the random-sampling survey (TAVES)

Objectives:

The primary goal of this study is to define the radiation exposure from drinking water to Finnish people. The most critical section of the population is those who consume water from drilled wells. The study provides a representative average concentrations of radon, uranium, radium, lead and polonium in the drilled wells. It will also clarify the use of water from drilled wells as drinking water in leisure houses and in workplaces.

Description of the work:

The proportions of users of different water sources among the Finnish population are estimated by sending a questionnaire to a random sample of 4,000 Finns. The amount of water used daily for drinking at home and elsewhere will be asked using a questionnaire.

2,000 Finnish people are selected by another well survey from those who do not have a communal water supply. Most of the users of the drilled and dug wells belong to this group. About 400 drilled well users and 200 dug well users are selected after they have agreed to participate in the study. Permission for sampling is asked before collecting the water samples. The local health officers collect the samples. Radon is measured from all samples, and uranium, radium, lead and polonium from a smaller sample. The indoor radon concentration is measured at all test locations. It is measured in the kitchen, where water consumption is highest, and in the bedroom.

The proportion of users of different water sources and daily water usage for drinking is determined by the national representative survey. Results from the well survey will give the distribution of radon in indoor air in houses where water is taken either from a drilled well or a dug well. The doses from ingested water are estimated according to the results of the study. Dose estimations in waterworks will be based on previous studies.

Exploitation of results:

The results will be utilized in the authorities' decisions and in planning water supply in areas where there is no communal water supply. The results are also utilized in the arrangement of a national account to the EU acceding to the directive on drinking water.

Collaborators:

Geological Survey of Finland, K. Backman, T. Tarvainen, FI.

Timetable:

The study will be carried out during the year 2000. The results are to be analysed and the international article is to be written during the year 2001.

Responsible scientists:

Pia Huikuri, Ilona Mäkeläinen

²¹⁰Pb in humans

Objectives:

The aim of the study is to be able to make a better estimation of the internal exposure of natural radionuclides by direct measurements of people instead of using indirect methods. With *in vivo* ²¹⁰Pb measurements a method for retrospective dose estimation will be developed. Because the measurement method is new, only learning the technique will take time and not many results from measurements of people should be expected.

Description of the work:

For the ²¹⁰Pb measurements of the skull a measurement geometry with two to five Ge detectors will be designed. The calibration work will be done in co-operation with the German GSF laboratory. The support for the person to be measured as well as detector holders and shieldings will be designed and constructed. In the first phase the method of measurement using the detector to be delivered in spring 2000 will be developed and tested. In 1999 a method to take the people to be measured to Germany proved to be complicated and expensive. In 2000 both STUKs own detectors and borrowed detectors from GSF will be used for measurements at STUK. The persons to be measured will be selected in co-operation with the laboratory for natural radiation. The requirements are that the persons are volunteers, have a long history of exposure to radon and its daughter products either by using water from drilled wells with high concentrations of the above mentioned sub-

stances or living in a house with high indoor air radon concentration. In these cases it is possible that measurable amounts of ^{210}Pb have been concentrated in the skeleton as has already been demonstrated by the measurements taken. For the possible variations in the intake of ^{210}Pb of the persons to be studied the concentration of radioactive substances in drinking water during different times of the year and different water consumption situations will be measured, as will the indoor air radon concentrations.

The project is planned for many years. In 2001 another Ge detector will be ordered, together with the electronic equipment needed. The detectors and the electronic devices will be installed and tested.

Exploitation of results:

The results will be used when a research program for retrospective determination of radon exposure and radiation doses is planned. A new EU project proposal for January 2001 will be prepared. Articles for international journals will be written in co-operation with the German scientists.

Collaborators:

GSF, München, W. Wahl, D.

Timetable:

2000 - 2004

Responsible scientists:

Tua Rahola, Matti Suomela, Laina Salonen, Ilona Mäkeläinen

2.3 Other sources of natural radiation exposure

Exposure to natural radiation in industry (NORMA)

Objectives:

In this study, the exposure of the population and the workers to the natural sources of radiation are investigated. The exposure may take place in industrial work and in activities utilising materials or producing wastes that contain excessive amounts of natural radionuclides.

Description of the work:

The study will primarily be based on literature and on the measurements and inspections previously carried out by STUK. If need be a set of complementary measurements can be carried out for materials and wastes that may contain significant amounts of natural radionuclides but for which there is no information about their specific activity. The work will be performed in co-operation with department of Radiation Practices Regulation.

Exploitation of results:

Based on the study, the necessity of taking measures against excessive radiation within different branches of industry will be established. This study also serves also as the national survey required by the implementation of the BSS directive.

Timetable:

Final report (in English) 31.12.2000. (The report will be written in English because this study serves as the national survey required by the implementation of the BSS-directive).

Responsible scientist:

Tuukka Turtiainen, Hannu Arvela, Mika Markkanen

Impacts of natural stone production to radiation exposure*Objectives:*

This project is part of a larger cross-scientific project called Development of Environmental Database Management System for Natural Stone Industry and the Life Cycle of Natural Stone Production. The project is affiliated to the development programme of natural stone production. The project aims at strengthening the environmental and marketing strategies of the natural stone industry. The aim of this sub-project is to find out the radiation impacts on humans caused by natural stone production. The objects of the investigation are a quarry and its environment and the final product of natural stone.

When we know the radioactivity of the stone and the purpose for which it is used we can estimate the radiation dose for humans. The purpose of the

project is to produce dose estimates based on radiation measurement results and reference values for foreign natural stones and for valid regulations.

Description of the work:

The Finnish Natural Stone Association carries out the stone technology and development programme. Project is linked to the environmental cluster research programme. The responsible executive of this project is Kari Pääkkönen, head of the regional office of Geological Survey in Kuopio. The project is jointly financed. The cost estimate for three years is about 1;5 million FIM. STUK's contribution is 91,000 FIM.

The radiation part of the project will focus on two quarries with different levels of radioactivity: a rapakivi granite quarry in Ylämaa (Palin Granit Oy, Hujakkala quarry) and a soap stone quarry in Suomussalmi (Vuolukivi Oy, Saarikylä quarry). The final targets of natural stone are going to be chosen from the metropolitan area. Before starting the field measurements the materials are studied from the literature.

Matters to be investigated and measured: gamma radiation measurements in the laboratory of stone and dust samples, gamma radiation measurements in the field, outdoor air radon measurements, analyses of water samples, model calculations. GSF takes care of water sampling and STUK is responsible for other matters.

Exploitation of results:

The results can be utilised by the natural stone industry, the environmental authorities and the authorising body.

Publication plan:

Results are to be published in Finnish in an extensive report and in English in a summary report. In addition, a scientific article is to be written for an international journal. The basic conclusions are also reported to the public.

Collaborators:

Geological Survey of Finland, K.Pääkkönen, FI.

Timetable:

STUK activities 2000-2001. Final report of the project 2002.

Responsible scientist:

Anne Voutilainen

3 ENVIRONMENTAL TRANSFER OF RADIOACTIVE SUBSTANCES AND NUCLEAR EMERGENCY PREPAREDNESS

3.1 Environmental transfer of radioactive substances

Framework for Assessment of Environmental Impact (FASSET)

Objectives:

Radiation protection is generally based on the principles of the ICRP, according to which plants and animals are sufficiently protected when man, the most sensitive organism, is protected. During recent years it has been widely recognised that this principle is not sufficient on all occasions to protect other living organisms than humans from the harmful effects of radiation. In the legislation of many countries concerning nuclear energy it has been mentioned that radiation protection of the environment must be taken care of properly, but internationally accepted criteria or national frameworks do not yet exist.

The objective of this project is to create a framework for the protection of the environment. This is achieved by combining sources, exposure, dosimetry and environmental effects. Exposure pathways of various organisms, radiation doses and their effects will be considered in various discharge scenarios in typical European environmental conditions.

Description of the work:

Four work packages belong to the project. STUK will mainly participate in the packages of exposure pathways and the frameworks. On the basis of the results from the various work packages and by taking into account the crite-

ria for the protection of the environment against other harmful subjects in the environment, for instance chemicals, criteria for radiation protection of the environment will be created.

The project is a shared cost EU project, which has eight partners. The coordinator of the project is SSI from Sweden. Three units from STUK in addition to Ecology and Foodchains will participate in the project. These are the NPP Environment, Nuclear Waste Management and the Regional Laboratory in Northern Finland. The Laboratory for Ecology and Foodchains contributes to the project data on pathways and distribution patterns of radionuclides in freshwater and terrestrial biota and the Regional Laboratory in Northern Finland in terrestrial and marine arctic biota, respectively. The contribution of the NPP Environment is based on the biota and special characteristics of the Baltic Sea. The project takes place during 2000-2002.

Exploitation of results:

Creating criteria for radiation doses received by organisms will improve radiation protection of the environment. Simultaneously, the principle of maintaining biological diversity and durable use of natural resources will be observed. Information obtained during the project is expected to be useful for decision-makers, for instance in connection with final disposal of nuclear waste.

Publication plan:

Results will be published according to the plan of the EC-project. The results will be published in international report series.

Collaborators:

Swedish Radiation Protection Institute, SSI, C-M Larsson (co-ordinator) S; Swedish Nuclear Fuel and Waste Management Co., U. Kautsky, SKB, S; Norwegian Radiation Protection Authority, NRPA, J. Brown, N; Bundesamt für Strahlenschutz, BfS, W. Donhaerl, D; National Centre for Environment and Health, GSF, G. Proehl, Research Centre in Energy, D; Environment and Technology, CIEMAT, C. David, S; The Environment Agency, EA, D. Woodhead, UK.

Timetable:

2000 - 2002

Responsible scientists:

Ritva Saxén, Riitta Hänninen, Erkki Ilus, Kristina Rissanen, Kirsti-Liisa Sjöblom

3.1.1 Forests

Forest radioecology and distributions of ^{137}Cs

Objectives:

The aim is to complete the database on radiocaesium in forest vegetation for purposes of modelling and information. The project is directed to the forest types lacking domestic data.

Description of the work:

^{137}Cs distribution in a spruce stand at the stage of final felling will be measured. Samples of trees, undervegetation and soil have been collected in summer and autumn 1999 in co-operation with the Finnish Forest Research Institute and Ecology and Foodchains. Time consuming preparation of the samples has begun at STUK and will continue in both laboratories until 2001. Gamma-spectrometric measurements will be carried out in 2000-2001. Nutrient concentrations of soil and vegetation samples will be determined at the laboratories of the Finnish Forest Research Institute. Data analysis will begin when the results of the measurements are available in 2001. Based on the results of the measurements, the effect of the growth conditions on the ^{137}Cs distribution will be assessed.

Exploitation of results:

The results will be used in providing information for the forestry sector, in assessing the consequences of the Chernobyl accident in the project for wood energy and in developing calculation models (RODOS Migration).

Publication plan:

The results will be published in scientific publication.

Collaborators:

The Finnish Forest Research Institute, L. Aro, FI.

Timetable:

1999-2002

Responsible scientists:

Aino Rantavaara, Virve Vetikko

Radioactivity of timber*Objectives:*

The objective is to assess the radioactivity of timber based on the timber received at sawmills and on radioactivity measurements of samples from commercial forests. Variation in the radioactivity of timber due to differences in site types is studied. Based on the level of radioactivity in young tree stands, the ^{137}Cs concentrations in the future will be assessed.

Description of the work:

The results of the measurements of a sampling carried out in sawmills in 1996-1997 will be analysed. The domestic wood industry has supported the sampling. The corresponding results of radioactivity in timber in 1993-1994 have been reported previously (report STUK-A133).

The radiocaesium measurements for commercial forests are based on samples of stemwood and soil collected in co-operation with the wood industry. The samples of trees and soil collected in 1999 will be analysed. The radioactive caesium and potassium in different fractions of trees will be determined gammasspectrometrically.

The results of the radioactivity in timber will be reported in 2000 together with the first results describing growing tree stands. Laboratory analyses for the samples describing growing tree stands will continue until 2001. The radioactivity of timber will be monitored until the situation concerning the wood industry and the export of timber is clear enough and the follow-up is no longer needed.

Exploitation of results:

The new information is for the needs of the forestry sector, and for development of calculation methods for dose assessments.

Publication plan:

Reports or articles on the results will be written in 2000-2001 and will be published in STUK report series.

Timetable:
2000 - 2001

Responsible scientists:
Virve Vetikko, Aino Rantavaara

Radiological consequences of the use of wood energy

Objectives:

Adequate quantitative knowledge of the radiation effects of production of wood energy, and the storage and use of ash will be produced for preparing radiation protection instructions at STUK. The aim is to commence the project with a preliminary study, where the practical issues about the acquisition of wood or mixed fuel (wood and peat), the handling and storage of ash, and the possible returning of ash to the forests, will be analysed in a couple of wood energy plants. The preliminary study may lead to a more comprehensive project together with the wood industry.

Description of the work:

The plan is based on a study carried out in 1996-1997 (Rantavaara and Moring 1999). The essential factors for the field of wood energy relating to the accumulation, transfer and cause of the radiation dose of radionuclides will be assessed. A holistic assessment of the radiation in the production chain of wood energy will be made. The focus is on analysing the consequences of the accident at the Chernobyl nuclear power plant. The project will also serve the forestry sector in preparedness for radiation situations at large. The project will be conducted in co-operation with energy and forest industries.

Samples of ash, fuel wood and mixtures of wood and peat from the energy industry and small users will be measured. Assessments of the radioactivity of ash will be made based on the fuel acquisition plans of individual energy plants. The importance of the combustion technique will be evaluated in connection of the total inventory of radioactivity. Significant dose pathways will be identified and doses will be estimated for the selected wood energy concept in Finland.

The project will result assessments of radiation foses through significant pathways for the current wood energy concept in Finland.

Exploitation of results:

The results will be exploited in preparing the radiation protection guidance for the field of wood energy in Finland. The project will also improve the knowledge of radiation issues in the field of wood energy through co-operation and a separately organised seminar for the interest groups.

Publication plan:

Reports will be written in a popular way to facilitate the acquaintance by the interest groups. The reports will be published in STUK report series. In addition results will be published in scientific journals.

Timetable:

The project will start with preliminary studies with private industry in 2000. A joint research project will be prepared simultaneously. Radioactivity data will be collected in 2000-2001. A seminar for the interest groups will be arranged in 2002. Final publications will be given in 2002-2003.

Responsible scientists:

Aino Rantavaara, Olli Taskinen, Virve Vetikko, Ritva Saxén, Eila Kostiainen, Tuomas Valmari

Plutonium in forests (NKS-BOK-2.1.1. b)

Objectives:

A small-scale analysis of plutonium activity in a stand representing boreal pine forest is the main aim of the study. Transuranic elements have until now mostly been analysed in samples from a brackish water environment. Because forest ecosystems seem to retain deposited radionuclides for long periods, the activity contents of $^{239,240}\text{Pu}$ in mushrooms, berries, other forest vegetation and soil is of interest. The results will indicate the significance of Pu contamination in forests as a dose contributor.

Description of the work:

Some samples from soil, berries, mushrooms and understorey spruce, taken for another project by STUK, will be analysed for ^{238}Pu and $^{239,240}\text{Pu}$. Samples

were collected at a site situated in a southern boreal vegetation zone where conifers predominate. Plutonium as a radiation source for Finnish people will be compared with exposure from other sources.

Exploitation of results:

The study will complete knowledge of radiation exposure from environmental sources in Finland.

Publication plan:

Results will be published in the final project report of the NKS.

Timetable:

1999 - 2001

Responsible scientists:

Aino Rantavaara, Eila Kostainen

Forest ecosystem study in the environs of Finnish nuclear power plants

Objectives:

Radiation monitoring in the environs of Finnish nuclear power plants, which is carried out by the NPP Environmental Laboratory of STUK as a consultant service ordered by the power companies, requires not only implementation of the permanent monitoring programmes, but also more profound study projects which focus on different sectors of the surveillance. The aim of these projects is to ensure that the conclusions based on the results of the monitoring programmes are correct. At the same time they aim to develop the dose calculation models used in the monitoring programmes.

Description of the work:

From the very beginning soil samples have been an essential part of the permanent radiation monitoring programmes in the environs of the power plants. According to the present programmes, soil samples are taken in the vicinities of the Loviisa and Olkiluoto power plants every four years. In connection with the soil surveys, samples of wild berries and mushrooms are taken in the surrounding areas. Furthermore, samples of hair moss, reindeer lichen and pine needles are taken annually. In general, only natural radioactive substances and certain long-lived radionuclides originating from the Chernobyl accident and the global fallout caused by the atmospheric

nuclear weapons tests are detected in these samples. Traces of radionuclides originating from the local nuclear power plants have been detected very seldom. Great variability has been characteristic for the concentrations of radionuclides in these samples. This may be due to variability in local ecological factors such as type soil and habitat.

A small preliminary project will be arranged in connection with the regular sampling of soil and gathered forest products, which will be performed at Loviisa in 2000. The purpose is to obtain representative samples from different layers of soil and from moss, lichen, twig and other plant species typical of the site. The samples are taken from a restricted area where the quality of soil, type of habitat and quantity of deposition are as homogeneous as possible. The estimated number of samples is 20-30. In 2001 a similar project will be arranged at Olkiluoto.

Exploitation of results:

The study yields new data on the occurrence, transport and concentrations of radionuclides in the environs of the Finnish nuclear power plants. The results are exploited in developing and revision of the environmental monitoring programmes.

Publication plan:

The results will be published in STUK report series in 2002-2003.

Timetable:

At Loviisa in 2000, at Olkiluoto in 2001.

Responsible scientists:

Tarja K. Ikäheimonen, Erkki Ilus, Seppo Klemola

3.1.2 Freshwater ecosystems

Behaviour of long-lived radionuclides in lake ecosystems and their storage in the bottom sediments of the lakes

Objectives:

Lake ecosystems are a significant part of Finnish nature. After the Chernobyl accident the importance of lake radioecology was emphasized, because the highest radiation doses received by Finnish people were obtained by

eating freshwater fish. The radioecology of lakes is not yet totally known. Bottom sediments have an important role in lake radioecology, because the majority of the radionuclides transferred into lakes are gradually transferred into and finally stored in bottom sediments. Fish use sediments and biota living in them as their food. Therefore, it is important to obtain information on radioecological processes in bottom sediments to be able to estimate how long the radionuclides deposited in the bottom sediments will be in the biological cycle and available for biota and thus affecting radiation doses received by humans. Our previous results indicated that the radionuclide content of the sediment correlate with eutrofication of the sediment.

The objectives of this project are 1) to follow the long-term gathering of the radionuclides and removal of the nuclides from the biological cycle, 2) to study the effect of eutrofication and humic substances on the sinking of the radionuclides to the bottom sediment and 3) to form a total picture of the distribution of radionuclides in the catchment, in water, in aquatic plants, in bottom animals, in bottom sediments and in fish.

Description of the work:

The lakes selected for the study include lakes for which numerous previous data on other compartments exist and lakes where the fish have exceptionally high contents of ^{137}Cs . Lake selection is also affected by limnological and hydrological background information available on the lakes. The effect of conventional contamination or eutrofication on the radionuclide contents of sediments is studied in areas where sampling both on the upper flow and on the lower flow of the contamination source is possible and where these stations are close to each other. The total duration of the project is four years. Sampling and analyses are to be commenced in 2000.

Exploitation of results:

The results provide new information on differences in behaviour and sedimentation of radionuclides in various types of lakes. The results can be utilised in the validation and further development of environmental models used for estimation of the radionuclide contents of fish and water and for estimation of radiation doses.

Publication plan:

The results will be published in scientific journals and detailed produced data in STUK report series in 2003.

Timetable:

2000-2003

Responsible scientists:

Ritva Saxén, Erkki Ilus

¹³⁷Cs and ⁹⁰Sr in freshwater fish*Objectives:*

The main objective of the project is to produce data on the contents of long-lived radionuclides in freshwater fish for estimation of radiation doses at present and in the long term. A special goal of the study is to determine factors for which levels of ¹³⁷Cs in fish stay high for an exceptionally long time after a deposition. The study also focuses on production of new information on behaviour of ¹³⁷Cs in a large lake basin in cases when deposition of ¹³⁷Cs in various parts of the lake differed greatly and the water chemical parameters in various parts of the lake are also different. Determination of the distribution pattern of the long-lived radionuclides in fish is also included in the study. Besides ¹³⁷Cs, data on regional and temporal changes of ⁹⁰Sr in fish in Finland will also be studied.

Description of the work:

Much information already exists on the factors affecting transfer of radionuclides to fish. For instance, the nutrition level has proved to be one of the most important factors causing effective transfer of ¹³⁷Cs to fish. However, there is still a lack of data on factors keeping ¹³⁷Cs levels in fish high during an exceptionally long time after deposition. For that purpose the results of ¹³⁷Cs obtained in gammaspectrometric measurements of freshwater fish after the accident at Chernobyl will be analysed together with data on the water chemical parameters of the lakes and data on the catchments of the lakes.

Data on transfer of ¹³⁷Cs in a chain of small lakes will be obtained by analysing the results obtained from determinations of samples from a group of small lakes after 1986. How the uneven distribution of deposition affects the contents of ¹³⁷Cs in fish in a large lake basin can be studied, because this kind of lake has been included in the study. Besides unevenly distributed deposition, differences can possibly be caused by different water chemistry in different parts of the lake.

New fish samples are still to be taken during the fishing season 2000 on a planned basis and analysed for ^{137}Cs . Samples of three types of fish with different feeding habits will be analysed. By analysing the results of the determinations of ^{90}Sr in fish, obtained until now, temporal and regional variations of ^{90}Sr in fish will be obtained. Based on the same material, radiation doses caused by ^{90}Sr in fish can also be estimated. The other objectives will be achieved by analysing the results of ^{137}Cs in fish from various lakes with other types of data on the lakes and on the catchments.

Exploitation of results:

The results of the project will improve the utilisation of dynamic transfer models, because the results can be used for the validation of the models (RODOS, DETRA). The results also help to find the most critical lakes and thus improve preparedness for an emergency situation. Distribution patterns of ^{137}Cs and ^{90}Sr will be needed in the project FASSET.

Publication plan:

The results will be published in scientific publication.

Collaborators:

Finnish Game and Fisheries Research, J. Ruuhijärvi, P. Vuorinen, FI

Timetable:

2000-2003

Responsible scientists:

Ritva Saxén, Olli Taskinen, Aino Rantavaara

Radionuclides in sludge in waterworks and wastewater treatment plants

Objectives:

Radionuclides are transported via different routes from nuclear power stations to the communal water works and wastewater treatment plants situated near the power plants. The purpose of this study is to determine the amounts of radionuclides in sewage sludge and to obtain information on the transport routes of the radionuclides from the nuclear power plants to the water works and waste treatment plants, via air discharges or via other routes.

In addition to radionuclides derived from nuclear power plants the existence and concentrations of natural radionuclides will also be studied in the sludge of waterworks and wastewater treatment plants. Radiation doses for the staff of treatment plants will be estimated using these results.

Description of the work:

Data on radionuclide discharges reported by the power plant will be collected and temporal variation analysed. The composition and amounts of the radionuclides discharged as well as temporal behaviour will be compared with the composition, amounts and temporal behaviour of radionuclides in the sludge samples taken in the municipal wastewater treatment plant at Loviisa. The period of the study consists of the results for the years 1998 and 1999. The radionuclides in the sludge samples have been measured gamma spectrometrically. The spectra will be reanalysed for the concentrations and amounts of natural radionuclides in the sludge samples.

Exploitation of results:

Using these results the transport routes of radionuclides from the nuclear power plant to the wastewater treatment plant can be estimated. Investigation of natural radioactive materials provides more information about the radiation doses received by the staff of treatment plants.

Publication plan:

The project will finish in 2000. The results will be published after the analyses are completed.

Responsible scientist:

Marketta Puhakainen

Amounts of ^{137}Cs and ^{90}Sr discharged by river runoff from Finland into the Baltic Sea

Objectives:

Determinations of long-lived radionuclides, ^{137}Cs and ^{90}Sr , in Finnish river waters together with information on water discharges to various areas of the Baltic Sea give an opportunity to estimate the amounts of these nuclides removed by the rivers from Finland. It is known that these two nuclides be-

have in a different way in the environment. ^{137}Cs is removed from water quickly after deposition and sinks to the bottom, while ^{90}Sr stays more in the water phase. The amount of ^{137}Cs deposited in 1986 was remarkably higher than the amount of ^{90}Sr . This study shows how much the different behaviour of these nuclides alters this ratio in water flowing out to the sea. In addition to the amounts of total discharges, temporal changes in the amounts of these nuclides removed by various rivers will be studied. The roles of various large rivers as carriers of the nuclides will be discussed. The amounts transferred after the Chernobyl accident are compared with the respective amounts in the fallout period of nuclear weapon tests.

Description of the work:

Estimations are based on the results of radionuclide analyses of river waters and other surface waters carried out regularly at STUK since 1986. The water discharges needed for the calculations are obtained from publications of the Finnish Environment Institute.

Exploitation of results:

Results improve knowledge of the radioactive contamination of the Baltic Sea and give comparisons between amounts of radionuclides from various sources e.g. from discharges by nuclear power stations. River discharges during the nuclear weapon test period and after the Chernobyl deposition show the effects of these two different types of depositions on radionuclide transfer by rivers.

Publication plan:

A report on the discharged amounts of ^{137}Cs and ^{90}Sr will be published in scientific publication in 2000.

Timetable:

2000

Responsible scientists:

Ritva Saxén, Erkki Ilus

3.1.3 Baltic and Nordic Sea

Study of coastal ecosystems in the environs of Finnish nuclear power plants

Objectives:

Radiation monitoring in the environs of Finnish nuclear power plants, which are carried out by the NPP Environmental Laboratory of STUK as a consultant service ordered by the power companies, requires not only implementation of the permanent monitoring programmes, but also more profound study projects which focus on different sectors of the surveillance. The aim of these projects is to ensure that the conclusions based on the results of the monitoring programmes are correct. At the same time they aim to develop the dose calculation models used in the monitoring programmes.

Description of the work:

In addition to natural radioactive substances and certain long-lived radionuclides originating from the Chernobyl accident and the global weapons tests fallout, radioactive substances originating from the discharges of local nuclear power plants are also regularly detected in the samples taken in the marine environs of the plants (e.g. Co-60, Co-58, Mn-54 and Ag-110m). In 1988-1989 a preliminary study was carried out in the discharge area (Hästholmsfjärden bay) of the Loviisa power plant. The aim was to obtain representative samples of all such organisms of the local marine ecosystem, which were characteristic of the area and could be sufficiently collected with a reasonable workload. In addition, the internal organs and reproductive products of fish and water birds were sampled.

The results showed that the concentration on radiocaesium increased when moving towards the top consumers. However, local discharge nuclides were principally detected only in the samples representing the lowest levels of the food web, such as phytoplankton and zooplankton, macro algae, other aquatic plants and benthos. In spite of the interest of the results, they were not properly published owing to the insufficient data.

The study focusing on the different levels of the food web will be continued in the discharge areas of cooling water at the Loviisa and Olkiluoto nuclear power plants. In 2000 a project will be arranged in Hästholmsfjärden at Loviisa, in which *complementary samples* are taken from phytoplankton, zooplankton, macro algae, other aquatic plants, benthic animals, the internal

organs of fish, water birds, their internal organs and eggs. The estimated number of samples is 30-40. In 2001 a similar project will be arranged in Olkiluoto.

Exploitation of results:

The study yields new data on the occurrence, transport and concentrations of radionuclides in the environs of the Finnish nuclear power plants. The results are exploited in developing and revision of the environmental monitoring programmes. Furthermore, the results can be exploited in the "FASSET" EC project.

Publication plan:

The results will be published in STUK resport series in 2002-2003.

Timetable:

At Loviisa in 2000, at Olkiluoto in 2001.

Responsible scientists:

Erkki Ilus, Jukka Mattila, Seppo Klemola, Tarja K. Ikäheimonen

Radiation surveillance and studies in the Baltic Sea

Objectives:

All of the Baltic Sea countries have ratified the Helsinki Convention, the Convention on the Protection of the Marine Environment of the Baltic Sea Area. The Helsinki Commission (HELCOM) co-ordinates the international co-operation, which focus on the implementation of the Convention. The objective of this project is to fulfil Finland's responsibility in the international HELCOM/MORS (Monitoring of Radioactive Substances) co-operation.

Description of the work:

Radiation surveillance in the Baltic Sea is carried out to the extent defined as Finland's contribution to the HELCOM monitoring programme of radioactive substances. The Finnish proportion consists of about 120 samples and radionuclide analysis from seawater, bottom sediments, fish and other biota. STUK maintains the HELCOM/MORS Discharge Register, in which the Contracting Parties report discharge data from all the nuclear facilities operat-

ing in the Baltic Sea area. This part is performed as a consultant service to the HELCOM.

The international HELCOM/MORS Project Group, which includes representatives from all the Contracting Parties meets by turns in each Baltic Sea country. In 2000 the annual meeting will be held in Poland. The Group is preparing a joint report on Radioactivity in the Baltic Sea in 1992-1998. Specialists from the NPP Environmental Laboratory have been nominated Convenors of the Chapters "Sediments" and "Quality assurance". In addition, STUK is responsible for publishing the results of the sediment sampling intercomparison arranged by the Group.

Exploitation of results:

The study yields data on the occurrence, transport and concentrations of radionuclides in the Baltic Sea. The results are exploited in preparation of joint evaluation reports of the HELCOM/MORS Group at regular intervals.

Publication plan:

Finnish results are published separately in the STUK-A report series. The results are reported annually to the HELCOM/MORS database.

Collaborators:

Risø National Laboratory, S.P. Nielsen, DK; National Institute of Radiation Hygiene, M. Oehlenschlaeger, DK; Estonian Radiation Protection Centre, E. Jakobson, EN; European Commission G. Hunter; Federal Maritime and Hydrographic Agency, J. Herrmann, D; Federal Research Centre for Fisheries, G. Kanisch, D; Ministry of Environmental Protection and Regional Development of Latvia, A. Skujina LG; Joint Research Centre, R. Petrosius, LH; Central Laboratory for Radiological Protection, M. Suplinska, PL; Central Laboratory for Radiological Protection, D.Grzybowska, PL; Institute of Meteorology and Water Management, J. Tomczak, PL; V.G. Khlopin Radium Institute, V. Tishkov, RS; Swedish Radiation Protection Institute, M. Luning, S; International Atomic Energy Agency; S. Mulsow; Finnish Environment Institute, P. Kotilainen, FI.

Timetable:

A continuous program.

Responsible scientists:

Erkki Ilus, Tarja K. Ikäheimonen, Vesa-Pekka Vartti, Jukka Mattila

Radioactive tracers in Nordic sea areas (NKS/BOK-2.2)

Objectives:

NKS (Nordic Nuclear Safety Research) Marine Radioecology project in 1998-2001 is focusing on radioactive tracers in Nordic Sea areas. It is divided into two sections: a) Use of Tc-99 as a tracer for transport of contaminated water masses from the Irish Sea to Nordic waters, including the Baltic Sea, b) Use of radioactive tracers in studies of radionuclide processes and transport in the Baltic Sea, in its catchment and adjacent areas. The main interest of STUK is in the Baltic Sea, but it also takes part in the Tc-99 survey conducted in all the Nordic Sea areas. For this purpose, bladder-wrack (*Fucus vesiculosus*) samples were taken at 26 stations along the Finnish coast in the summer of 1999.

The aim of the Baltic Sea project is to present an overall view of radionuclide processes in the Baltic Sea and adjacent areas. The main emphasis is on the use of long-lived radionuclides Cs-137 and Sr-90 as tracers for the flow of contaminated water masses into, in and out of the Baltic Sea, its sub-areas (e.g. the Gulf of Finland and the Gulf of Bothnia) and the adjacent areas (e.g. along the Norwegian west coast). The role of sedimentation in the loss of long-lived radionuclides from the water column is also considered, as well as determining residence times for these radionuclides in the Baltic Sea and in its drainage areas.

Description of the work:

Most of the work will be done using data already available. However, the sedimentation study still requires still some additional field and laboratory work. Discharges of Cs-137 and Sr-90 by Finnish rivers into the Baltic Sea are evaluated (see the project plan below, Amounts of ¹³⁷Cs and ⁹⁰Sr discharged by river runoff from Finland into the Baltic Sea). An extensive, unpublished set of sediment data collected by STUK in the 1960s and 1970s is intended to be analysed and published during the project period.

Exploitation of results:

The results provide new data on the usability of radioactive substances as tracers when monitoring 1) the flow of water masses and 2) the processes in water and sediments in the Baltic Sea and adjacent areas. The results can be

exploited in developing transport and dose calculation models for the Baltic Sea.

Publication plan:

The results will be published in 2000-2001.

Collaborators:

Geislavarnir Ríkisins, S. E. Pálsson, IC; University of Faroe Islands, H. P. Joensen, Faroe Islands; Institute of Marine Research, S.A. Malmberg, Iceland; NLH, D. Oughton, N; NRPA, T. Kolstad, N; IFE, G. C. Chrinstensen, N; IMR, L. Føyn, Norway; University of Lund, E. Holm, S; University of Uppsala, M. Meili, S.

Responsible scientists:

Erkki Ilus, Jukka Mattila, Tarja K. Ikäheimonen, Vesa-Pekka Vartti

Sedimentation, transport and fate of organic pollutants in the Gulf of Finland/sediment timing by radioactivity measurements

Objectives:

The transport, sedimentation and fate of organic pollutants, such as DDT, PCBs, PCDD/Fs, in the Gulf of Finland are poorly known. The aim of the project is 1) to clarify the temporal fluctuation and load of organohalogen compounds in different study areas in the Gulf of Finland, 2) to study the migration of these compounds from the estuaries of the Rivers Kymijoki and Neva to the open sea, 3) to find possible "missing sources of PCDD/Fs", 4) to clarify the natural background level and origin of PCDD/Fs in the old sediments, 5) to clarify the effects of organohalogen compounds on microbial organisms at the lowest level of the food chains.

Description of the work:

The allocated task of the STUK is the dating of sediments with methods based on depth profiles of radionuclides in sediments.

Exploitation of results:

The results increase knowledge on the occurrence, transport and effects of organic pollutants in Finnish coastal areas. The target for the dating of sediments is to set the discharges of pollutants from different sources on a correct time-scale.

Publication plan:

To be submitted to a scientific journal.

Collaborators:

The National Public Health Institute, the Finnish Institute of Marine Research, the Finnish Environment Institute and the Geological Survey of Finland. The principal investigator is Terttu Vartiainen from the National Public Health Institute,FI.

Timetable:

The results will be published in 2000-2001.

Responsible scientists:

Jukka Mattila, Erkki Ilus

The history of cyanobacterial blooms in the Baltic Sea: A multi-disciplinary study/sediment timing by radioactivity measurements

Objectives:

The aim of the study is to provide a systematic, historical overview of the occurrence and intensity of cyanobacterial blooms in the Baltic Sea over the last centuries. The study will utilise all available information, consisting of early historical notes and navigation logbooks from the Baltic Sea area, as well as phytoplankton records published since the late 19th century. Additionally, paleolimnological studies of the pigment composition in the Baltic Sea sediments will be made.

Description of the work:

The allocated task of STUK is the dating of sediments with methods based on depth profiles of radionuclides in sediments. The sediment cores to be dated are chosen on the basis of the pigment determinations made by the Finnish Institute of Marine Research. The duration of the project is 1999-2001.

Exploitation of results:

The results provide data on the state of the Baltic Sea and the eventual occurrence of cyanobacterial blooms from the time before the increased load of nutrients during recent decades. The target for the dating of sediments is to

set the eventual markers of past cyanobacterial blooms in the sediments on a correct time-scale.

Publication plan:

To be submitted to a scientific journal.

Collaborators:

The University of Helsinki, the Department of Economic and Social History, the University of Uppsala, the Department of Botany, the Finnish Institute of Marine Research. The principal investigator is Dr. Kaisa Kononen from the Maj and Tor Nessling Foundation.

Timetable:

The results will be published in 2000-2002.

Responsible scientists:

Jukka Mattila, Erkki Ilus

3.1.4 Arctic and subarctic regions

Radioecological assessment of the consequences of radioactive contamination of Arctic marine areas (ARCTICMAR)

Objectives:

The operational area of STUK's Regional Laboratory in Northern Finland is the northern half of Finland, comprising the two northernmost provinces of Lapland and Oulu. The goal of the Laboratory's research is to study the transport and accumulation of radionuclides in Arctic and sub-Arctic food chains, and in locally produced foodstuffs. Since 1993 the radioecological research has been expanded to the Arctic Sea areas and the shores of NW Russia.

The aim of the ARCTICMAR Project is to integrate current knowledge (AMAP, ARMARA) and the new information obtained from model-oriented experimental work in order to further develop a model which predicts the behaviour and fate of radionuclides in estuarine and marine environments. This also includes modelling the transfer of radionuclides to biota.

Description of the work:

ARCTICMAR is a joint project being carried out by four countries: Norway (co-ordination), Russia, Ireland and Finland, within the framework of the EC INCO-Copernicus programme. The project period is 1998-2001.

STUK is mainly exploiting the extensive sample material collected during scientific expeditions with the Murmansk Marine Biological Institute during 1993 – 1996 in the Russian Arctic Seas and stored in STUK's sample bank in Rovaniemi. Determination of plutonium concentrations and isotope ratios in sediment samples from the Kola Bay, and in quantitative surface vegetation and soil samples from the Russian Arctic coast and islands, is being continued. The aim is to identify the origin of plutonium particles in the Kola Bay. The particle-distribution results will also be useful in the modelling work being carried out on the Kola Bay. These results, as well as $^{238}\text{Pu}/^{239,240}\text{Pu}$ and $^{137}\text{Cs}/^{239,240}\text{Pu}$ ratios from four islands in the archipelago of Franz Joseph Land and from Svalbard, indicate that global fallout is the main terrestrial source of plutonium.

Research on gamma nuclide, ^{90}Sr and plutonium isotope concentrations in biota will be continued by analysing new samples of seals from the Baltic and Norwegian seas, and of Baltic and Arctic salmon. ^{137}Cs concentrations are 100 times higher in Baltic Sea biota than in Arctic species. The new results will be stored in the GIS database of the previous ARMARA project, and the bioconcentration factors calculated.

Exploitation of results:

The new and earlier results stored in STUK's database will improve in the Arctic marine environment modelling.

Publication plan:

Joint publications with the ARMARA and ARCTICMAR partners according to the plan of the EC project.

Collaborators:

Norwegian Radiation Protection Authority, Mikhail Iosjpe, P. Strand, J. Brown, N; Agricultural University of Norway, B. Salbu, N, Roshydromet, Federal Service of Russia for Hydrometeorology and Environmental monitoring, Y. S.Tsaturov, RS; Scientific Production Association "Typhoon", Federal Service of Russia for Hydrometeorology and Environmental monitoring, M. Kolomeev, RS; Regional Center "Monitoring of Arctic", Federal Service of Russia for Hydrometeorology and Environmental monitoring, S.

A. Melnikov, RS; Scientific Production Association "Typhoon", Federal Service of Russia for Hydrometeorology and Environmental monitoring, A. I. Nikitin, RS; University College Dublin, Department of Experimental Physics, P. Mitchell, IRL.

Timetable:

2000-2002

Responsible scientist:

Kristina Rissanen, Tarja K Ikäheimonen, Jarkko Ylipieti, Marko Junntila

Arctic Monitoring and Assessment Programme, Phase II - Trends and Effects Programme (AMAP)

Objectives:

The Ministers of 8 Arctic countries adopted the Arctic Environmental Protection Strategy AEPS at a meeting in Rovaniemi in 1991. AMAP was requested to examine the levels of anthropogenic pollutants from all sources, and to assess their effects on all relevant compartments of the Arctic environment. The implemented monitoring programme and assessments were documented in the report: *AMAP Assessment Report: Arctic pollution issues*. In 1997, AESP and all its individual programmes, including AMAP, were reorganised under the newly established Arctic Council (AC).

One of the key pollutants in the AMAP programme is radioactivity. Chapter 8 of the *Assessment report* covers all the data available in 1997 on past and present contamination of the Arctic, source-related assessment of past and present releases and potential releases, including a spatial analysis of the vulnerability of Arctic ecosystems

The Radioactivity expert group has decided to validate the previous Radioactivity Report, to include new information from Alaska and Canada, and to rewrite the radioactivity section of the Arctic Monitoring Programme. Phase II of AMAP is concentrating on an assessment of the possible consequences of potential major radiation accidents, or releases, in the terrestrial or aquatic environment. Environmental impact assessment, as part of the implementation of actions, is also essential for well-developed action plans (e.g. Arctic Council Action Plans ACAP). In order to fill some of the gaps, the tasks of the Radioactivity expert group are to obtain, in co-operation with

the Human Health group, more data about food consumption in the Arctic, and to study vulnerability aspects.

Description of the work:

Phase II of the Finnish AMAP work, Trends and Effect Programme, 1998 – 2003, is based on ongoing National Implementation Plans (NIPs). STUK is responsible for the radioactivity data in the Finnish NIP:

- continuous monitoring of external radiation and the analysis of aerosol and precipitation samples
- analysis of radioactivity concentrations in samples from the same areas where the other Finnish participants are analysing POPs, heavy metals, acidity etc. The monitoring is being performed in the terrestrial environment (permanent lichen and vascular plant sampling plots, reindeer, ptarmigan, wild mushrooms, milk), in the fresh water environment (surface water, lake and river fish), and in the marine environment (Arctic and Baltic Sea salmon).
- whole body counting of the Sami reindeer herders, including food consumption data

Exploitation of results:

Long term data series are the basic prerequisite in studying changes and trends in radioactivity levels in our Arctic environment. Owing to the overgrazing of the lichen fields, the accumulation and transport of radioactivity in the most important foodchain, lichen – reindeer – man, is today not the same as it was in the 1960's. The models, as well as the vulnerability aspects presented in phase I of the AMAP report, will have to be re-evaluated.

Publication plan:

New AMAP Radioactivity report and Arctic monitoring programme in 2002.

Collaborators:

Norwegian Radiation Protection Authority, P. Strand, N; Norwegian Radiation Protection Authority, T. Bergan, N; Risø National Laboratory, H. Dahlggaard, DK; FOA, National Defence Research Establishment, R. Bergman, S; Islandic Radiation Protection Institute, S. Magnusson, IC; Roshydromet, Federal Service of Russia for Hydrometeorology and Environmental monitoring, Y. S. Tsaturov, RS; Institute of Radiation Hygiene, M. I. Balonov, RS; at present in IAEA; M.J. Bowers, CA; US Department of Energy, V. J. McClelland, US; US Department of Energy, A. Heinrich, US; University of

California, D. Layton, Lawrence Livermore Laboratory, US; Alaska Department of Environmental Conservation, D. Dasher, US; U.S. Arctic Research Commission, L. D. Perrigon, US; Institute of Terrestrial Ecology, B. Howard, Radioecology Section, UK; SEPA Scottish Environment Protection Agency, G. Hunter, UK, **at present in DG 11 C 1, Luxembourg**; European Commission DG 11 Environment, Bruxelles, L. Cecille, B; O. Mähönen, Lapland Regional Environment Centre, FI.

Timetable:

1999-2002

Responsible scientists:

Kristina Rissanen, Jarkko Ylipieti, Tua Rahola

The Thule sediments

Objectives:

In January 1968, a US B52-bomber carrying 4 nuclear weapons caught fire and crashed on the ice in Bylot Sound off the Thule Air Base in N.W. Greenland. The aeroplane and the nuclear weapons were totally destroyed in the subsequent explosive fire. Part of the weapons' plutonium was scattered over some square kilometres of the ice. The heat of the fire melted a wreck-sized hole in the ice, but it was immediately covered by ice again in the -40°C frost.

During the following months a very extensive cleaning campaign was organized in the area and significant amounts of contaminated ice and the residues of the wreck were shipped back to the US. The underlying sediments (water depth about 200m) received, however, a fraction of the weapons' plutonium either through the hole in the ice or when the ice melted the following summer. Based on the previous surveys (1968, 1970, 1974, 1979, 1984, 1991) it has been estimated that the pollution remaining in the seabed in Bylot Sound as a consequence of the accident amounts to approximately 1.4 TBq (~0.5 kg) plutonium-239,240, 0.025 TBq plutonium-238, 4.6 TBq plutonium-241 and 0.07 TBq americium-241.

The aim of this study was to continue the monitoring at the accident site and to check and correct the earlier picture of the distribution pattern, total inventory and behaviour of plutonium in the sea area off Thule.

Description of the work:

In August-September 1997 a new expedition financed by Danish Co-operation for the Environment in the Arctic was directed to the site of the Thule accident. Dr. Henning Dahlgard from Risø National Laboratory, Denmark, convened an international team of scientists, and he was the chief scientist on the cruise. STUK was invited to take care of sediment samplings with a Finnish Gemini Twin Corer on board the RV Adolf Jensen. In total about 1000 samples were taken. STUK has received about 100 sediment samples (freeze-dried by the Risø Laboratory) for analysis.

The samples will be analysed for α and β nuclides of plutonium (Pu-238, Pu-239,240, Pu-241). The samples are also checked by means of gamma spectrometry with the object of searching for fractions with "hot" plutonium particles. The particles will then be separated and their activity, size and composition will be analysed (project description below).

Exploitation of results:

The results provide new data on the distribution, inventory and behaviour of plutonium in an Arctic marine environment. In Denmark the results are used in public debate on the alleged health consequences of the accident for the genuine Inuit population.

Collaborators:

Risø National Laboratory, H. Dahlgard and S.P. Nielsen, DK; Radiological Protection Institute of Ireland, T.P. Ryan, IRE, University College Dublin, C.A. McMahon, IRE, Lund University Hospital, M. Eriksson, S.

Publication plan:

The results will be published in 2001.

Timetable:

Analyses in 2000

Responsible scientists:

Erkki Ilus, Tarja K. Ikäheimonen, Seppo Klemola

3.1.5 Methodology and measurement techniques

Analysis of fission-bomb particles detected in marine sediments in Thule

Objectives:

A US B52 bomber carrying four nuclear bombs crashed on the ice near Thule air base, Greenland, in 1968, resulting in the dispersion of radioactive particles into the environment. Individual bomb particles will be separated from marine sediment samples. Characteristics of the particles will be analysed thoroughly. The overall objective of the present particle analysis is to investigate methods to be used e.g. in environmental surveillance of radioactive materials or in safeguard applications.

Description of the work:

Particles will be separated from sediment samples using gamma-ray spectroscopy and autoradiography. The particles will be visualised by a scanning-electron microscope. The isotopic ratio of Pu and U will be investigated by alpha analysis and mass spectrometry.

Exploitation of results:

The operation, structure and characteristics of nuclear bombs may be estimated on the basis of particle characteristics. In general, particle analyses lead to better understanding of the behaviour of radioactive material in the environment and, consequently, may help us to estimate possible radiation hazards.

Publication plan:

The results will be published in high-quality international journals and at conferences in 2000.

Collaborators:

The Technical Research Centre of Finland, Chemical Technology, R. Zilliacus and the University of Helsinki, Electron Microscopy, J. Juhanoja, FI.

Timetable:

2000

Responsible scientists:

Mikael Moring, Erkki Ilus

Determination of several alpha and beta emitting radionuclides from one sample

Objectives:

In emergency situations or analytical studies the quantity of a sample may be so small that it is not possible to divide it for several determinations. If it is possible to separate different elements from one sample by chemical separations, even a small quantity of a sample may be sufficient. By fractionating a sample it is possible to speed up obtaining the results and to reduce the time used for analysis. With this technique it is also possible to examine several nuclides from particles, which are always unique.

The aim of this project is to test and give guidance for a method with which it is possible to separate chemically from one sample strontium, plutonium and americium (+curium), as well as thorium, technetium and nickel if needed. Thereafter it is possible to analyse separately the existing alpha and beta isotopes. The aim is to develop two applications for the method: a fast method for emergency situations and a method for detecting very low activity concentrations.

Description of the work:

Already existing sample material is used in the project. The discharge samples from nuclear power plants and the sediment samples taken from the site of the Thule accident are especially usable. The aim is to initiate the developing of an analysis method for nickel-63 based on Quantulus measurements by using discharge samples from nuclear power plants. In the sediment samples from Thule there are plenty of "hot particles", which it is furthermore attempted to separate for analysis.

Exploitation of results:

In the future the method to be developed can be used in eventual emergency situations and in cases when there is only a small quantity of some unique sample material available.

Publication plan:

The results will be published in STUK report series.

Responsible scientists:

Tarja K. Ikäheimonen, Vesa-Pekka Vartti

Optimising the size of environmental samples*Objectives:*

There is a general practice of taking large quantities of sample material for radioecological studies to be able to detect even small concentrations of radionuclides. It is obvious, however, that the sampling routines have often led to unnecessary large quantities of samples, which are causing significant losses of working time and costs both in sampling and in pre-treatment of the samples.

Thanks to the development of analysis methods and instruments the required sensitivity of radionuclide analyses can today be reached either by shorter measuring times or by smaller samples. If the measuring time gets shorter it is possible to measure more samples in the same time by using one spectrometer. By reducing the sample volumes it is possible significantly to save working time both in sampling and in pre-treatment of the samples. Effective use of the more versatile instrument arsenal implies careful control of the sample flow so that a proper detector is used for the proper purpose.

The aim of the project is to fix optimal quantities for different types of the samples, so that they are sufficient for the analyses, but large enough bearing in mind the requirements set for the representativeness of the samples. In addition, optimal measuring times for different sample types in different circumstances will be determined.

Description of the work:

Samples are not taken especially for this project, but results of typical samples taken for NPP environmental surveillance or radioecological study purposes will be used as study material. The optimal sample quantities are determined on the basis of expected nuclide specific detection limits and measuring uncertainties, taking into account the necessary measuring times with different spectrometers. By planning the sample quantities and measuring times the measurements can be allocated so that the time available for

the day (=8-hour) measurements can also be exploited with all the detectors as effectively as possible.

Exploitation of results:

The results are used in updating the Guidelines of the NPP Environmental Laboratory (possibly also of the other laboratories) for sampling and pre-treatment of the samples and in updating and developing the Guide 6.2.1 in the Gamma Handbook (Guidelines for choosing detectors and measuring times) of the NPP Environmental Laboratory.

Publication plan:

The results will be published.

Timetable:

The duration of the project is 2000-2001.

Responsible scientists:

Seppo Klemola, Tarja K. Ikäheimonen, Erkki Ilus

3.2 Internal exposure to man-made radioactivity

Foodstuffs research

Objectives:

- Determining parameters needed for modelling in agricultural and terrestrial environments.
- Prediction of internal dose due to ingestion of foodstuffs.
- Determining the transfer factors of cereal grains for different soil types and cereal types.
- In forest research, acquiring information about the present radiation situation and follow-up of changes during long-term intervals.

Description of the work:

Sampling of main foodstuffs. Representative sampling in forests taking the regional differences into consideration. Long-term transfer factors of caesium and strontium are calculated for cereal grains in Finland including different types of grains and soils.

Exploitation of results:

The results are used to determine transfer parameters needed in modelling and to calculate internal radiation dose due to ingestion. Follow-up of long-term changes in radioactivity of foodstuffs. Public information.

Publication plan:

The results will be published in STUK report series.

Timetable:

Measuring of samples (main foodstuffs) continues. The transfer factors for cereal grains are to be determined in 2000 and reported at the beginning of 2001.

Responsible scientists:

Eila Kostiainen, Aino Rantavaara, Ritva Saxén

¹⁴C in foodstuffs

Objectives:

In 1999 a method for determination of ¹⁴C in foodstuffs was tested at STUK. The objective was to test whether using a rather simple tube furnace system to produce CO₂ from a foodstuff sample combined with the use of a liquid scintillation spectrometer, Quantulus, makes it possible to determine existing levels of ¹⁴C in Finnish foodstuffs. The tests showed that the method is sensitive enough. As a continuation to this testing of ashing and counting methods temporal changes of ¹⁴C in some foodstuffs will be determined starting from the nuclear weapon test period up till the present. Radiation doses caused by ¹⁴C will be estimated.

Description of the work:

Samples for the analyses are chosen from foodstuff sample material available at STUK, both from the nuclear weapon test period and from the period after the Chernobyl accident. Analyses will be carried out using the ashing method tested.

Exploitation of results:

The project improves the preparedness for emergency situations, because in some cases this kind of determination may be of importance.

Publication plan:

The results will be submitted for publication in a scientific report series.

Timetable:

2000 - 2001

Responsible scientist:

Ritva Saxén

¹³⁷Cs content and internal radiation doses to the population

Objectives:

The objectives are to study the changes in internal radiation doses for the population and especially for population groups receiving more ¹³⁷Cs from the diet than the population in general. Such a diet includes much fresh water fish, wild mushrooms and wild berries from the areas with high ¹³⁷Cs deposition and in the reindeer-herding area, reindeer meat. By annually performed measurements of the population groups the changes in amounts of ¹³⁷Cs are monitored.

Description of the work:

Of the special groups, the groups from Padasjoki and Viitasaari will be measured with the mobile whole-body counter in 2000. The group from Padasjoki represents a population consuming fresh water fish caught in small lakes in a region of high fallout, and the Viitasaari group consumes much fresh water fish and other products of wild origin. The groups will be measured twice in the year 2000. The study will end in 2001.

Exploitation of results:

The results are used for the estimation of radiation doses from cesium. The results also give information on the highest radiation doses to Finns due to Chernobyl.

Publication plan:

The results of the study will be presented at international meetings and in 2001 a publication in a international journal will be prepared.

Responsible scientists:

Tua Rahola, Sauli Pusa, Eero Illukka, Matti Suomela

Development of dietary surveillance

Objectives:

Methods of dietary surveillance are considered to find appropriate ways to carry out continuous ingestion dose monitoring. The impact of regional factors or different types of diets is assessed in planning the monitoring. The introductory information will be used in preparing an EC project proposal to establish and promote a coherent approach in ingestion dose monitoring.

Description of the work:

Facts needed for planning dietary surveillance are worked out; e.g. the need for monitoring main foodstuffs and other factors substantially contributing to the ingestion dose. Sampling programmes for detecting regional differences and for devising a model diet are planned.

Exploitation of results:

Information is used in developing dietary surveillance.

Timetable:

Regional differences and the basis for a model programme of dietary surveillance will be reported at the beginning of 2001.

Responsible scientists:

Eila Kostiaainen, Ritva Saxén, Olli Taskinen

The dependence of the biological half-life of cesium on age

Objectives:

The possible changes of the biological excretion rate of cesium with age or other body parameters will be studied. The biological half-lives of the persons studied were previously determined earlier about 30 years ago. The information is important when estimating radiation doses.

Description of the work:

So far four of these persons studied earlier have taken part. In 2000 we hope that one or two volunteers more will take part. A known amount of cesium solution will be administered to the persons studied. The study requires many whole-body counting measurements during 12 months to determine the long component of the retention function also. The study also includes excretion measurements. With these the excretion rate will be determined. The amount of cesium administered will be big enough so that the cesium intake via food will not affect the measurement results. The results of the measurements of the STUK reference group can if needed be used for eliminating any possible influence on the results. In connection with this study the amount of cesium excreted in urine will also be determined.

The measurements will be finished during 2000 but the schedule depends on the possibilities of volunteers taking part.

Exploitation of results:

The results will be used for estimating the influence of biological half-life on the radiation doses received by Finns.

Publication plan:

The results will be published after the study is finished at an international conference or in a journal.

Responsible scientists:

Tua Rahola, Sauli Pusa, Tarja Heikkinen

Indirect methods of analyses for internal contamination and estimated doses*Objectives:*

The objective is to estimate the amounts of radioactive materials in the body and the doses from these materials by analysing the activities of radionuclides in urine samples. For this purpose the following studies will be performed:

- a) Estimation of the amounts of ^3H and ^{90}Sr in a selected group of people by analysing urine samples.
- b) Investigation of published analysing methods for actinides. The purpose is to provide for determination of radiation doses potentially caused by actinide contamination.
- c) Development of analysing methods of ^{210}Pb in urine. The aim is to participate in a project in which indirect methods of analyses will be developed for the estimation of doses caused by radon and its progeny in water from drilled wells and later also the estimation of doses from radon in indoor air.

Description of the work:

Urine samples for ^3H and ^{90}Sr analysis will be collected from groups of people participating in different whole-body counting studies and samples for ^{210}Pb analysis from people consuming water from drilled wells with high radon concentrations. As a consequence of the relatively poor effectiveness of the methods and the low concentrations in urine, pooled samples collected over a period of several days may be needed.

Exploitation of results:

The results of ^3H and ^{90}Sr analyses are used for checking the possibility of using the tested methods for the estimation of radiation doses. The analytical method of ^{210}Pb in urine will be developed for routine use.

Publication plan:

The results of ^{90}Sr investigations of a few persons have already been presented at an international meeting. The results of ^3H and ^{90}Sr analyses will be collected in a report. The date and forum for publication will be chosen when the results are available. An internal report will be produced on the methods for analysing actinides.

Timetable:

2000 - 2002.

Responsible scientists:

Marketta Puhakainen, Tarja Heikkinen

The Nordic (NKS) projects on assessment of internal doses

Objectives:

The aim of the projects is to develop the methods of measurement for internal contamination and give instructions for calculations of internal radiation doses. The target group in the Nordic countries includes persons responsible for internal contamination surveillance and dose assessment among the authorities and in research and industrial institutes.

Description of the work:

The following subprojects will be undertaken in 2000:

a) The efficiency calibration of thyroid measurement systems will be continued using a thyroid phantom. Among the participants in the project a survey of existing, simple instruments suitable for thyroid measurements and the state of calibration of these instruments will be performed. In 2000 short manuals will be prepared with instructions for performing thyroid and whole-body measurements in emergency situations.

b) Radiation doses will be calculated based on the results of activity measurements of foodstuffs and on consumption rates. These doses will be compared with the doses estimated based on whole-body counting measurements. The reasons for possible differences will be investigated. Finland takes part in this study with the group from Padasjoki. The dietary interviews and the consumption estimates will be done by a consultant.

c) To improve quality assurance in the Nordic countries, whole-body inter-comparison measurements will be continued. For the phantom owned by the radiation protection institutes rods labelled with new nuclides were purchased.

These subprojects will be carried out as planned for all the Nordic countries.

Exploitation of results:

The reports on the results are valuable for the persons and institutes responsible for determination of internal contamination and radiation doses. The reliability of the measurements and dose calculations will be improved and comparisons made possible. The reports produced will also be of use in emergency situations.

Publication plan:

The results will be reported following a separately determined schedule. The reports of all the subprojects will be started in 2000 and finished in 2001.

Collaborators:

SSI, R. Falk, S; NRPA, L. Skuterud, N.

Timetable:

2000 - 2001

Responsible scientists:

Tua Rahola, Sauli Pusa

Radiation doses to the population from depositions of nuclear weapon tests and the Chernobyl accident (NKS-BOK-2.1.1.a)*Objectives:*

Earlier joint Nordic Nuclear Safety Research (NKS) projects in terrestrial radioecology have dealt with the effects of the accident at Chernobyl (1986) and long half-lives of radionuclides in the environment. These projects have given a relatively good picture of the impact of the Chernobyl deposition on the Nordic countries. A respective analysis of data on the effects of the deposition from nuclear weapon tests has not been carried out for the whole area of northern Europe.

In this project the long-term human radiation doses for Nordic people are assessed, including the nuclear weapon test period and the period after the accident at Chernobyl. Each Nordic country will make its own estimations based on the contents of radionuclides determined in basic foodstuffs (milk, grain, and meat). Freshwater fish have caused a significant contribution to the ingestion dose after the Chernobyl accident; therefore fish are included in this study. Mathematical modelling will be used to complete the assessment, which is not entirely based on surveillance data. As far as possible, the doses through the main pathways will be estimated for ^{137}Cs , ^{90}Sr and ^{131}I .

Description of the work:

In Finland, determinations of radionuclides in deposition and in basic foodstuffs are available from the 1960s and later. The radionuclides studied are

^{137}Cs , ^{90}Sr and, to a minor extent, ^{131}I . The data for ^{90}Sr and ^{137}Cs in deposition, milk, grain and meat, collected from various sub-regions of the main production area are available for the assessments. Fish from various lakes or fishing areas have been surveyed and the countrywide averages calculated earlier. Reindeer meat important for Northern Finland will be covered based on information since 1960. Models such as UNSCEAR, DETRA and RODOS, available at STUK, will be used. The main part of the work will be done in 2000-2001.

Exploitation of results :

Long-term reviews are useful for information packages to be applied as background information in radiation emergencies. Further, the results will facilitate improvement of long-term environmental modelling. The Nordic final report will be written in a style convenient for utilisation in emergency preparedness training and in public information.

Publication plan:

Reporting follows the schedule of the co-operative Nordic project. The main findings will be made available to the Finnish interest groups as a brochure or equivalent. The results will be published in the NKS publication series.

Collaborators:

Risö National Laboratory, S.-P. Nielsen, DK; Icelandic Radiation Protection Institute, S. E. Palsson, IC; Norwegian Radiation Protection Authority, NRPA, P. Strand, N.

Timetable:

2000- 2001

Responsible scientists:

Aino Rantavaara, Ritva Saxén, Kristina Rissanen

Optimisation of monitoring for internal exposure (OMINEX)

Objectives:

A worker in the nuclear industry may receive radiation doses either from external exposure or from internal exposure (eg from inhaled radionuclides). The costs of monitoring and control of internal exposure in the workplace are usually significantly greater than the equivalent costs for external exposures, and there is therefore a need to ensure that resources are employed

with maximum effectiveness. This project aims to develop practical methods that could be used to optimise the design and implementation of internal exposure monitoring programmes for specified exposure situations.

Description of the work:

The project is divided into five work packages. In the first, headed by Tua Rahola, the current internal dose monitoring programmes in EC nuclear industries will be surveyed. Even after the implementation of the Basic Safety Standards there will be differences between national regulations. For optimisation information on these will also be needed. A questionnaire will be designed for gathering the information. The former experience and personal contacts of the consortium members will be used.

Exploitation of results:

The outcome of the project should be a common approach to the design and implementation of internal dose monitoring programmes throughout the EC.

Publication plan:

The results will be published in international journals and in EC-reports.

Timetable:

According to plans this work will start in 2000 and continues in 2001.

Collaborators:

NRPB, G. Etherington, (co-ordinator) UK; IPSN, P. Berard, F; SCK-CEN, C. Hurtgen, B; BNFL, M. S. Peace, UK; EdF, B. Le-Guen, F; TVONS, R. Sundell, FI.

Responsible scientists:

Tua Rahola, Sauli Pusa

3.3 Decision support systems for emergency preparedness

RODOS Users' Group (RUG)

Objectives:

A RODOS Users Group will provide a forum for the exchange of experiences of the users of the RODOS system. The aim of the User Group is to reinforce the feedback between users and model and system developers in order to enhance the quality and efficacy of the system. The main objectives of the User Group are:

- to stimulate the communication between model and system developers on the one hand and the users on the other;
- to share technical know-how, experience gained and software developed during the implementation, customisation and operation of the RODOS system, in particular in its networking and remote operation in local/regional/national emergency centres, and in establishing links with radiation monitoring and meteorological networks and with remote users;
- to share common experience with integrating RODOS in the national emergency management arrangements and development of improved strategies and structures;
- to identify faults and limitations of the RODOS system during implementation and operation and to provide feedback for the development teams;
- to promote the system and its use in nuclear emergencies and for training and exercises;
- to identify where further R&D may be needed to improve the operational efficacy of the RODOS system;
- to enhance communication and exchange experience with users of decision support systems for off-site nuclear emergency management other than RODOS.

Description of the work:

In response to the objectives set out above, the main actions are to be as follows:

- organisation and hosting of meetings of RODOS users and/or potential users biannually for discussing and sharing information on different tasks, i.e., to implement, apply and operate the RODOS system, to stimulate communication between system developers and users, to share technical know-how, to identify limitations, to discuss quality assurance, etc;
- establishment of a World Wide Web page at STUK to offer an open and fast communication forum for frequently asked questions, to distribute information, technical reports and RODOS outputs within the User Group and also between institutes interested in the operational use of the RODOS;

- to co-ordinate, prepare and distribute various kinds of reports, proceedings of the meetings or notes concerning the operational use of RODOS;
- to provide support in organising, performing and attending regional, national and international emergency exercises, training courses and elicitation exercises;
- to provide support in establishing networks of information exchange between the RODOS systems and radiological and meteorological data;
- to interface with other institutes/emergency centres developing or operating decision support systems for off-site nuclear emergency management other than RODOS.

Members of the User Group would be representatives of those institutes, which are responsible for installing, customising and operating the RODOS system and/or which have expressed an interest in using the system within their countries in the near future.

The secretariat of the User Group will be organised and managed by the Radiation and Nuclear Safety Authority (STUK). The tasks of the secretariat comprise the following:

- co-ordination, organisation and announcement of the biannual meetings or working group meetings when needed;
- organisation and maintenance of WWW 'news group' page;
- organisation, co-ordination and preparation of technical reports;
- providing administrative support (accommodation, daily allowance, etc.) during meetings.

Exploitation of results:

Internal exercises of RUG will be published as RODOS reports. Information on issues discussed in Users' Group meeting will be distributed within the RUG and R&D community. When support is provided in organising, performing and attending regional, national and international emergency exercises, training courses and elicitation exercises, reports on issues discussed in meetings would also be produced.

Collaborators:

Forschungszentrum Karlsruhe GmbH, FZK, J. Ehrhardt, D; Institut de Protection et de Sûreté Nucléaire, IPSN, B. Crabol, F; Consejo de Seguridad

Nuclear, CSN, J. C. Lentijo, SP; National Center for Scientific Research "Demokritos", NRCSD, J. Bartziz, GR; Direcção Geral do Ambiente, DGA, J. M. Oliveira Martins, P; Radiological Protection Institute of Ireland, RPII, D. Howett, IRL.

Publication plan:

RODOS reports will be written to facilitate the communication between RODOS users and the R&D community. Especially reports describing the findings of RUGs benchmark exercises.

Timetable:

The project has started in 1998 and will end in December 2000. WWW page has been established and three RUG meetings organised in 1999 and 2000. In meetings close site and the early phase issues of an accident, links to meteorological networks, review of implementation status of RODOS in emergency centres, behaviour of contamination in rural and urban areas, food-stuffs have been discussed. The first comparison exercise of the RODOS Users' has been reported in 2000 and the second consequence assessment analysis of the RUG will be organised and reported in late 2000.

Responsible scientist:

Kari Sinkko

Improvement, extension and integration of operational decision support for nuclear emergency management (DSSNET)

Objectives:

RODOS is currently being installed for (pre-) operational use in emergency centres of eight Eastern and Western European countries with the perspective of an increasing number of users during the 5th Framework programme. Therefore, it is timely and opportune to initiate a broader discussion and interaction, both to provide essential feedback to the developers and to familiarise the users (and decision makers) with the nature and level of support they can expect in practice. The overall objective of this proposal aims at establishing an effective and accepted framework for better communication and understanding between the operational community and the many and diverse disciplines involved in R&D for making well informed and consistent judgements with respect to practical improvements of emergency response in Europe.

Description of the work:

Participants in the network will be primarily nuclear off-site emergency centres with (pre-) operational installation of RODOS and end users of the information provided by RODOS; interested institutes operating other support tools, in particular, monitoring systems, will be integrated. As a counterpart, the leading R&D institutes involved in developing, customising and/or maintaining RODOS - and other decision support tools - will become partners in the network.

The structured evaluation of the experience gained with decision support systems and the information exchange between them will be performed by Working Groups. Each Working Group addresses one of four work packages, which cover areas identified by the partners of the network as relevant with respect to improving the practical applicability of decision support systems: user interfaces, results and interaction with decision-makers; exchange of data and information relevant for decision-making; system functions and networks; and processing of on-line data. In this way, all interfaces between the users and the systems developed by the R&D community will be covered.

To stimulate these activities and to facilitate the communication between the users and the R&D community, problem-oriented emergency exercises will be prepared, which cover the various time phases of an accident, extending from near range to greater distances with frontier-crossing transport of radionuclides. They will help to understand the strengths and weaknesses of decision-support systems, their interaction within data-exchange networks, and their administrative arrangements on the local, regional, national and international levels.

To support interaction between all partners of the proposal and co-ordination within the network, a secretariat will be established for supporting co-ordination and management. A Steering Committee is proposed for keeping track of network activities.

Exploitation of results:

Four emergency exercises will be prepared, conducted and evaluated. Each of the five working groups under the lead of working group convenors will deliver reports as input to five network meetings; they summarise the experience gained with RODOS and its networking during the past reporting period, in particular, the emergency exercises, and formulate proposals for further improving decision support systems and emergency management more generally.

Collaborators:

Forschungszentrum Karlsruhe GmbH, J. Ehrhardt (co-ordinator) FZK, D; Joint Research Centre, JRC Ispra, I; and 30 other institutes from the Middle and Eastern Europe.

Publication plan:

The work will be promoted in RODOS reports, seminars and in scientific publications produced by each working groups. Reports will also be written to facilitate the communication between RODOS users and the R&D community. Especially reports describing the findings of exercises.

Timetable:

2000-2004 (EC Concerted Action), Exercises at months 8, 20, 32, 44 .

Responsible scientist:

Kari Sinkko

Finnish Decision Conferences: Protective Actions in Urban and Rural Environment

Objectives:

Within the European Commission's Framework Programmes, the RODOS (Real-time, On-line DecisiOn Support system) has been in progress in order to develop a comprehensive software package for emergency management. As part of the RODOS project a series of Finnish Decision Conferences / will be organised, the subject of which in 2000 are later phase protective actions. The meetings are aimed to be attended by official decision-makers and experts/ technical level people, i.e., those who are responsible for preparing advice or making presentations of matters for decision-makers of a higher level of responsibility.

The objectives recognise that it is necessary to understand the factors, decision-making processes, organisational structures and interactions, which lead to effective, harmonised and informed responses to nuclear accidents. The overall objective is to plan protective actions and on the other hand to catalyse the development of future versions of DSS's that are better tailored to the DM's *practical* needs in terms of the information provided and the

interface design and to take advantage of the full potential of DSS's. Specifically, the project's objectives are as follows:

- to understand better the needs of DM's at different stages in the management of emergency by clarifying what information DM's need and in what form, thus providing guidance for the further development of consequence models to be included in RODOS and other DSS's;
- by identifying the factors (radiological, socio-psychological, economic, etc.) which drive decision-making, exploring how these factors relate to the bases for international (generic) guidance on intervention and eliciting the relative importance of the factors in the given accident scenario, thus identifying and defining attributes and value trees to be tailored into RODOS and other DSS's;
- To improve the communication of uncertainties to the DM's and support them in their task of explaining the uncertainties and risks to the wider public by identifying how to present information on uncertainties via the DSS so that it supports known good practice in public risk communication.

Description of the work:

The project seeks to achieve its objectives through conducting a number of workshops in which a realistic and very careful planned scenario is explored with decision-makers to understand the motivation behind their decisions. The aims of the events are to identify the factors driving decision-making, to explore the issue of uncertainty, including how the DM's perceive it and how their advisers can best communicate their assessment of the uncertainty, to identify the forms of countermeasure strategy that the DMS wish to consider, to consider the key issues that they would wish to communicate with the public and what information they would need from the DSS in order to support decision-making and communication.

Working meetings and a decision conference are planned to extend the work commenced with the interviews performed concerning early phase protective actions to the later phase of decision-making. Interviews, working meetings and the decision conference are based on the same accident scenario. All in all, three decision points are envisaged. In the threat of a release or even during ongoing release urgent actions to protect humans, that is iodine prophylaxis, sheltering and evacuation, were of major concern. The interviews documented in the published report are concerned with this decision point. Working meetings are meant to deal with urgent measures to protect livestock during the first day following an accident. A decision con-

ference with follow-up and more extensive countermeasures applicable to milk and dairy products at a time when the fallout pattern and composition are measured.

Exploitation of results:

There will a report in addition to publications in open reviewed journals, which will emphasise the following aspects:

- deliberation on issues affecting decision on information needs dairy products and practical consideration of countermeasure to be taken
- the experiences from different decision conference processes and analytical methods;
- the overall problem structures related to the different scenarios. What factors are found important and their definition as well as how the countermeasure alternatives were generated;

Collaborators:

Authorities and experts in radiation protection.

Exploitation of results:

The results will be exploited in emergency planning of competent safety authorities. The basic objective is to provide a shared understanding between the decision makers and the radiation protection community on concerns and issues related to decisions on protective actions after a nuclear accident.

Publication plan:

As it is now under exploitation of results.

Timetable:

The work has been carried according the evolution of the hypothetical accident. A interview analysis in order to shed light on urgent protective actions like iodine prophylaxis sheltering and evacuation was conducted in 1999. The meetings that relate to milk and milk products dealt with urgent measures to protect the livestock (milk) and the decision conference with follow-up and more extensive countermeasures applicable to milk and milk products was organised in 2000. The reports will be written by the end of 2000.

Responsible scientist:

Kari Sinkko

Migration of RODOS to practical applicability for supporting decisions in operational emergency response to nuclear accidents (RODOS Migration)

Objectives:

STUK together with IPSN, France has during 1997 - 1999 developed a dose calculation model for contaminated forests to be used in the RODOS decision support system. This Forest Food Chain and Dose Module will be complemented by a new module for calculation of the effects of countermeasures on forests. In this connection, the current database and source code will be updated. Forest management methods that are known to reduce the effects of radioactive deposition in the long term will be considered.

Description of the work:

The project will be activated by the co-ordinator Forschungszentrum Karlsruhe FZK, Germany, after the decision on funding by the EC. The Laboratory for Ecology and Foodchains, STUK, is responsible for updating the current forest module according to the feedback from users. The work starts with further development of the current model and programme.

Exploitation of results:

Further development of the Forest Food Chain and Dose Module improves its usability in emergency preparedness plans and exercises. The development work also improves STUK's facilities for making more effective use of the RODOS system.

Publication plan:

The model description will be published at the end of the project in 2003. The model and its applications will be described in scientific articles after the EC project.

Timetable:

2000 - 2003. The content of the countermeasure submodule will be planned and the programming carried out in 2000-2001. Programming, testing, finalisation and documentation of the model will continue in 2002. The duration of the project is 3 years from the start.

Collaborators:

Forschungszentrum Karlsruhe GmbH, FZK J. Ehrhardt, D.

Responsible scientists:

Aino Rantavaara, Michael Ammann, Virve Vetikko

Food and agriculture restoration management involving networked groups (FARMING)

Objectives:

General project objectives: "To create a European network initially in 5 Member states and involving more than 50 individual stakeholders, to assist in the development of robust and practicable strategies for restoring and managing contaminated rural areas sustainably. To carry out a comprehensive evaluation of these strategies under the diverse range of food production systems encompassed by the participating member states, to establish lines of communication between those organisations who have not hitherto collectively considered the implications of contamination of the foodchain." (From proposal summary Oct. 99/NRPB, A. Nisbet)

In addition to the general objectives, the Finnish stakeholder-group aims at identification of practicable strategies applicable in sub-Arctic conditions, including large sparsely-inhabited areas.

Description of the work:

The existing Finnish stakeholder group will be expanded to cover a wider diversity of interests. The group will meet annually over a three-year period to evaluate the practicability of restoration techniques and strategies following widespread contamination of the rural environment in northern Europe. The sub-Arctic conditions make the agricultural industry particularly vulnerable and there is therefore a need to find sustainable long-term strategies. Consideration will be given to local conditions on the applicability of different management techniques. The working group will report its findings annually. Opinion will be exchanged with other national groups via the network, and reconsidered in an iterative process.

Exploitation of results:

The current state of the art on restoration strategies in northern Europe will be presented during the UK workshop and subsequently translated into recommendations for consideration by the Finnish and European Authorities.

Collaborators:

National Radiological Protection Board, NRPB, A. Nisbet (co-ordinator), UK; Institut National Agronomique Paris Grignon, INAPG, F; Nuclear Research Centre, SCK-CEN, C. Vandecasteele, B; University of Ioannina, UOI, K. Ioannides, GR.

Publication plan:

Internet articles and project final report.

Timetable:

2000 - 2003

Responsible scientists:

Aino Rantavaara, Ritva Saxén, Eila Kostiainen, Riitta Hänninen

Radiation surveillance by unmanned aerial vehicle (UAV)*Objectives:*

The aim is to design radiation measurement instrumentation for unmanned aerial vehicles (UAV) and to study the applicability of UAVs in radiation surveillance. Special emphasis is placed on the studies of data acquisition, on dose rate measurements and on the sampling and identification of airborne radioactive material.

Description of the work:

The study is performed in cooperation between STUK and the Finnish Defence Forces' Research Centre. The feasibility of different radiation detectors and sampling techniques will be studied by laboratory tests and by constructing a prototype device to be tested in target drones. The optimal use of UAV for plume tracking, fallout mapping and identification of the location of point-sources will be investigated.

Exploitation of results:

The Finnish Defence Forces will receive unmanned aerial vehicles in 2001 and the results of the present project will be directly utilised for the instrumentation of the UAV's. In addition, the results will be exploited in emergency preparedness.

Publication plan:

The Final report of the project will be ready on 31.12.2000. Scientific publications will be issued later.

Collaborator:

Defence Forces Research Institute of Technology, FI.

Responsible scientist:

Kari Kurvinen

4 HEALTH EFFECTS OF RADIATION

4.1 Radiation biology

Genomic instability and radiation-induced cancer (RADINSTAB)

Objectives:

The recent discovery of radiation-induced genomic instability has raised concern for its implication in the radiation protection of the public, especially quantification of human risk for low doses and high LET exposure. The role of radiation-induced genomic instability in radiation carcinogenesis will be studied with animal models and mechanistic investigations of induction and transmission. Genes and genome regions involved will be studied and the basis of individual susceptibility investigated. The relationship of genomic instability endpoints to radiation dose, dose rate and quality will be determined.

In STUK, the aim is to study radiation-induced changes in gene expression related to genomic instability. The aim is also to identify genes playing a pivotal role in inducing genomic instability and to study how the genomic instability can be transmitted to cells that are not hit during irradiation with low doses (so called bystander effect).

Description of the work:

The work is part of an EC funded project (Genomic Instability and Radiation-Induced Cancer) co-ordinated by STUK. Irradiated cell cultures and control cell cultures are provided by English and French collaborators and the gene expression studies (mRNA differential display and cDNA expression array) will be carried out at STUK.

Exploitation of results:

The purpose of the EC project is to produce information about the role of genomic instability in cancer induction which in turn may have implications for the estimation of radiation risk.

Publication plan:

The results will be published in international journals.

Collaborators:

University of Dundee, W. Wright, UK; University of Cambridge, P. Schofield, UK; Gray Laboratory Cancer Research Trust, Medical Research Council, M. Barry, K. Prise, M. Joiner, UK; Commissariat à l'Energie Atomique, L.Sabatier, F; Dublin Institute of Technology, C. Mothersill, IRL; National Centre for Environment and Health, J. Schmidt, D; Karolinska Institute, B. Lambert, S.

Timetable:

The work will be completed by 2003.

Responsible scientists:

Riitta Mustonen, Sisko Salomaa

The use of FISH techniques for retrospective biological dosimetry (COD)

Objectives:

To investigate further the achievements and limitations of using FISH techniques (translocation analysis) for biological dosimetry in cases of past exposures.

Description of the work:

More information is collected concerning the control levels of stable chromosome aberrations in individuals exposed to normal background levels of radiation. Data are needed to identify other possibly confounding factors than age which cause individual variations in control levels. The victims of the recent radiation accidents are monitored with respect to their aberration frequencies in order to gain more knowledge on the stability of translocations with time. The project involves laboratories in seven countries with specialists in biological dosimetry.

Exploitation of results:

The results are exploited to achieve a pan-European consensus on the usability of the FISH technique for retrospective dosimetry.

Collaborators:

National Radiation Protection Board, A. Edwards (co-ordinator) UK; West-lakes Research Institute, C. Whitehouse, UK; Institut de Protection et de Sécurité Nucléaire, I. Sorokine, F; State University of Leiden, F. Darroudi, NL; Bundesamt für Strahlenschutz, G. Stephan, D; Universitat Autònoma de Barcelona, F. Barquinero; SP.

Timetable:

The project will commence in 2000 and will be completed in 2002.

Publication plan:

The results will be published in international journals.

Responsible scientist:

Carita Lindholm

The significance of individual radiation sensitivity to secondary cancer

Objectives:

The aim of the work is study individual radiation sensitivity related factors affecting induction of secondary sarcomas in patients after receiving radiotherapy cancer treatment.

Description of the work:

The material of the study consists of approximately 20 live secondary sarcoma patients (case patients) and of 3-4 controls for each of these case patients. The control patients have received the same radiotherapy treatment for the same primary cancer as case patients but they have not developed a secondary sarcoma after radiation therapy. The samples to be studied are blood samples and tumour paraffin blocks out of which both the tumour and the normal tissues are examined. For some patients frozen fresh samples of the tumour and irradiated skin and paraffin block of the irradiated skin are also available. Possible mutations of various relevant genes are studied from appropriate samples. The amount of radiation-induced DNA damage and the function of the DNA damage repair genes are defined.

Exploitation of results:

The results of the present work may help in the estimation of cancer risk after irradiation. The results may also have implications for clinical medicine.

Collaborators:

The Helsinki University Central Hospital, Clinic for Radiotherapy and Oncology, T. Wiklund, R. Huuhtanen, M. Miettinen, H. Joensuu, FI.

Timetable:

The work will commence in 2000 and will be completed in 2002.

Publication plan:

The results will be published in international journals.

Responsible scientist:

Riitta Mustonen

Inter-individual changes in the number of radiation-induced chromosome aberrations

Objectives:

The aim of the study is to determine the inter-individual differences in sensitivity to ionising radiation.

Description of the work:

Blood samples have been collected from ten persons whose genotype of a certain drug-metabolizing enzyme (GST) is known and who have not been exposed to radiation in their work. Blood samples have been irradiated *in vitro* using different doses of radiation. Translocations and other chromosomal aberrations are studied from these blood samples using chromosome painting. The number of chromosome aberrations is compared between different persons and individual dose response curves are prepared. Radiation induced DNA breakage peripheral blood lymphocytes will also be studied by using the single cell gel electrophoresis technique (Comet method).

Exploitation of results:

More detailed knowledge of the individual differences in radiation sensitivity may have implications in the estimation of radiation risk and clinical medicine.

Collaborators:

The project is carried out in collaboration with the Institute of Occupational Health, H. Norppa, FI.

Timetable:

The work will be completed in 2000.

Publication plan:

The results will be collected in publications in international journals.

Responsible scientist:

Riitta Mustonen

Radiation-induced changes in gene expression

Objectives:

The aim of the work is to study radiation induced changes in gene expression.

Description of the work:

The project is carried out with the German partner (Ludwig-Maximilians University). Changes in gene expression will be studied in three radiation-induced primary human tumour cell lines derived from childhood thyroid carcinomas among Byelorussian children. As a control, a cell line has been established from the normal thyroid tissue of each child. Gene expression is analysed by using two genome-wide expression methods: cDNA Expression Array can simultaneously display differences in several hundreds or thousands of known genes. The other fragment analysis based method, DDRT-PCR, can also identify differences in previously unknown genes. If novel genes (ESTs; expressed sequence tags) are found, their base composition will be defined by sequencing. The sequences of novel genes will be submitted to EMBL sequence database and their possible function and relationship to known genes will be clarified by using Internet based programs and GCG (Genetics Computer Group) software.

Exploitation of results:

The aim of the project is to increase knowledge of changes in gene expression linked to radiation-induced carcinogenesis. In the project, we will try to figure out the signalling pathways or cascades in which changes in gene expression lead to failure of growth control and tumorous growth. The project will produce know-how on the use of genomic and bioinformatic methods in molecular biology.

Collaborator:

Ludwig-Maximilians Universität, L. Hieber, D.

Timetable:

The work will be completed in 2001.

Publication plan:

The results will be published in international journals.

Responsible scientist:

Riitta Mustonen

4.2 Epidemiology

Minisatellite mutations and biodosimetry of the population around the Semipalatinsk nuclear test site (SEMIPALATINSK)

Objectives:

The aim of the work is to assess exposure to radiation and to determine the rate of heritable mutations in the germline among population exposed to chronic radiation around the Semipalatinsk nuclear test-site in Kazakhstan.

Description of the work:

The work will be carried out as an international collaboration study funded by EC Inco Copernicus programme. At STUK, translocation frequencies will be analyzed by using the FISH chromosome painting technique in the lymphocytes of two generations of people. A biosample database of blood samples will be established of about 50 families in three generations living close to the Semipalatinsk nuclear test site and control families in three

generations from clean areas. The biosample database will consist of isolated whole blood DNA, frozen lymphocytes stored in liquid nitrogen, cultured lymphocytes in fixative and fixed erythrocytes for GPA mutation analysis. DNA will be used for minisatellite mutation analyses. Translocation analysis will be used for dose assessment.

Exploitation of results:

Results will be used in assessing heritable mutations among populations exposed to chronic radiation.

Collaborators:

Institute of General Genetics and Cytology in Kazakhstan, R. Bersimbaev, KZ,
University of Warwick, M. Hultén, UK; University of Leicester, Y. Dubrova and A.J.Jeffreys, UK.

Timetable:

The work will be completed in 2000.

Publication plan:

The results will be published in international journals.

Responsible scientists:

Sisko Salomaa, Riitta Mustonen, Matti Suomela

Radiation-induced heritable mutations in humans

Objectives:

The aim of the work is to determine the rate of heritable minisatellite mutations in a radiation exposed population, Estonian Chernobyl clean-up workers.

Description of the work:

The number of heritable mutations in children of the Estonian Chernobyl clean-up workers are determined by using 13 minisatellite markers: APO B, B 6.7, CEB 1 (D2S90), CEB 15 (D1S172), CEB 25 (D10S180), CEB 36 (D10S473), Hras, MCOB 19 (D19S20), MCT 118 (D1S80), MS 1 (D1S7), MS 31 (D7S21), MS 32 (D1S8), and YNZ 22 (D17S5). The case children come

from families where a baby / babies were born 9-33 months after the father of the family returned from Chernobyl. Intrafamily control children are children born to these same families before the accident in Chernobyl. Interfamily controls are families whose fathers have not been exposed to radiation.

Exploitation of results:

The results will help in estimation of the radiation-induced heritable risk in humans.

Collaborators:

Estonian Institute of Experimental and Clinical Medicine, T. Veidebaum, M. Tekkel, M. Rahu, EN; Finnish Cancer Registry, T. Hakulinen, FI, the North Savo Regional Environment Centre, K. Servomaa, FI; the University of Kuopio, T. Rytömaa, FI.

Publication plan:

The results will be published in international journals.

Timetable:

The work will be completed in 2000.

Responsible scientists:

Anssi Auvinen, Anne Kiuru, Riitta Mustonen

Mobile phones and the risk of brain tumours (INTERPHONE)

Objectives:

To assess the possible risk of brain tumours associated with the use of mobile telephones.

Description of the work:

The project is funded by EC Quality of Life programme. As part of an international collaborative study, all brain tumours diagnosed in patients between 20 and 69 years of age are identified prospectively from neurosurgery departments at five university hospitals. The total number of cases expected during 2000-2002 is 800. Controls will be identified from the Population Registry. Exposure information is based on personal interviews and telephone company records.

Exploitation of results:

The results will clarify the possible health effect of radiofrequency magnetic fields.

Coordinators:

IARC, Institute of Cancer Epidemiology, E. Cardis, (co-ordinator) F; The Danish Cancer Society, J. Olsen, DK; University of Claude Bernard, G. Prost, F; University of Mainz, K.P.C. Spath, D; Chaim Sheba Medical Centre, S. Noy; ISS, G. Benagiano, I; NRPA, O. Harbitz, N; Karolinska Institute, A. Ahlbom, S; London School of Hygiene and Tropical Medicine, W. Surridge, UK; University of Leeds, R. Cartwright, UK; New South Wales Cancer Council, B. Armstrong UK; INRS-IAF, J. Siemiatycki, CA; University of Otago, A. Woodward, NZ; University of Illinois, Mi Ja Kim, US.

Timetable:

The study will start in 2000 with collection of material over two years.

Publication plan:

The results will be collected in publications in international journals.

Responsible scientist:

Anssi Auvinen

Pooled analysis of European case-control studies of radon and lung cancer (RADON EPIDEMIOLOGY)*Objectives:*

To provide more accurate risk estimates of lung cancer risk from indoor radon than can be obtained from single studies. In addition, a new retrospective exposure assessment method (surface monitor) will be tested.

Description of the work:

The project is part of an international collaborative study funded by EC Nuclear Energy Programme (concerted action). Anonymised data from the Finnish study is delivered to England for analysis. In a validation study, the air and surface measurements are compared. A new surface measurement will be performed for a small sample of the study subjects of the Finnish study.

Exploitation of results:

The results will improve risk assessment.

Collaborators:

NRBP, C. Muirhead, J. Miles, UK; ICRF, S. Darby, UK; University of Gent, A. Poffijn, B; GSF, H-E Wichmann, D; Institute for Biometrics, School of Veterinary Medicine Hannover, L. Kreienbrock, D; IPSN, M. Tirmarche, F; EPI, F. Bochicchio, I; TILAK, W. Oberaigner, A; NRPI, L. Tomasek, EZ; Finnish Cancer Registry, M. Hakama, FI; NUID, J. McLaughlin, IRL; SSI, R.Falk, S; Karolinska Institute, G. Pershagen, S.

Timetable:

The validation study will start in 2000. The first results of the pooled analysis will be available in 2002.

Publication plan:

The results will be published in international journals.

Responsible scientist:

Anssi Auvinen

Cancer risk among nuclear workers (LOWDOSERISK)

Objectives:

To estimate cancer risk from low doses of ionising radiation.

Description of the work:

Cancer risk among nuclear power plant workers is analysed as part of an international collaborative study, funded by EC Nuclear Energy Programme (concerted action). A cohort of Finnish nuclear power plant workers has been established and exposure information obtained from the records maintained by STUK. The first version of data has been sent to the International Agency for Research on Cancer for analysis.

Exploitation of results:

The results will provide the most accurate estimates so far of cancer risk from low doses of radiation.

Collaborators:

IARC, E. Cardis, F; University of Bielefeld, M. Blettner, D; NRPB, C. Muirhead, UK; OPRI, A. Biau, F; Institut Gustav-Roussy, C. Hill, F; Finnish Cancer Registry, M. Hakama, FI; CSN, A. Diez Sacristán, SP; SCK-CEN, P. Deboodt, B; Socialstyrelsen, G. Engholm, S.

Timetable:

The first version of data has been sent to Lyon. The data will be updated and sent to the co-ordinating centre in 2000. The analyses of the Finnish data will be up-dated and manuscript prepared.

Publication plan:

The results will be collected in publications in international journals.

Responsible scientist:

Anssi Auvinen

Cancer risk among airline personnel

Objectives:

To compare cancer risk among pilots and cabin crew with the general population.

Description of the work:

The study is carried out in collaboration with Nordic and European partners. Finnish pilot and cabin attendant cohorts have been established and information on cancer incidence obtained from the Finnish Cancer Registry. Pooled analyses with other cohorts is planned.

Exploitation of results:

The study will provide information on the health effects of cosmic radiation.

Collaborators:

Karolinska Institute, N. Hammar, S; Danish Cancer Society, H. Storm, DK; Cancer Registry of Norway, T. Haldorsen, N; University of Bielefeld, M. Feychting, H. Zeeb, G. Hammer, D; ISS, A. Verdicchio, I; British Airways, D. Irvine, UK; University of Wageningen, D. Heederik, NL.

Timetable:

The Finnish material has been collected. The Nordic analyses of pilots will be completed in 2000 and of cabin crew in 2001. The results of the European study will be available in 2001-2002.

Publication plan:

The results will be published in international journals.

Responsible scientist:

Anssi Auvinen

Cancer among Saami people (Lapps)

Objectives:

To assess cancer incidence among Saami (Lapps), especially reindeer herding Saami who were exposed to radioactive fallout from A-bomb testing.

Description of the work:

The project is a collaborative study with the Norwegian Cancer Registry, the Norwegian Radiation Protection Authority, the Swedish Radiation Protection Institute, the Karolinska Institute and the Finnish Cancer Registry and receives funding from the Nordic Cancer Union. The study population will be identified through the statistics office/population registry in each country. Information on cancer incidence is obtained from national cancer registries.

Exploitation of results:

The results provide information about cancer in a culturally and genetically unique population and especially on the reindeer-herding Saami with internal contamination from A-bomb testing.

Collaborators:

Norwegian Cancer Registry, T. Haldorsen, N; Norwegian Radiation Protection Authority, T. Tynes, N; Swedish Radiation Protection Institute, L.-E. Holm, S; Karolinska Institute, P. Hall, S; Finnish Cancer Registry, E. Pukkala, FI.

Publication plan:

The results will be published in international journals.

Timetable:

The study will commence in 2000.

Responsible scientist:

Anssi Auvinen

Kidney toxicity of uranium in drinking water (JURMU)

Objectives:

To assess the possible effects of uranium in drinking water on kidney function (chemical toxicity).

Description of the work:

The study is carried out in collaboration with the National Public Health Institute. Approximately 300 subjects will be enrolled among persons with drilled wells that have been measured at STUK. Blood and urine samples will be collected to assess uranium exposure and kidney function.

Exploitation of results:

The results will clarify the effects of low uranium concentration in humans and facilitate setting guidelines values.

Publication plan:

The results will be collected in publications in international journals.

Collaborators:

National Public Health Institute, H. Komulainen (co-ordinator), J. Pekkanen, FI; University of Tampere, H. Saha, FI.

Timetable:

The material was collected in 1999, the analyses will be completed and the manuscript prepared in 2000.

Responsible scientists:

Päivi Kurttio, Laina Salonen, Anssi Auvinen

Radioisotopes in drinking water and cancer risk (JUORAAS)

Objectives:

To assess the possible effect of radioisotope concentrations frequently encountered in Finnish wells drilled in bedrock on cancers of the kidney, bladder and stomach as well as on leukemia.

Description of the work:

All Finns using wells drilled in bedrock as a source of drinking water were identified as the base cohort. A sample was drawn to form a subcohort and water samples analysed as a reference. All cases occurring in the base cohort were identified and their water concentration is compared with the subjects in the subcohort.

Exploitation of results:

Due to the small size of the sample, the results are unlikely to be conclusive, but any results will be informative as there are no human studies published so far.

Publication plan:

The results will be published in international journals.

Collaborators:

National Public Health Institute, J. Pekkanen, H. Komulainen, E. Kokki, FI, Geological Survey of Finland, H. Sandström, R. Salminen, H. Kahelin, N. Gustavsson, FI, Finnish Cancer Registry, E. Pukkala, FI.

Timetable:

The material was collected in 1999. The analyses will be completed and a manuscript reporting on the results prepared in 2000.

Responsible scientists:

Päivi Kurttio, Anssi Auvinen

Chernobyl fallout and adult leukemia

Objectives:

To assess whether the fallout from Chernobyl has had a detectable effect on the incidence of adult leukemia in Finland.

Description of the work:

Cancer incidence data are obtained from the Finnish Cancer Registry. Fallout patterns have been measured by STUK. A follow-up study is conducted to find out if there has been an increase in leukemia incidence in the areas with the highest level of fallout.

Exploitation of results:

The study will quantify the public health impact of the Chernobyl accident in Finland and is conducted as part of the surveillance activities of STUK.

Collaborator:

Finnish Cancer Registry, M Hakama, FI.

Publication plan:

The results will be published in international journals.

Timetable:

The material will be up-dated, analyses completed and a manuscript prepared in 2000.

Responsible scientist:

Anssi Auvinen

Brain tumours and X-ray examinations

Objectives:

To assess the contribution of radiological examinations to the risk of brain tumours.

Description of the work:

The material collected for the study of mobile telephones and brain tumours (INTERPHONE) with all brain tumours diagnosed in patients between 20 and 69 years of age will be used. Information on head and neck X-rays will be obtained through interviews and validation is obtained from medical records. The study is funded by the Academy of Finland. Collaboration with other Nordic countries is planned.

Exploitation of results:

The results will clarify the effect of radiological examinations on the risk of brain tumours as most previous studies are prone to recall bias and confounding by socio-economic status.

Publication plan:

The results will be collected in publications in international journals.

Timetable:

The study will commence in 2000.

Responsible scientist:

Anssi Auvinen

Leukemia incidence in the vicinity of nuclear facilities

Objectives:

To find out if the risk of leukemia around nuclear facilities differs from other parts of the country.

Description of the work:

All cases of leukemia occurring in the municipalities adjacent to nuclear power plants are identified from the Finnish Cancer Registry. Controls are identified from the population registry. Residential history is obtained for all subjects and the distance from the nuclear plant calculated.

Exploitation of results:

The results will provide further information about the possible health effects of nuclear power plants.

Collaborator:

The Finnish Cancer Registry, M. Hakama, FI.

Publication plan:

The results will be published in international journals.

Timetable:

Analyses have been completed and a manuscript will be ready in 2000.

Responsible scientist:

Anssi Auvinen

Radon and lung cancer: an analysis using additive generalised linear models (RALMA)

Objectives:

The aim is to describe the lung cancer risk of indoor radon without an assumption on the linearity the dose-response ratio using the novel technique of additive models.

Description of work:

The nationwide data concerning radon and lung cancer will be re-analysed using additive generalised linear models. This non-parametric method enables us to describe the connection between indoor radon and lung cancer without an assumption on the linearity of the dose-response ratio, so that an adjustment for smoking is also possible. This study will utilise the unmatched data of the previous Finnish nationwide study. These data are considerably greater than the matched data, and were analysed in the first article only superficially.

Exploitation of results:

This study has the potential to illuminate the possible different proportional risks of high and low indoor radon concentrations.

Publication plan:

An article in a scientific journal

Responsible scientists:

Ilona Mäkeläinen, Anssi Auvinen

5 NON-IONISING RADIATION

5.1 Radiation metrology and dosimetry

Development of exposure systems for animal and cell culture studies

Objectives:

The COST 244 bis project "Electromagnetic fields from mobile telephones as a possible health risk" was commenced in 1998 as a follow-up project to COST 244, which was concerned with the possible health risks from mobile telephones. The research institutes and funders are in the main the same as in the previous COST project. The objectives of STUK are 1) to develop cell exposure equipment (in vitro exposure equipment) that works at 900 MHz, where the level of exposure and the temperature are strictly controlled, and 2) to develop exposure equipment for rats (in vitro exposure equipment) that works at 900 MHz, where a large number of test animals can be exposed simultaneously, each animal can move freely in its chamber and the whole body SAR of the animals is precisely determined.

Description of the work:

The cell exposure chamber intended for the University of Kuopio has been constructed in the fine-mechanical workshop in the University of Kuopio and partly tested at STUK. This is a similar piece of equipment to the one to be constructed in the NAMS project for STUK's use. The absolute value of SAR is precisely determined in various culture dishes by temperature measurements, and the absolute value and distribution of SAR is compared with

VTT's FDTD calculations. The efficiency of the water-cooling is tested. It is intended to do all this by the end of March 2000.

The in vivo exposure equipment will be designed and constructed during the first half of the year 2000. Judging by the pre-planning the best solution seems to be an enclosed chamber made up of two round discs 1.6m in diameter at a distance of approx. 15 cm. Radio frequency power is fed through a cone-shaped antenna in the centre. The antenna radiates a radial TEM wave, most of which is absorbed by the rats in the periphery of the chamber. The rest of the power is attenuated by absorbers located at the edges of the chamber behind the rats. The SAR induced in the rats is determined experimentally (calorimetric temperature measurements) and numerically, partly using VTT's FDTD calculations.

Exploitation of results:

The cell exposure chamber is used in biological research at the University of Kuopio, designed to discover the effects of microwave radiation from mobile telephones on cell activity. The in vivo exposure equipment is used in animal tests at the University of Kuopio to study the possible combined effects on rats of carcinogens in drinking water and of microwave radiation from GSM mobile telephones.

Publication plan:

When the COST 244bis project concludes at the end of 2000 the results will be set out in the final report and the main results will be presented at a briefing meeting at the beginning of 2001. The results will also be published in international scientific publication series.

Collaborators:

University of Kuopio, J. Juutilainen, FI; Technical Research Centre (VTT) K. Laukkanen, FI.

Responsible scientist:

Lauri Puranen

Improving the accuracy of ultraviolet radiation measurement

Objectives:

The study is part of a comprehensive EC project co-ordinated by the National Physical Laboratory, UK. This in turn is part of the SMT (standards, measurements and tests) programme. The purpose of the EC project is to improve the accuracy of UV radiation measurement, particularly UV radiation from the sun.

The objective of STUK's contribution to the project is to develop, in cooperation with the Metrology Research Institute of Helsinki University of Technology (HUT), an accurate calibration chain based on filter radiometers for spectroradiometers measuring UV radiation. STUK's main task is to develop a field calibrator based on quartz-halogen lamps for the sun monitoring spectroradiometers. The field calibrator is to be stabilized with the aid of semiconductor detectors and calibrated by the filter radiometers provided by HUT against an absolute cryogenic radiometer.

Description of the work:

For optical source a 1 kW quartz-halogen lamp is used, and it is located in the upper part of a two-part calibrator. The aim is to minimize the heat transfer to the lower part, where the beam is limited by apertures to be as narrow as possible. The beam illuminates the monitoring detectors and output aperture, and the diffuser of the spectroradiometer to be calibrated (the optic component receiving the radiation) is attached to it. The monitoring detectors used are two temperature stabilized semiconductor detectors supplied with interference filters. The detectors are being developed by HUT and National Physical Laboratories (NPL). One of the detectors operates in the UV-B range and the other in the UV-A range.

The calibrator is being designed, constructed and tested in the NIR laboratory, except for the filter detectors, which are being manufactured by HUT. The mechanical parts are being manufactured in the STUK precision engineering workshop. The field tests are being conducted with STUK's Bentham DM ISO spectroradiometer and also with Brewer spectroradiometers located at the Meteorological Institute's observatories at Jokioinen or Sodankylä. The study commenced on 1.1.1999 and will conclude on 1.1.2002.

Exploitation of results:

The calibration accuracy of spectroradiometers monitoring the solar UV radiation improves significantly.

Publication plan:

The results will be presented in a project workshop and will be published in international scientific publications series.

Collaborators:

Helsinki University of Technology (HUT), E.Ikonen, P. Kärhä, FI; NPL, Neil Harrison, UK.

Timetable:

The project commenced 1.1.1999 and will be completed by 1.1.2002.

Responsible scientist:

Kari Jokela

New antennas and measurement methods for 3rd generation cellular systems (NAMS)

Objectives:

This is a large national multi-centre study where the main objective is to improve the performance of antennas used in new cellular systems. The main objective of STUK is to develop methods for SAR tests of mobile phones. Additionally, the plan of operation for 2000 includes the construction, testing and dosimetric measurement of two 900 MHz exposure chambers for in vitro research of biological effects of mobile phones. It is, however, possible that part of this work will be done within the framework of the new follow-up project to the COST projects, funded by TEKES.

Description of the work:

For the calibration of the SAR probes three calibration systems will be designed and constructed: a TEM transmission line will be employed at frequencies 20-450 MHz, a waveguide at 2000 MHz and at 2450 MHz. In all equipment calibration is based on the accurate measurement of the rise in temperature caused by the radio frequency power absorbed by the lossy material, using small thermistor antennas that do not disturb the radio frequency field. The dielectric characteristics and specific heat capacity of the tissue-simulating material are accurately measured. The estimated uncertainty of calibration is $\pm 5 - \pm 10$ %.

The accuracy of the conductivity measurement of the tissue-simulating liquid will be improved by developing with HUT a method based on a TEM-line filled with the liquid. It is estimated that this method reduces the uncertainty from $\pm 8\%$ to less than $\pm 2\%$.

The accuracy and reliability of SAR measurements and calibrations will be ensured by conducting intercomparison campaigns with other RF dosimetry laboratories.

For the in vitro exposure chambers, see the summary of the COST bis project.

Exploitation of results:

The accuracy and the reliability of the SAR determinations in mobile phone tests and in vitro research will improve.

Publication plan:

Technical reports will be written for the project and the main results will be published in international scientific publications series.

Collaborators:

Nokia Research Centre, K. Kiesi, FI; Helsinki University of Technology (HUT), A. Toropainen, FI.

Responsible scientist:

Lauri Puranen

The ASTE Project: EMC & Safety of Multimedia Terminals

Objectives:

The purpose of the project is to find out the radiation safety of multimedia satellite terminals intended for the public broadcasting on high frequencies, over 9 GHz, to determine standards applicable to safety assessments, and to develop testing methods to ensure radiation safety.

Description of the work:

This is a follow-up project funded by ESA, the European Space Agency, and the co-ordinator is the French MATRA Systems & Information Technology

(MS&I). STUK is the main party in Finland. STUK's sub-contractor is the Technical Research Centre of Finland (VTT). The focus of the project is on the year 2000 for STUK. The work is to begin in March. The main purpose is to find out the most suitable compliance testing method around 9 GHz, whether to use SAR or power density measurement. At first a testing frame will be constructed in an anechoic chamber, to measure easily the power density distribution in a plane located in front of a satellite antenna. Measurements will be made using a suitable commercial satellite antenna (on loan from Aerial Ltd.) in the frequency range of 8-12 GHz. A horn antenna will be used to irradiate a cubical liquid phantom, in which SAR measurements will be made with temperature sensors. The results of power density and SAR measurements will be compared with VTT calculations.

During the year 2000 a study will be made of exposure and emission standards applicable to evaluation of the radiation safety of satellite antennas, covering both the occupational and the general public exposure. Standards proposed by international organizations and national authorities will be compared in an attempt to find out in particular whether standards are up-to-date, practical and sufficiently unambiguous. Special attention will be paid to the frequencies where SAR measurements will be changed to power density measurements and to how the averaging mass is defined in the SAR tests.

The project includes a critical report on the biological effects of microwave radiation over 2 GHz. This will be written mainly in 2001.

Exploitation of results:

The commissioner of the project can make use of the results in designing radiation-safe multimedia terminals. STUK can use the results in a standardization work.

Publication plan:

Technical reports will be written on the different tasks in the project, and the final report on the whole project will be written at the beginning of 2001. The main results will also be published in international scientific publications series.

Collaborators:

MATRA Systems & Information, A. Soubeyron, F; Technical Research Centre (VTT) K. Laukkanen, FI.

Responsible scientist:

Lauri Puranen

The combined effects of electromagnetic fields with environmental carcinogens (CEMFEC)

Objective:

This is an EC project belonging to the 5th framework programme co-ordinated by University of Kuopio. Its purpose is to investigate the combined effects of the MX carcinogen in drinking water and 900 MHz GSM radiation. STUK's task is to develop equipment to be used in exposure and to determine the SAR of rats. The aim is to design such a large exposure chamber that approx. 25 animals can be exposed to radiation simultaneously, in such a way that all the animals can move freely in their cage.

Description of the work:

The equipment will be designed and constructed at the beginning of 2000. On the basis of the pre-design the best solution seems to be an enclosed chamber made up of two round discs approx. 1.6m in diameter at a distance of approx. 15 cm. Radio frequency power is fed through a monopole antenna in the centre. The antenna radiates a radial TEM wave, most of which is absorbed by the animals placed at the edge of the chamber. The final power is absorbed by the absorbers located behind the rats or mice.

Exploitation of results:

The University of Kuopio will use the equipment in exposing rats to 900 MHz GSM radiation.

Publication plan:

A report will be written on the development of the equipment. The accuracy of the dosimetry will be improved during the period of exposure of the rats, approx. 2 years. A final report on dosimetry will be written in 2002 or 2003. The results will also be published in international scientific publications series.

Collaborators:

University of Kuopio, J. Juutilainen (co-ordinator) FI; Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung, München, Ger-

many, H. Ernst, D; VITO-Vlaamse Instelling voor Technologisch Onderzoek NV, L. Verschaeve, B; Università degli Studi di Genova (UGOA), M.-R. Scarfi, I.

Responsible scientist:

Lauri Puranen

5.2 Biological effects and radiation protection

Development of *In Vitro* Dosimetry and Bio-Markers (LaVita)

Objectives:

The issue of the potential health hazards of mobile telephones remains unclear. The objective of STUK is to study whether changes in expression of heat-shock proteins could be used as a marker of the severity of cellular exposure and/or response to radiofrequency-modulated electromagnetic fields.

Description of the work:

The proposed project will consist of *in vitro* dosimetry and biological studies. In particular there will be development of dosimetry for a variety of cell culture set-ups and biological markers of cell exposure to RF-ELF of varying SAR.

Exploitation of results:

The results will be used in the development of new health safety standards for portable phones.

Collaborators:

The project is part of the LaVita consortium project that is funded by the National Technology Agency. Kuopio University, J. Juutilainen (co-

ordinator). The consortium consists of 9 research groups from Kuopio University, Turku University, Tampere University, the Finnish Institute of Occupational Health, VVT-Information Technology, FI.

Timetable:

Project has been funded for 2000-2001 with possible extension for 2001- 2003.

Publication plan:

The results will be published in international journals.

Responsible scientist:

Dariusz Leszczynski

Potential health hazards of mobile telephones (REFLEX)

Objectives:

The issue of the potential health risks of mobile telephones remains unclear. The objective of STUK is to study whether radiofrequency-modulated electromagnetic fields have effect in expression of genes or protein and on cell cycle kinetics in vitro.

Description of work:

This research project is part of a EC-funded (Quality of Life) consortium. STUK will investigate the effects of radiofrequency-modulated electromagnetic fields (RF-ELF, 900MHz GSM signal) on the pattern of expression of genes and their protein products and on cell cycle kinetics (proliferation, cell cycle and cell death).

Exploitation of results:

The results obtained in the execution of this project, together with the results of the ongoing study of the RF-ELF effects on protein phosphorylation and receptor function (ongoing since 1998 the National Technology Agency funded project) and the future LaVita/National Technology Agency project, will determine whether there is any potential risk of hazardous effects of cell exposure to radiation emitted by portable telephones. This issue is still uncertain and requires clarification in order to address the public's health concerns.

Publication plan:

The results will be collected in publications in international journals.

Collaborators:

VERUM-Foundation for Behaviour and Environment, F. Adlkofer (coordinator), Munich, D; Universitätsklinikum Benjamin Franklin, R. Tauber, D; Institut fuer Pflanzengenetik und Kulturpflanzenforschung, A.M. Wobus, D; Universität Hannover, H.A. Kolb, D; Universitätsklinik fuer Innere Medizin IV, O. Jahn, A; Hospital Ramon y Cajal, J. Leal, SP; University of Bologna, F. Bersani, I; University of Milan F. Clementi, I; Ecole Nationale Supérieure de Chimie et de Physique, B. Veyret and I. Lagroye, F; Swiss Federal Institute of Technology, N. Kuster, SZ.

Timetable:

The project will commence in 2000 and will take 3 years.

Responsible scientist:

Dariusz Leszczynski

Effects of mobile-telephone-emitted microwave radiation on the functioning of cells*Objectives:*

The issue of the potential health risks of mobile telephones remains unclear. The objective of STUK is to study whether radiofrequency modulated electromagnetic fields have effect on cellular signal transduction.

Description of work:

This research project is part of the National Technology Agency-funded consortium The consortium projects are part of the European Commission COST-244bis programme Biological effects of electromagnetic fields. STUK investigates the effects of radiofrequency-modulated electro-magnetic fields (RF-ELF, 900MHz GSM signal) on receptor-ligand interaction and protein phosphorylation.

Exploitation of results:

The results obtained in the execution of this project, together with the results of the REFLEX/EC and LaVita/National Technology Agency will provide information concerning the potential risk of hazardous effects of the expo-

sure to radiation emitted by portable telephones. This issue is still uncertain and requires clarification in order to address the public's health concerns.

Publication plan:

The results will be published in international journals.

Timetable:

The project began in 1998 and will end in the summer of 2000.

Collaborators:

This research project is part of the National Technology Agency-funded consortium. Kuopio University, J. Juutilainen (co-ordinator) FI, Consortium consists of partners also from Finnish Institute of Occupational Health, VTT Information Technology, FI. The consortium projects are part of the European Commission COST-244bis program "Biological effects of electromagnetic fields".

Responsible scientist:

Dariusz Leszczynski

UV effects on melanoma metastasis (SYTTY)

Objectives:

The study aims at providing information on UV-compromised human immune surveillance of skin cancer, in particular malignant melanoma, evaluating the connection between UV radiation and infectious diseases and examining the possible effect of UV radiation on tumour metastasis.

Description of work:

The project is part of the Finnish Academy programme on Environment and Health (SYTTY).

Exploitation of results:

The results obtained at STUK will provide information concerning the potential health risks of exposure to long-wave UV radiation (UVA) that is, beside solar UV radiation, a major part of the UV-spectrum emitted by solarium. This issue is still uncertain and requires clarification in order to address the public's health concerns.

A PhD thesis of a researcher will be based on this work.

Publication plan:

The results will be published in international journals.

Collaborators:

Turku University, C. Jansén (co-ordinator) FI, Harvard Medical School, Boston, MA, US (Dariusz Leszczynski, R. Rox Anderson, Charles P. Lin).

Timetable:

Project began in 1998 and will end in the summer of 2001.

Responsible scientist:

Dariusz Leszczynski

Use of sunbeds in Finland

Objectives:

This study is divided to two main tasks:

The first task is to assess the ultraviolet radiation dose caused to the population by artificial UV equipment used for cosmetic tanning, i.e. sunbeds. This additional UVR-load is compared to the estimated annual solar UV-dose in Finland. The frequency and characters of the use of sunbeds in different sub-populations is evaluated in order to identify those groups which may be in elevated risk due the high additional UVR-dose.

In the second task the aim is to diminish the hazards and risks associated to excessive UVR exposure while using artificial UVR sources. UV appliances intended for cosmetic tanning shall meet the safety requirements given in the European standard IEC 335-2-27:1995. Additionally, only appliances of UV type 3 are allowed for cosmetic purposes. The compliance with the requirements of the sunbeds marketed and used in Finland, as well as the other safety aspects in the commercial and public solarium facilities is inspected.

Description of the work:

The first task is performed by a randomised population study based on questionnaire. Demographic data is collected as well as information about patterns of use of sunbeds, about attitudes towards solar UVR and sunbathing,

and about colours of eye, hair and constitutive skin in the aim to assess individual sensitivity UVR and risk of skin cancer. Statistical analysis is used to find out how sunbeds are used among different groups of Finnish population. Collected data is used in combination with former measurements of sunbeds UVR output to evaluate the actual UV doses caused by sunbeds.

The second task is done in co-operation with municipal health authorities. In this survey the compliance with the safety requirements of commercial and public solarium facilities is inspected by the local health officers. During the inspections required instructions and warnings are checked, type of used appliances and lamps is detected and information booklets are delivered for the facilities.

Exploitation of results:

Information about the hazards of excessive use of sunbeds can be targeted to the groups of elevated risks. Knowledge of safety requirements and the effects of UVR exposure are enhanced among public and commercial sunbeds enterprises. Safety of sunbeds users is ensured when the observed defects in UV facilities are corrected and marketing UV appliances, which do not meet standards, is prohibited.

Publication plan:

Two STUK-A-series publications based on population survey and inspections of solarium facilities will be published. An information booklet concerning the safety requirements and intended for the sunbeds importers and other professionals has been published. The results will be published also in international scientific series.

Timetable:

The study is completed and the report will be published in STUK-A-series.

Responsible scientist:

Kari Jokela

Restricting exposure to broadband and pulsed electric and magnetic fields

Objectives:

International Commission on Non-Ionizing Radiation (ICNIRP) published in 1998 new recommendations for electromagnetic fields and waves. The guidelines dealing with the exposure to the general public were adopted by the EU Council on the limitation of exposure of the general public to electromagnetic fields. The exposure limits can easily be applied for continuous sinusoidal fields, but in the case of fields consisting of harmonic frequencies at a broad band the recommended practices result in extremely strict limitations having no biological justification. The objective of this project financed by STUK is to develop a biologically sound method and instruments to assess exposure to broadband and pulsed fields below 100 kHz. ICNIRP is currently preparing a clarifying statement on the exposure assessment for pulsed and broadband fields on the basis of this proposition.

Description of the work:

The new exposure assessment method is based on electrophysiological nerve cell stimulation model calculations: The external field strength or induced current density is weighted with a simple high- and low-pass function, respectively, and the instantaneous peak value of the weighted exposure is compared with the exposure limits obtained from the ICNIRP guidelines. This practice results in less severe limitations of the exposure without violating basic exposure criteria. Additionally, exposure measurements are simplified because time domain measurements can be used instead of complex spectral measurements.

The new exposure assessment method has been tested with exposure measurements carried out for different sources of broadband magnetic fields including electronic article surveillance devices (EAS), metal detectors MRI devices and high-power industrial sources. A joint study with the University of Kuopio has been started to systematically study the exposure of cashiers to magnetic fields from near-by EAS devices. New instruments will be developed to facilitate broadband exposure measurements.

Exploitation of results:

The European industry avoids costly investments based on over restrictive exposure limits.

Publication plan:

The results will be presented in conferences, technical reports and scientific journals.

Responsible scientist:

Kari Jokela

STUK-A reports

STUK-A178 Rantavaara A, Calmon P, Wendt J, Vetikko V. Model description of the Forest Food Chain and Dose Module FDMF. Helsinki 2000.

STUK-A177 Rantavaara A, Moring M. Puun tuhkan radioaktiivisuus. Helsinki 2000.

STUK-A176 Lindholm C. Stable chromosome aberrations in the reconstruction of radiation doses. Helsinki 2000.

STUK-A175 Annanmäki M, Turtiainen T, Jungclas, Hartmut, Rausse, Christof. Disposal of Radioactive Wastes by Water Treatment Methods: Recommendations for the EC/ Vedenkäsit-

telyssä syntyvien radioaktiivisten jätteiden hävittäminen: Suosituksia Euroopan Komissiolle. Helsinki 2000.

STUK-A174 Servomaa A, Parviainen T (toim). Säteilyturvallisuus ja laatu röntgendiagnostiikassa 2000. Koulutuspäivät 24. - 25.2.2000 ja 10. - 11.4.2000. Helsinki 2000.

STUK-A173 Hämäläinen RP, Sinkko K, Lindstedt M, Ammann M, Salo A. Decision analysis interviews on protective actions in Finland supported by the RODOS system. Helsinki 2000.

STUK-A172 Turtiainen T, Kokkonen P, Salonen L. Removal of Radon and

Other Natural Radionuclides from Household Water with Domestic Style Granular Activated Carbon Filters. Helsinki 1999.

STUK-A171 Voutilainen A, Mäkeläinen I, Huikuri P, Salonen L, Arvela H. Porakaivoveden radonkartasto/Radon Atlas över borrhunnar/Radon Atlas of wells drilled into bedrock in Finland. Helsinki 1999.

STUK-A170 Saxén R, Koskelainen U, Alatalo M. Transfer of Chernobyl-derived ¹³⁷Cs into fishes in some Finnish lakes. Helsinki 1999.

STUK-A169 Annanmäki M, Turtiainen T (Eds.). Treatment Techniques for Removing Natural Radionuclides from Drinking Water. Helsinki 1999.

STUK-A168 Suomela M, Bergman R, Bunzl K, Jaakkola T, Rahola T, Steinnes E. Effect of industrial pollution on the distribution dynamics of radionuclides in boreal understory ecosystems (EPORA). Helsinki 1999.

STUK-A167 Thoring H, Steinnes E, Nikonov V, Rahola T, Rissanen K. A summary of chemical data from the EPORA project. Helsinki 1999.

STUK-A166 Rahola T, Albers B, Bergman R, Bunzl K, Jaakkola T, Nikonov V, Pavlov V, Rissanen K, Schimmack W, Steinnes E, Suomela M, Tillander M, Äyräs M. General characterisation of study area and definition

of experimental protocols. Helsinki 1999.

STUK-A165 Ilus E, Puhakainen M, Saxén R. Strontium-90 in the bottom sediments of some Finnish lakes. Helsinki 1999.

STUK-A164 Kosunen A. Metrology and quality of radiation therapy dosimetry of electron, photon and epithermal neutron beams. Helsinki 1999.

STUK-A163 Servomaa A (toim.). Säteilyturvallisuus ja laadunvarmistus röntgendiagnostiikassa 1999. Helsinki 1999.

STUK-A162 Arvela H, Rissanen R, Kettunen A-V ja Viljanen M. Kerrostalojen radonkorjaukset. Helsinki 1999.

STUK-A161 Jokela K, Leszczynski D, Paile W, Salomaa S, Puranen L, Hyysalo P. Radiation safety of handheld mobile phones and base stations. Helsinki 1998.

STUK-A160 Voutilainen A, Vesterbacka K, Arvela H. Radonturvallinen rakentaminen - Kysely kuntien viranomaisille. Helsinki 1998.

STUK-A159 Hämäläinen RP, Sinkko K, Lindstedt M, Ammann M, Salo A. RODOS and decision conferencing on early phase protective actions in Finland. Helsinki 1998.

STUK-A158 Auvinen A, Rahu M, Veidebaum T, Tekkel M, Hakulinen T,

Salomaa S, Boice JD Jr (eds) . Cancer incidence and thyroid disease among Estonian Chernobyl clean-up workers. Helsinki 1998.

STUK-A157 Klemola S, Ilus E, Ikäheimonen TK. Monitoring of radionuclides in the vicinities of Finnish nuclear power plants in 1993 and 1994. Helsinki 1998.

STUK-A156 Eloranta E, Jokela K (toim.). The Eight National Electromagnetics Meeting, August 27, 1998. Extended Abstracts. Helsinki 1998.

STUK-A155 Salomaa S, Eloranta E, Heimbürger H, Jokela K, Järvinen H, (toim.). Säteilyturvakeskuksen tutkimushankkeet 1998 – 2000. Helsinki 1998.

The full list of publications is available from:

STUK- Radiation and Nuclear Safety
Authority
P.O. BOX 14
FIN-00881 HELSINKI
Finland
Tel. +358 9 759 881