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RADIATION PRACTICES

Annual Report 2005

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Abstract

1764 safety licences for the use of radiation were current at the end of 2005. 1907 responsible parties were engaged in notifiable licence-exempt dental X-ray practices. Regulatory control of the use of radiation was performed through regular inspections performed at places of use, test packages sent by post to dental X-ray facilities and maintenance of the Dose Register. Radiation safety guides were also published and research was conducted in support of regulatory control.

STUK conducted 458 inspections of licensed practices and 62 inspections of notifiable licence-exempt dental X-ray practices in 2005. 273 remedial orders and recommendations were issued. Use of one appliance was prohibited.

A total of 11 698 workers engaged in radiation work were subject to individual monitoring in 2005. 137 000 dose entries were made in the Dose Register. In no case did the individual dose of any worker exceed the dose limits stipulated in the Radiation Decree.

Regulatory control of natural radiation focused on radon at workplaces and exposure of aircrews to cosmic radiation. 90 workplaces including a total of 233 work areas were subject to radon monitoring during 2005. 2600 pilots and cabin crew members were monitored for exposure to cosmic radiation.

Metrological activities continued with calibration and development work as in previous years.

Regulatory control of the use of non-ionizing radiation in 2005 continued to focus particularly on mobile phones and sunbeds. 15 mobile phone types were tested in market surveillance of mobile phones. A total of 44 sunbed appliances were inspected at 36 sunbed facilities. Most research and development work took place within jointly financed research projects. This work focused especially on developing testing and measuring methods for determining exposure to electromagnetic fields caused by mobile phones and their base stations.

There were 13 abnormal incidents involving the use of radiation in 2005. Eight of these incidents concerned the use of radiation in industry, research and education, and five involved the use of radiation in health care. None of these incidents resulted in serious consequences.

Contents

ABSTRACT 3
MANAGEMENT FOREWORD 5
1 BACKGROUND 7
1.1 Principal Key Figures 7
2 REGULATORY CONTROL OF THE USE OF IONIZING RADIATION 11
2.1 Use of Radiation in Health Care 11
2.2 Use of Radiation in Industry, Research and Education 13
2.3 Inspections of Licensed Radiation Practices 13
2.4 Inspections of Notifiable Dental X-ray Practices 14
2.5 Import, Manufacture and Export of Radioactive Substances 14
2.6 Radiation Doses of Workers 14
2.7 Approval Decisions and Verification of Competence 15
2.8 Radioactive Waste 15
2.9 Abnormal Incidents 16
3 REGULATORY CONTROL OF PRACTICES CAUSING EXPOSURE TO NATURAL RADIATION 19
3.1 Radon at Workplaces 19
3.2 Other Natural Radiation from the Ground 19
3.3 Cosmic Radiation 19
4 REGULATORY CONTROL OF THE USE OF NON-IONIZING RADIATION 20
4.1 General 20
4.2 Optical Radiation 20
4.3 Electromagnetic Fields 21
4.4 Abnormal Indicents 21
5 REGULATION WORK 22
5.1 ST Guides 22
5.2 Other Regulation Work 22
6 RESEARCH 23
6.1 Ionizing Radiation 23
6.2 Non-Ionizing Radiation 24
7 INTERNATIONAL CO-OPERATION 26
8 CO-OPERATION IN FINLAND 28
9 INFORMATION ACTIVITIES 30
10 METROLOGY 31
10.1 Ionizing Radiation 31
10.2 Non-Ionizing Radiation 31
11 SERVICES 33
12 OTHER ACTIVITIES 34
APPENDIX 1 TABLES 35
APPENDIX 2 PUBLICATIONS IN 2005 44
APPENDIX 3 ST GUIDES PUBLISHED BY STUK 49

Management Foreword

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A good standard of safety in the use of ionizing radiation continued in Finland in 2005. The combined total annual radiation dose of workers was slightly lower than in 2004. There was no detectable increase in exposure of the population due to the use of radiation compared to previous years. Rapid technological progress, particularly in the use of radiation in health care, is an international challenge for the sector. This progress also involves increasingly diverse applications and provides greater opportunities for using radiation.

During 2005, the Radiation and Nuclear Safety Authority (STUK) assisted in preparing an amendment to the Radiation Act. This amendment was required by the European Union Directive on the control of high activity sealed sources. The amendment to the Radiation Act took effect on 1 January 2006 and has some impact on users of radiation sources, in particular by requiring the holders of the highest activity sources to furnish a security. A few sources of this kind are used in Finland. While preparing the amendment, STUK asked the holders of sealed sources to prepare an inventory of all of their sources and to check their entries in the source register and their safety licence details. This inventory will be repeated in a few years.

The requirements for reprocessing of decommissioned smoke detectors were revised with a Decree of the Ministry of the Interior. Detectors may no longer be discarded together with ordinary household waste. STUK revised the terms and conditions of safety licences for importers of smoke detectors to require these importers to arrange device recycling, for example by joining a producer organization that organizes collection of decommissioned devices.

STUK has been seeking to improve co-operation with various interest groups. The most important outcome of this work in 2005 was a guide to paediatric X-ray examinations published in association with an organization of paediatric radiologists.

Computed tomography is an increasingly popular examination method involving exposure to radiation. The number of CT appliances has increased by about 30 per cent over the last decade. The new multislice appliances improve diagnostics and provide new opportunities for use. Radiation exposure must be optimized more frequently nowadays. This requires clinical evaluations of image quality that must be systematic and established.

One new type of device that has been discussed and used during 2005 is PET-CT equipment that enables a combination of nuclear medicine examination and computed tomography. When using two imaging modes, attention must be paid not only to radiation safety but also to proper interpretation of images, which requires expertise in both of these special fields.

Digital technology has become an established part of X-ray diagnostics. Development of harmonized methods of digital equipment quality control is an ongoing process requiring further research and develpment by all parties involved. STUK has also been involved in research work in the course of European Union co-operation.

Some new radiotherapy centres are to open in Finland. There is a high level of demand for radiotherapy, which has continued to be an important form of treatment. The accuracy of radiotherapy has been monitored through regular comparison measurements and found to be of a very good standard. The metrological activities of STUK are part of the process of ensuring accuracy in treatment. International comparisons and evaluations of metrological activities conducted in 2005 have likewise demonstrated the high standard of these activities.

A total of 13 abnormal incidents occurred in the use of ionizing radiation during 2005. None of these incidents caused dose limits to be exceeded. The review of abnormal incidents at regular expert seminars has proved to be a good practice. There have been no significant changes in the number of abnormal incidents compared with previous years.

The Laboratory for Non-Ionizing Radiation Surveillance (NIR Laboratory) serves as a regulatory authority for non-ionizing radiation and provides specialist assistance to the National Agency for Medicines and the labour protection authorities. Regulatory control of non-ionizing radiation has focused particularly on sunbed facilities and mobile phones have also been a special area of investigation since 2003. Some of the main points of research in recent years have included dosimetry of radio and low frequency electromagnetic fields, pulsed magnetic fields and the development of increasingly accurate methods of measuring ultraviolet radiation. Implementation of the European Union Directive on electromagnetic fields in Finland by the year 2008 is increasing the need to assess worker exposure to such fields and to train personnel who are responsible for ensuring health and safety at work. A great deal of information regarding the safety of electromagnetic fields has been exchanged in recent years.

In 2005, STUK was responsible for preparing a Nordic opinion on the use and radiation safety of sunbed equipment. This opinion will influence the development of standards in Europe. The radiation values of mobile phones tested in the course of market surveillance did not exceed the prescribed maximum value. Work was done in association with the Finnish Defence Forces to improve statutes and control measures for RF radiation from radar and radio equipment.

The main topics of investigation for non-ionizing radiation were the effect of UV-A radiation on melanomas in mice, exposure of workers to stray RF radiation from high-frequency heaters and the development of testing and measuring methods for determining the exposure caused by electromagnetic fields from mobile phones and their base stations.

1 Background

The expression "use of radiation" refers to the use and manufacture of, and trade in radiation appliances and radioactive substances, and to related activities such as possession, safekeeping, servicing, repairs, installation, import, export, storage, transport and rendering radioactive waste harmless. The expression "radiation practices" refers to the use of radiation and also to operations or circumstances in which human exposure to natural radiation causes or may cause a health hazard.

The expression "radiation" refers to both ionizing and non-ionizing radiation.

Regulatory control of safety in uses of radiation and other practices causing exposure to radiation in Finland is the responsibility of the Department of Radiation Practices Regulation (STO) and the Laboratory for Non-Ionizing Radiation Surveillance (the NIR Laboratory) at STUK.

1.1 Principal Key Figures

The principal key figures for uses of radiation and other practices causing exposure to radiation are shown in Figures 1–6.

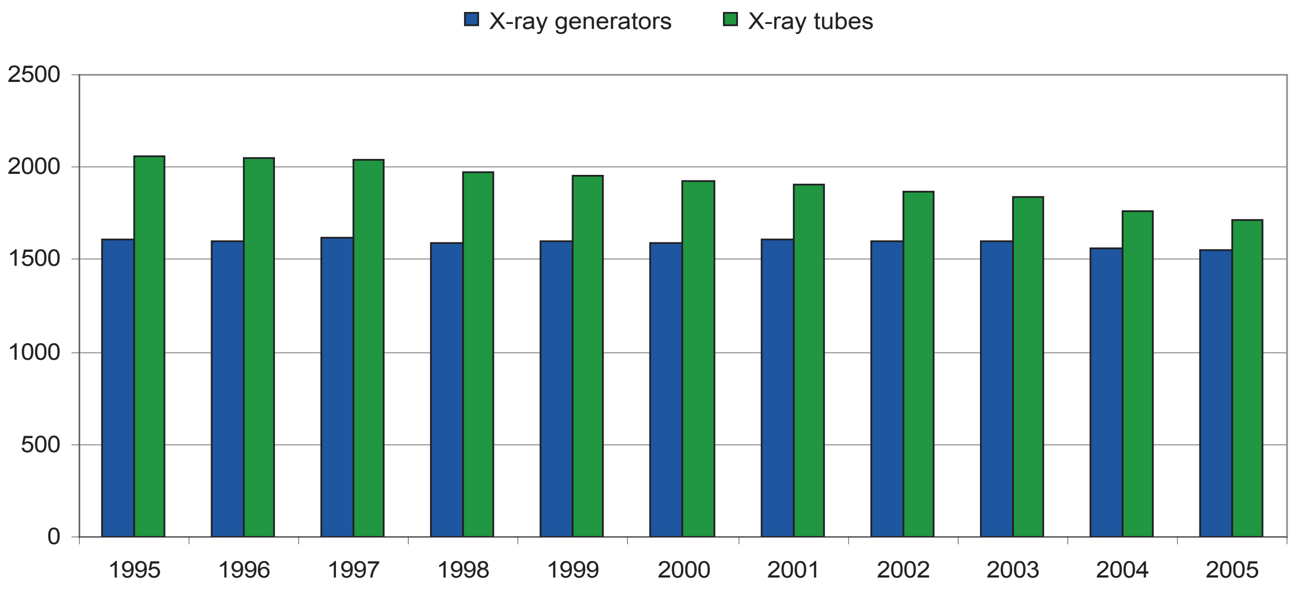

Figure 1. Licensed X-ray generators and tubes in health care, 1995–2005.

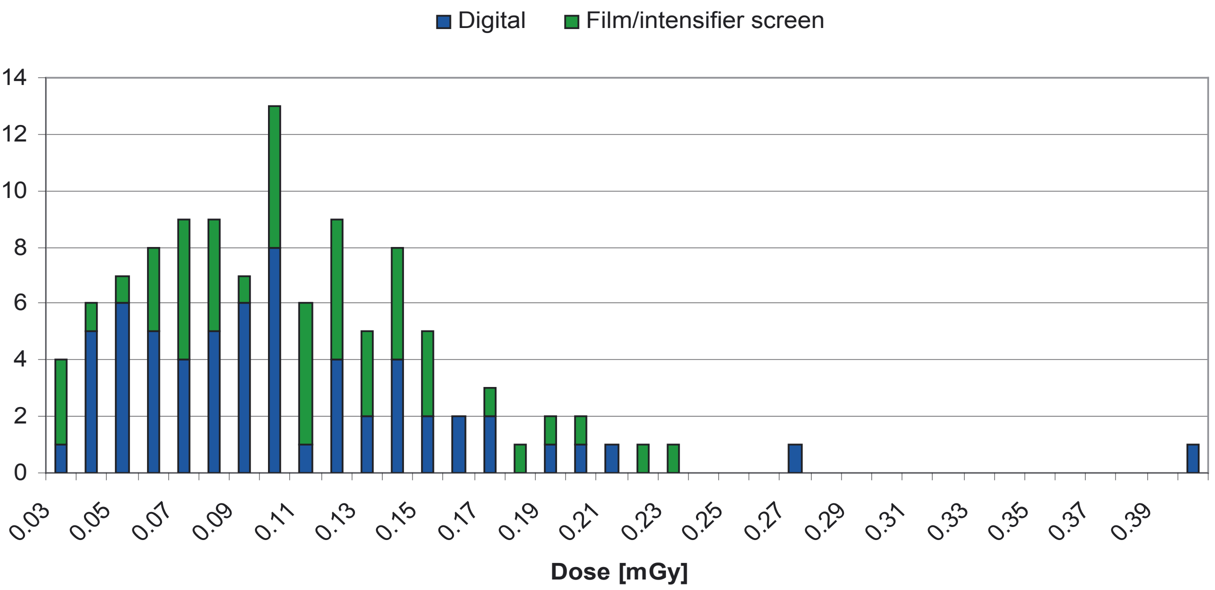

Figure 2. Patient (thorax PA) dose distributions measured in the course of inspections by STUK in 2005. Averages: Digital 0.10 mGy, film/intensifier screen 0.11 mGy. Averages in previous years: 1995: 0.19 mGy, 2000: 0.13 mGy. Reference level 0.2 mGy.

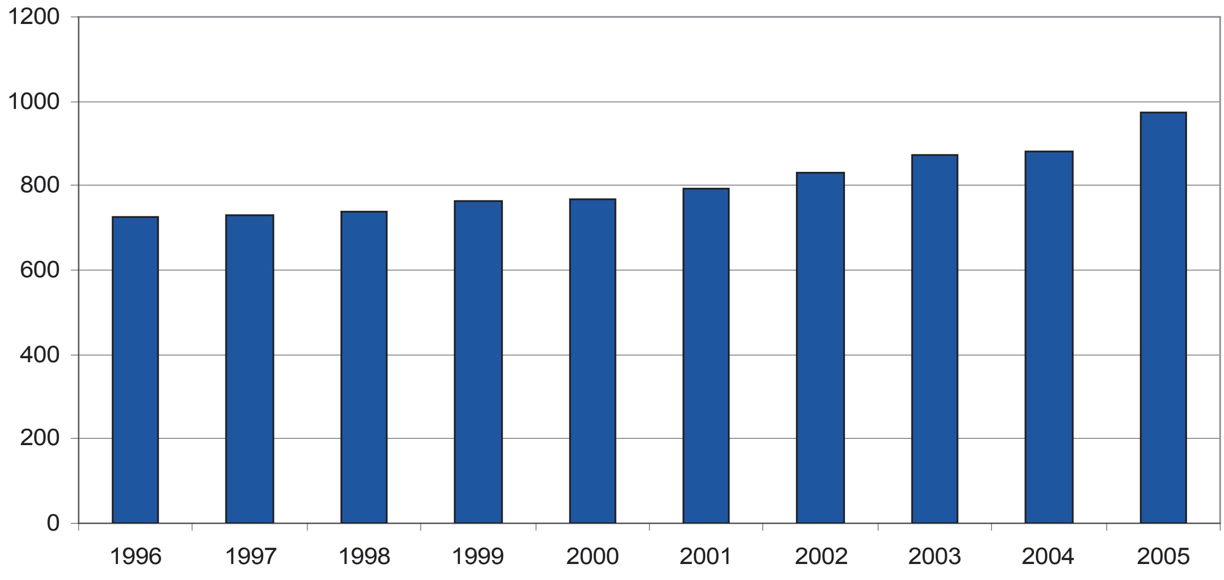

Figure 3. X-ray equipment and accelerators in industry, research and education, 1996–2005.

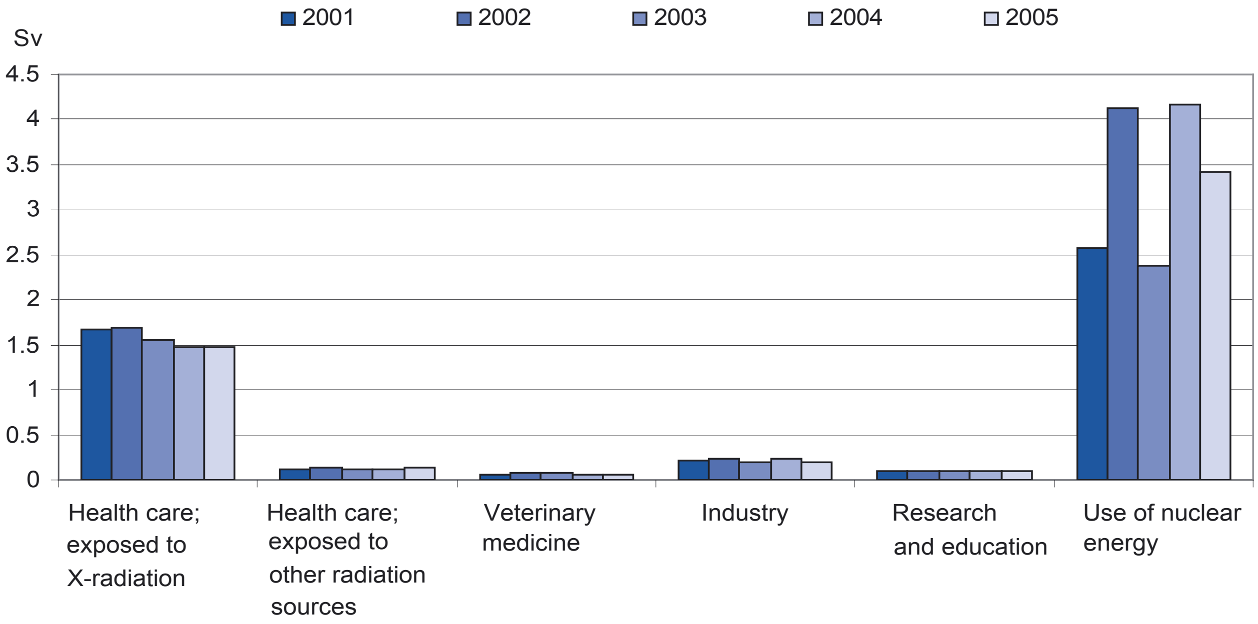

Figure 4. Combined doses ($H_p(10)$) of workers subject to individual monitoring by occupational category, 2001–2005.

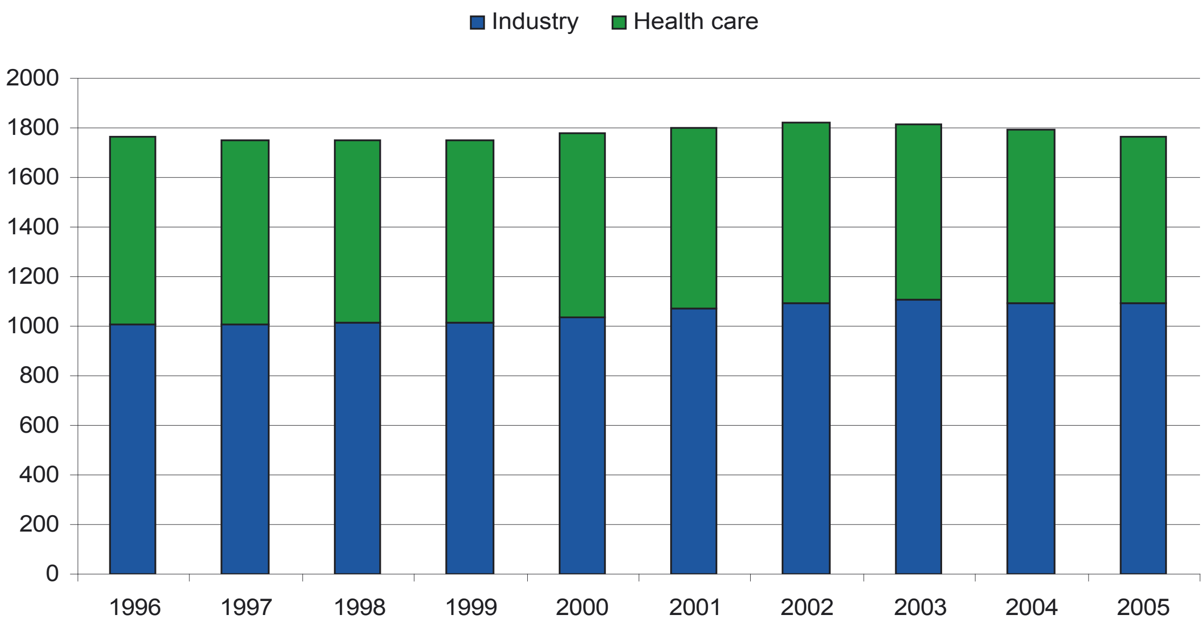

Figure 5. Current safety licences, 1996–2005.

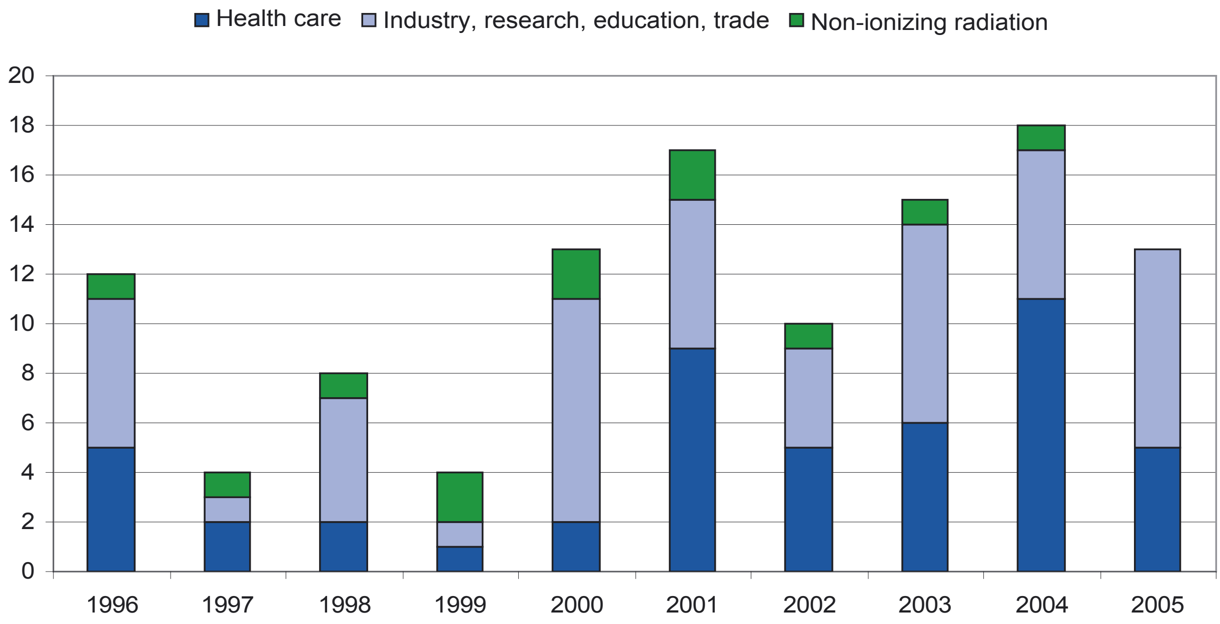

Figure 6. Abnormal incidents, 1996–2005

2 Regulatory Control of the Use of Ionizing Radiation

2.1 Use of Radiation in Health Care

Safety licences

670 safety licences for the use of radiation in health care were current at the end of 2005. The numerical distribution of radiation practices referred to in these licences is shown in Table I of Appendix 1. There was no substantial change in the total number of safety licences compared to the previous year (Figure 5 in item 1.1). The total number of licences is falling. The licences for some small X-ray establishments have been discontinued or combined with other licences at the request of the licensee. The safety licences of some university hospital districts have been adjusted to correspond more closely to the current radiation user's organization. Some new safety licences were granted for veterinary X-ray practices, and the growth trend appears to be continuing both in the number of current licences and in the number of appliances used (see Figure 9). No new safety licences were granted in 2005 for radiotherapy or for the medical use of unsealed sources.

Radiation appliances and sources and laboratories

The number of computed tomography (CT) appliances is increasing. Since 1995 this number has risen by one third, with 80 such appliances in use by the end of 2005 (see Figure 7). 71 of these were used for traditional computed tomography imaging. Seven appliances were combined with single photon emission tomography (SPET) and one appliance was used with positron emission tomography (PET). One PET-CT appliance was also installed in a lorry for part-time use and five appliances were used for special purposes, principally dental computed tomography. A further six CT appliances were also used for radiotherapy simulation.

The information-gathering phase of an investigation into quality assurance of computed tomography equipment and optimization of examinations was concluded in 2005 and the provisional findings were reported at an expert seminar. As a result of this investigation, computed tomography equipment became one focus of regulatory control. The findings indicated that several radiation users should become more familiar with quality control and optimize their examinations. A full report of the investigation will be completed in 2006.

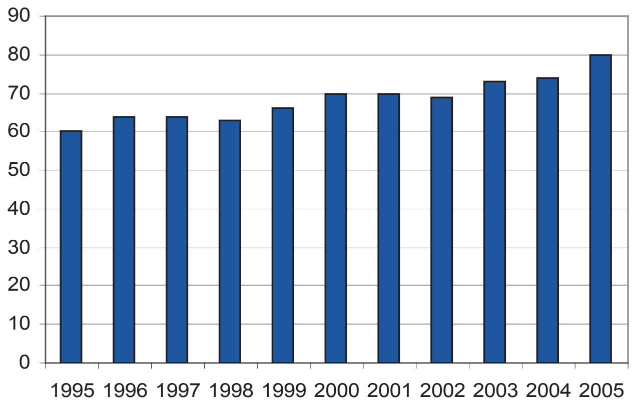

Figure 7. CT appliances, 1995–2005.

Bone mineral density measuring appliances based on the use of dual energy X-ray absorptiometry (DXA) have become substantially more common in recent years. The number of these appliances has increased fivefold since 1995 (see Figure 8). In 2004–2005, STUK took measurements from 17 of these appliances and investigated the patient doses arising from bone mineral density measurements (see item 6.1, Academic thesis work). Regulatory control measures noted a high rate of referrals for bone mineral density measurement in some districts. STUK would like to point out that under section 38 of the Decree of the Ministry of Social Affairs and Health on the Medical Use of Radiation (423/2000), the expression “screening involving exposure to radiation” denotes screening and other mass examination in which radiological equipment is used in early diagnosis of cases of disease for the examination of persons showing no symptoms and belonging to high risk population groups. Screening based on bone mineral density measurement must be separately justified and submitted for evaluation to the National Research and Development Centre for Welfare and Health (STAKES). Under section 39 of the said Decree, screening may be approved if it is assessed as justified and if the benefit to public health thereby achieved outweighs the overall drawbacks thereby caused.

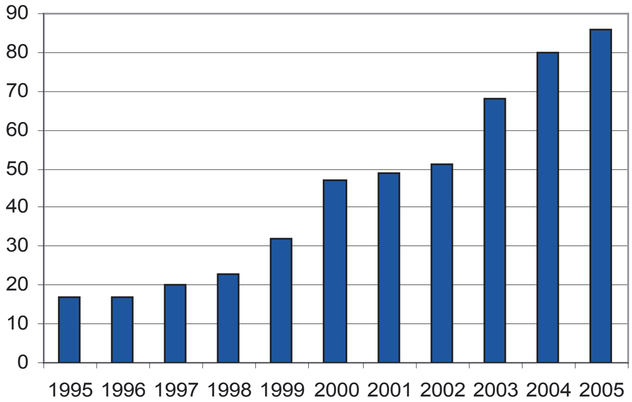

Figure 8. Bone mineral density measuring appliances, 1995–2005.

The number of veterinary X-ray appliances is increasing. This figure has risen by more than one quarter since 1995 (Figure 9). A particular increase has occurred in the number of appliances for X-ray imaging of small animals and of the number of places of use for such equipment.

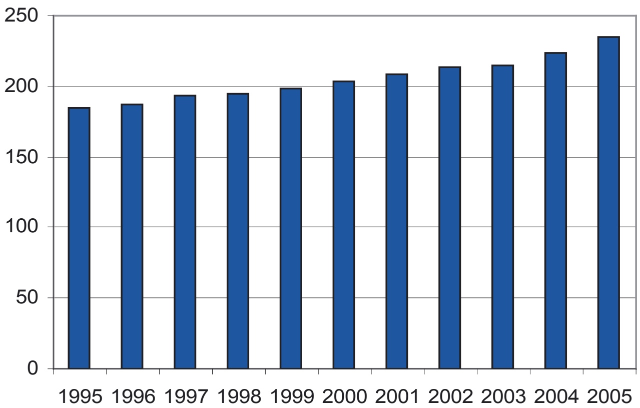

Figure 9. Veterinary X-ray appliances, 1995–2005.

Radioimmunological assays (in vitro) using indicator compounds labelled with radioactive substances have been supplanted by other technologies, leading to a rapid fall in the number of C-type radionuclide laboratories and unclassified other laboratories (Figure 10). Hospital nuclear medicine departments are mainly B-type laboratories. The number of these laboratories has remained virtually unchanged for a decade.

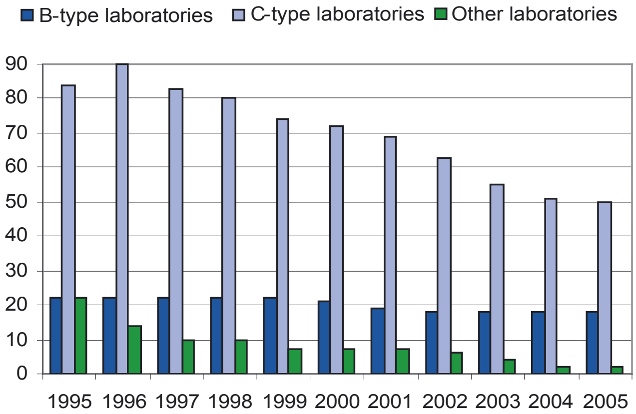

Figure 10. Radionuclide laboratories engaged in the use of radiation in health care, 1995–2005.

30 linear accelerators were used for radiotherapy in 2005. There were 23 such accelerators in 1995. The increase in the number of accelerators has been steady. The number of afterloading appliances has remained nearly constant at 11 appliances. They are mainly used at university hospitals. A boron neutron capture therapy (BNCT) unit was also used. CT appliances have been introduced for radiotherapy simulations, and this practice is still spreading.

Table II in Appendix 1 shows further details of radiation appliances and sources used in health care and in veterinary X-ray practices, and radionuclide laboratories that were entered in the safety licence register at the end of 2005. The number of licensed X-ray generators and tubes in health care in 1996–2005 is shown in Figure 1 (item 1.1).

Reference levels

In 2005, STUK issued reference levels for paediatric bronchial imaging, sinus imaging and mictiocystography, and for coronary angiography (CA) and percutaneous transluminal coronary angioplasty (PTCA).

Measurements taken in the course of inspections revealed that the reference levels issued for X-ray examinations of adults were exceeded at six inspection sites in 2005. Nuclear medicine examination reference levels are monitored through questionnaires completed at three-year intervals, the last of which was done based on data from 2003.

2.2 Use of Radiation in Industry, Research and Education

Safety licences

1094 safety licences for the use of radiation in industry, research, education, trade and servicing activities were current at the end of 2005. The number of licences has risen by about 10 per cent over the last decade (Figure 5 in item 1.1). The numerical distribution of radiation practices referred to in these licences is shown in Table III of Appendix 1.

47 new safety licences were granted and 239 applications for amendments to existing licences were processed during 2005. 102 of these amendments concerned a change in the radiation safety officer and 137 concerned other changes such as commissioning of new equipment. A further 144 decisions were made to discontinue a licence or part thereof due to discontinuation of the practice or decommissioning of a radiation source.

Radiation appliances and sources and laboratories

Figure 11 shows the number of appliances containing radioactive substances over the last ten years. Although the number of appliances of this kind increased clearly after the mid 1990s, there have been no appreciable changes in this figure since the year 2000.

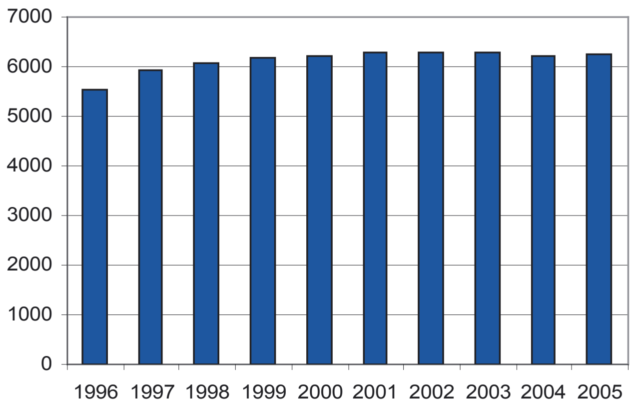

Figure 11. Appliances containing radioactive substances entered in safety licences for the use of radiation in industry, research and education, 1996–2005.

The number of X-ray appliances and accelerators used over a ten-year period is shown in Figure 3 (item 1.1). This number has increased by more than 30 per cent. New fluoroscopy appliances have been introduced for security checks and product inspections. And the use of X-ray tubes has also increased in analytical equipment.

Table IV in Appendix 1 shows further details of radiation appliances and sources and of radionuclide laboratories in industry, research and education that were entered in the safety licence register at the end of 2005.

Table V in Appendix 1 shows the number and total activities of radionuclides used in sealed sources.

Inventory survey

During 2005, an inventory questionnaire was sent to all responsible parties using sealed sources (600 recipients), requesting verification that all of the sources in the custody of the responsible party were in their appropriate places of use. It was discovered that three radiation sources had gone missing (see item 2.9). 94 other notifications were received that required modifications in safety licences. These included changes in the name of the responsible party, changes of radiation safety officer, and commissioning or decommissioning of new equipment. 113 amendments to contact details, revisions of radiation source serial numbers and other minor amendment notifications were received as a result of the survey.

The findings of the inventory survey indicate that STUK is not always notified promptly of changes in uses of radiation. The cases of lost radiation sources also revealed deficiencies in the bookkeeping of responsible parties. Similar surveys are clearly required in addition to periodic inspections in order to ensure the safe use of radiation.

2.3 Inspections of Licensed Radiation Practices

317 inspections were made of the use of radiation in health care. These inspections resulted in 149 remedial orders or recommendations issued to the responsible party. Use of one unlicensed accessory for X-ray practice was also prohibited. A safety licence must be obtained for this accessory before it may be used.

141 inspections were made of the use of radiation in industry, research, education and trading. These inspections resulted in 61 remedial orders or recommendations issued to 46 responsible parties. The most common shortcomings were in warning markings and labelling.

Table VI in Appendix 1 shows the number of inspections itemized by type of inspection. Table VII shows inspections of licensed practices itemized by type of inspection.

2.4 Inspections of Notifiable Dental X-ray Practices

1907 responsible parties were engaged in dental X-ray practices. Patient radiation exposure due to dental X-ray imaging was measured in 1302 appliances. The average dose was 2.5 mGy. This dose corresponds to the dose administered at the surface of the cheek when imaging a tooth. The reference level of 5 mGy was exceeded in 48 imaging appliances.

62 inspections of notifiable dental X-ray practices were made. These inspections resulted in 63 remedial orders or recommendations issued to 39 responsible parties.

Inspections of dental X-ray practices itemized by type of inspection are also shown in Table VI of Appendix 1.

2.5 Import, Manufacture and Export of Radioactive Substances

Details of radionuclides imported to, manufactured in and exported from Finland in 2005 are shown in Tables VIII–X of Appendix 1. The figures in the tables are based on data gathered from radiation safety licensees engaged in import, manufacture and export. The import and export statistics exclude radioactive substances imported and exported by responsible parties within the European Union for their own use. The statistics also exclude radioactive substances supplied to other countries via Finland.

Table VIII of Appendix 1 excludes smoke detectors and fire alarm system ion detectors containing americium (^{241}Am). A total of 354 982 such devices were imported with a combined activity of about 12.1 GBq.

2.6 Radiation Doses of Workers

A total of 11 698 workers engaged in radiation work were subject to individual monitoring in 2005. 137 000 dose entries were made in the register maintained by STUK.

In no case did the effective dose of a worker exceed the 50 mSv annual dose limit or the 20 mSv average annual dose based on the five-year dose limit (100 mSv). In no case did the dose to a worker's hands exceed the annual limit of 500 mSv.

The total dose was 1 per cent lower in use of radiation and 18 per cent smaller in use of nuclear energy than the corresponding figures for the previous year. Total doses in the use of nuclear energy vary considerably each year depending on the duration of annual servicing and the duties performed in servicing work.

The largest personal dose equivalent $H_p(10)$ arising from uses of X-radiation in health care was 42.2 mSv recorded for an interventional radiologist. This corresponds to an effective dose of about 0.7–4.2 mSv. The largest $H_p(10)$ in veterinary diagnostics was 8.3 mSv, recorded in the case of a veterinary surgeon. This corresponds to an effective dose of about 0.1–0.8 mSv. The largest effective dose in industry was a dose of 10.8 mSv sustained by a person who had used sealed sources.

The largest effective dose sustained in research and education was 17.1 mSv recorded for a person who had used unsealed sources. The largest dose to the fingers was 239.4 mSv, recorded in the case of a laboratory assistant who had used unsealed sources.

The total dose sustained by workers at Finnish nuclear power plants was 3.1 Sv (sum of effective doses). 2.6 Sv of this total dose was recorded for outside workers and the remaining 0.5 Sv was sustained by the permanent staff of the power plants. The largest Hp(10) was 14.8 mSv, sustained by a person working in mechanical and maintenance duties. Some of this dose was sustained while working at a nuclear power plant in Sweden. Some industrial radiographers working in industry also work at nuclear power plants. The radiation doses that they sustain at nuclear power plants are reckoned together with the dose for persons working in material testing (see Table XIII of Appendix 1).

Effective doses exceeding 0.1 mSv and arising from exposure to internal radiation were sustained in the case of nine nuclear power plant workers and one person working in research. The combined dose sustained by these workers from exposure to internal radiation was 1.7 mSv.

29 accounts of worker dosimetry were prepared.

Table XI of Appendix 1 shows the number of workers by occupational category subject to individual monitoring over the last five years. The combined doses of workers by occupational category are shown in Figure 4 (item 1.1) and in Table XII. Table XIII shows the doses in 2005 of persons sustaining high levels of exposure or of numerically large worker groups. The measurement results ($H_p(10)$ values) shown in the figures and tables are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the use of X-radiation in health care and veterinary diagnostics, in which workers use personal protective shields and in which the dose is measured by a dosemeter on the exposed side of the shield. The effective dose is then obtained by dividing the measurement result ($H_p(10)$ value) by a factor between 10 and 60.

Monitoring of radiation exposure when working abroad

67 radiological monitoring documents were supplied from the Dose Register during 2005. These documents were required by persons undertaking radiation work assignments abroad. The number of documents issued varies from year to year, for example due to training courses abroad. When the person returns to Finland the document is returned to STUK so that radiation doses sustained while abroad can be entered in the Dose Register. The radiation safety authorities of Finland and Sweden have agreed on a procedure whereby nuclear power plants in each country notify the dose sustained by a worker directly to the dose register of the worker's country of origin. This means that Finnish workers who are assigned to nuclear power plants in Sweden do not need radiological monitoring documents, and an extract from the Dose Register may constitute sufficient documentation.

2.7 Approval Decisions and Verification of Competence

Approved dosimetric services

There are four dosimetric services operating in Finland, three measuring worker exposure to external radiation and one measuring exposure to internal radiation. STUK controls the reliability of external radiation dosimetry by inspecting and approving dosimetric services and the methods that these services employ, and by conducting "blind tests" of these services. Blind tests of the external radiation measurement services (Doseco Oy and the nuclear power companies) conducted in 2005 indicated that the dosimetric services satisfied the applicable requirements. STUK's dosimetric service that measures exposure caused by internal radiation was audited in 2005. A new method of finger dose measurement was also examined and approved for use at Doseco Oy.

Training organizations providing radiation safety training for radiation safety officers

STUK stipulates the qualifications that are required for radiation safety officers and investigates compliance with these stipulations. Training organizations that arrange training and competence exams for radiation safety officers must therefore apply to STUK for the right to arrange such exams. 17 applications from training organizations were reviewed and decided in 2005. There is a list of approved training organizations on the STUK website.

Responsible practitioners

STUK verifies the qualifications of medical practitioners responsible for medical surveillance of category A workers. At the end of 2005, there were 215 responsible practitioners in Finland, 23 of whom were accredited during 2005.

2.8 Radioactive Waste

184 waste packages had been transported to the national storage facility for low-level radioactive waste maintained by STUK by the end of 2005 (there were no such shipments in 2005). The activities or masses of the most significant waste held in the storage facility are shown in Table XIV of Appendix 1.

Before the waste is sent to the storage facility it is transported to an interim storage unit at STUK's premises in Helsinki. This interim storage unit received 50 batches of low-level waste in 2005, comprising a total of 140 packages. Table XV of Appendix 1 shows the activities or masses of the waste consigned to STUK in 2005.

2.9 Abnormal Incidents

There were 13 cases in 2005 in which abnormal incidents or situations occurred or were suspected in the use of ionizing radiation. 8 of these cases concerned the use of radiation in industry and research and 5 involved the use of radiation in health care. The number of abnormal incidents that occurred between 1996 and 2005 are shown in Figure 6 of item 1.1.

The case histories set out below specify the abnormal incidents that occurred in 2005 and the reasons for them, together with the measures taken on account of each incident.

Incident 1

The wrong radiopharmaceutical was mistakenly administered to a patient. This patient was scheduled for skeletal gamma imaging using a ^{99m}Tc-labelled radiopharmaceutical, but was mistakenly given a ^{99m}Tc-labelled radiopharmaceutical intended for cardiac examinations. The additional radiation exposure caused to the patient was estimated at 1.5 mSv. The patient was immediately informed of this error and the workers concerned were re-instructed in the correct procedures with particular reference to the importance of proper care and attention in order to prevent any recurrence of such an incident.

Incident 2

When administering radionuclide therapy (^{153}Sm-EDTMP at an activity of 2385 MBq), a connection point failed between the medicine administration valve of the canula and the syringe, allowing the radiopharmaceutical to flow over the skin of the patient, onto a protective paper and to a limited extent also onto the patient’s clothing. Appropriate decontamination measures were taken and the contaminated clothing and decontamination instruments were consigned to a store to allow the activity to decay to a safe level. A gamma camera measurement indicated that the estimated activity sustained by the patient was less than 7 MBq. The estimated activity of the skin contamination to the patient’s arm was less than 4 MBq. A new round of radionuclide therapy was subsequently planned for the patient. The staff involved in the incident examined the sequence of events and the follow-up measures under the direction of the radiation safety officer.

Incident 3

A fume cupboard was contaminated during dilution of an ^{131}I-MIBG therapy dose after a syringe became detached from the needle. Based on the residual activities measured in the syringe and bottle, the activity released to the cupboard was estimated at 550 MBq. The worker concerned closed the cupboard and changed clothing. The dose rate within the cupboard was up to 100 µSv/h. For this reason, a decision was taken to keep the cupboard closed and operating on full power for not less than 1.5 months, after which its cleanliness was verified by measurements. The dose rate outside the cupboard did not exceed 2 µSv/h. The worker’s thyroid gland was monitored for internal contamination after four days, but no ^{131}I contamination was detected.

Incident 4

A patient scheduled for skeletal gamma imaging using a ^{99m}Tc-labelled radiopharmaceutical was mistakenly given 580 MBq of pure ^{99m}Tc pertechnetate. The additional radiation exposure caused to the patient was estimated at 7.5 mSv. The patient was immediately informed of the matter and the skeletal gamma imaging was performed at a later time. The workers concerned were instructed to consider ways of avoiding any recurrence of such an incident.

Incident 5

When changing the ^{192}Ir radiation source of a radiotherapy afterloading appliance, the said source emerged from its transportation container when the transfer hose was detached and two physicists were exposed to radiation. The ^{192}Ir radiation source (70 GBq) was transferred from the afterloading appliance to a transportation container. On detaching the transfer hose it was found, due to an alarm from a radiation monitoring meter and a visual inspection, that the radiation source had emerged from the container. The source was returned to the afterloading appliance and then transferred to the transportation container again. The cause of the incident was considered to be late engagement of the locking brake on the transportation container after the transfer hose had already been detached. One of the physicists was estimated to have sustained exposure of 2.1 mSv to the fingers and 0.3 mSv to the entire body. The corresponding estimates for the other physicist were 6.4 mSv and 0.3 mSv, respectively. The persons involved reviewed the incident together with the radiation safety officer.

Incident 6
An importer of sealed sources received a decommissioned ^{137}Cs radiation source (370 MBq) complete with shielding from a Finnish responsible party. On opening the transportation package it was observed that the radiation source was mounted sideways on the transportation pallet and that its shutter was open. The dose rate in the source radiation beam at a distance of 1 metre from the source was 15–20 µSv/h. While the importer had sent precise handling and packaging instructions to the responsible party, the shutter has evidently been turned to the “open” position at the packaging stage due to human error. The shutter position indicator signs were also hard to observe. It is unlikely that anybody sustained a significant radiation dose during transportation or other handling. The activity of the source is fairly low, the radiation beam is narrow (10 cm at a distance of one metre) and persons handling the transportation pallet would not have to work in the immediate vicinity of the source.

The responsible party that sent the radiation source was instructed to ensure in future that radiation sources are packaged and transported in accordance with regulations and as instructed.

Incident 7
A package containing glass tubes and bearing a label for radioactive material was delivered to a hazardous waste collection point. The glass tubes were old radar components. Although such tubes may contain a small amount of radioactive tritium, the quantity is so trivial that is was not detectable in measurements made through the glass tube wall by STUK. Handling or storage of the glass tubes therefore causes no radiation exposure to any person. The tubes were sent to STUK's storage facility for low-level waste.

Incident 8
STUK was notified of equipment bearing a radiation warning sign in the garage of a condominium building. Inspectors from STUK visited the site to investigate and take measurements on the equipment, and verified that it did not contain radioactive materials. It was also found that the equipment was a decommissioned measuring device for determining the filling level of beverage containers that the beverage plant radiation safety officer had temporarily stored in his own garage. Although the ^{241}Am sealed sources contained in the equipment had been properly removed before decommissioning, the warning labels had not been removed. The radiation safety officer then removed all radiation warning labels from the apparatus.

Incident 9
An inspection of a beverage plant revealed that two stored ^{241}Am radiation sources (with activities of 3700 and 3330 MBq) had been mislaid. The radiation safety officer was asked to provide an account of the incident and of the measures that would be taken to ensure that it did not recur. The whereabouts of the missing sources remains unknown.

Incident 10
An appliance bearing a radiation warning label was found in a scrap metal yard. An inspection at the scrap yard and subsequent measurements showed that the appliance in question was a ^{226}Ra reference source (activity of 0.37 MBq) for a liquid scintillation counter. Although use of such sources is exempt from safety licensing, decommissioned sources should nevertheless be treated as radioactive waste. The source was sent to STUK waste storage unit.

Incidents 11–13
An inventory survey conducted by STUK (see item 2.2) revealed that various responsible parties had lost three radiation sources:
- a ^{60}Co source for a density gauge, 18 MBq (activity on 31 December 2005)
- a ^{137}Cs test source, 366 kBq

- an ^{241}Am ionization source, 60 MBq.

The density gauge had been in long-term storage, and the cause and time of its disappearance has not been verified. The test source was lost when other goods kept in the same storage premises were taken out of use in 2004. The ionization source had been used for research and had obviously been loaned out for use by another party several years ago without proper bookkeeping. Neither the borrower nor the whereabouts of the source have been determined, however.

The responsible parties that lost these sources were instructed to maintain more precise records of their radiation sources.

3 Regulatory Control of Practices Causing Exposure to Natural Radiation

3.1 Radon at Workplaces

During 2005, STUK was notified of the results of a total of 226 radon measurements pertaining either to a measured radon concentration exceeding the action level of 400 Bq/m^3 in work area, or to further investigations of previously reported excessive levels. A total of 75 inspection reports were sent to enterprises on the basis of radon measurements. These reports required reductions in radon concentrations or an investigation of radon concentration during working hours in 70 work areas, and a measurement at another time of year in order to determine an annual average in 13 work areas. Radon concentrations were successfully reduced in 56 work areas during the year. STUK discontinued regulatory control in five work areas on the basis of further investigations (measurement during working hours or determination of annual averages). 90 workplaces including a total of 233 work areas were subject to control by STUK during the year.

A periodic radon inspection was conducted at two underground mines, at both of which the average radon concentration fell below the action level. Eleven underground excavation sites were inspected, at one of which the radon concentration exceeded the action level.

Radon exposure of workers was monitored by regular radon measurements and monitoring of working hours at four conventional workplaces and one excavation site where the radon concentration exceeded the action level. A total of 39 workers were subject to radon exposure monitoring during 2005.

The measuring instruments or methods used for establishing radon concentrations when determining worker exposure to radiation must be approved by STUK. Instruments provided by the organizations listed in Table XVI of Appendix 1 have been approved in this way. It is a condition of such approval that the instrument is properly calibrated.

3.2 Other Natural Radiation from the Ground

STUK monitors radiation exposure caused by radioactive substances that occur naturally in water intended for human consumption, construction materials and other materials. Inspection reports on four activity measurements of construction materials and one activity measurement of water intended for human consumption were prepared in 2005. Three statements were also issued on the use of materials as raw materials, on material processing and on worker exposure.

3.3 Cosmic Radiation

Six parties engaged in aviation operations were instructed to investigate the radiation exposure caused to their employees by flight work. These investigations indicated that exposure to cosmic radiation was sufficient to require four airlines to arrange radiation exposure monitoring for their employees.

The staff doses notified by Finnair Oyj and Oy Air Finland Ltd were recorded in the dose register. The largest individual doses of cosmic radiation were 4.3 mSv sustained by a pilot and 5.2 mSv sustained by a cabin crew member. The average annual doses sustained were 1.8 mSv for pilots and 2.0 mSv for cabin crews. The number of workers subject to individual monitoring of radiation exposure and their combined effective doses are shown in Table XVII of Appendix 1.

4 Regulatory Control of the Use of Non-Ionizing Radiation

4.1 General

The expression “non-ionizing radiation” refers to ultraviolet radiation, visible light, infrared radiation, radio-frequency radiation, and low-frequency and static electric and magnetic fields. STUK controls practices giving rise to non-ionizing radiation, even though this control is not directly comparable to regulatory control of the use of ionizing radiation.

The principal focus of regulatory control measures since 1995 has been sunbed appliances and their places of use. Another important focus is on mobile phones, which have been subject to market surveillance since 2003. The use of high power laser equipment at public performances fell considerably in the recession years of the early 1990s. In recent years, however, there has been renewed interest in “show lasers” with the development of advanced laser technology (semiconductor lasers).

Annual inspections have been made of a few public broadcasting stations, mobile phone base stations and radar stations.

The work of the NIR Laboratory in regulatory control of the use of non-ionizing radiation between 2000 and 2005 is shown in Table XVIII of Appendix 1. Most regulatory inspection work takes place at sunbed facilities and in market surveillance of mobile phones. The number of regulatory inspections has partly increased due to radiation testing of mobile phones.

4.2 Optical Radiation

Regulatory control of sunbed equipment

Collaboration with municipal health authorities began in 1998 with an extensive review of sunbed facilities and training of health inspectors in sunbed inspection procedures. Collaboration with health inspectors in 2005 chiefly consisted of consultancy regarding inspections, for example when determining the radiation characteristics of ultraviolet lamps in use and the compliance of equipment with safety standards. Some inspections were made in association with local health inspectors. Lectures on ultraviolet radiation, sunbed equipment and health were also delivered at an environmental medicine course arranged by the University of Kuopio and the Ministry of Social Affairs and Health for environmental health, health care and environmental protection staff.

Inspections of sunbed facilities began in 1995. The number of inspections made by STUK since the year 2000 is shown in Table XIX of Appendix 1. 36 facilities were inspected in 2005. Ten of these had either discontinued sunbed services or the enterprise was no longer operating. Deficiencies affecting the safety of sunbed users were found at almost all facilities. A total of 44 sunbed appliances were inspected. About one quarter of these did not belong to the appliance class that is approved in Finland (UV type 3), which is slightly more than in previous years. In only one case were there no written instructions for the user of an appliance. While about half of the appliances inspected had instructions that comply with safety regulations, nearly one third of these appliances also provided additional information that conflicted with the said regulations. Only just under half of the instructions for use included the recommendation limiting annual use of sunbed appliances and the 18-year age limit recommendation under the Decree of the Ministry of Social Affairs and Health on the Limitation of Public Exposure to Non-Ionizing Radiation (294/2002). Four out of every ten appliances lacked the required timer that enables selection of recommended exposure times and switches the appliance off after the set period has elapsed.

Other regulatory control

Negotiations conducted between STUK and the Finnish Psoriasis Association investigated the measures necessary to improve safety of ultraviolet therapy equipment leased to patients with skin disorders. It was found that the Association has engaged in independent work with dermatologists to create adequate illumination charts and other necessary instructions. STUK provided further guidance in dose calculation.

One commercially available ultraviolet appliance used for dermal analysis was inspected in the course of market surveillance procedures.

The health and safety risks of ultraviolet lamps installed at a brewery were investigated by measurements taken at the place of use.

Four high power laser appliances for use at public performances were inspected.

4.3 Electromagnetic Fields

Market surveillance of mobile phones

Market surveillance of mobile phones began in 2003. Radiation tests have been conducted on a total of 45 mobile phones to date (see Table XX of Appendix 1). 15 mobile phones were tested in 2005. The SAR values of these mobile phones varied between 0.27 and 1.23 W/kg, meaning that in no case did the SAR value of a mobile phone exceed the maximum value of 2 W/kg. Testing of UMTS mobile phones was deferred until 2006, as the importer was unable to supply a reasonably priced base station simulator suitable for testing.

Other regulatory control

The most significant radiation safety improvement project was work done in association with the Finnish Defence Forces to improve statutes and control measures for RF radiation from radar and radio equipment. Negotiations took place with the Defence Staff on the present state of control measures and statutes, and on the need to update them. As a result of these negotiations, the Defence Staff appointed a special investigator to prepare a proposal by the end of 2005 on how regulatory control of RF radiation should be organized in the Finnish Defence Forces and whether the current precautionary regulations are up to date. STUK measured the radiation emitted by Finnish Air Force radar installations in three districts, at which time Air Force personnel were also shown how to perform measurements. STUK also offered observations on draft versions of an upcoming Air Force radiation safety regulation. Measurements of radio and radar equipment were also taken aboard a Finnish Navy vessel. A civilian investigation was also made of exposure of dockside crane operators to RF radiation from the radio and radar equipment of nearby ships.

The radiation safety of two GSM base stations was assessed. The base station transmitters were also inspected.

The magnetic fields generated by rectifiers were measured on industrial and clerical premises.

4.4 Abnormal Incidents

The abnormal incident reporting required by section 17 of the Radiation Decree (1512/1991) also applies to incidents arising in the use of non-ionizing radiation (see item 2.9 above). There were no reports of abnormal incidents in the use of non-ionizing radiation in 2005.

5 Regulation Work

5.1 ST Guides

To achieve a standard of safety that complies with the Radiation Act, STUK publishes Radiation Safety Guides (ST Guides) for responsible parties that use radiation or that engage in practices causing exposure to natural radiation.

The following guides were published in 2005:

- ST 1.1 Safety Fundamentals in Radiation Practices
- ST 12.4 Radiation Safety in Aviation.

5.2 Other Regulation Work

STUK assisted the Ministry of Social Affairs and Health in preparing amendments to the Radiation Act (Amendment 1179/2005) and the Radiation Decree (Amendment 1264/2005). These amendments implemented European Union Council Directive (2003/122/EURATOM) on the control of high activity sealed radioactive sources and orphan sources. They also allowed for the code of conduct of the International Atomic Energy Agency (IAEA) on importing and exporting of radiation sources. An entirely new chapter 8 a was added to the Radiation Act, imposing stricter requirements on the use of high activity sealed sources. The most important new requirement is for the holder of a high activity sealed source to furnish a security in the form of a deposit ensuring that the costs of waste management will be covered when the source is decommissioned. State and municipal authorities and other public sector entities are exempt from this requirement, however.

Some specifications were also made to the Radiation Act that affect all uses of radiation. These concern the duty of a responsible party to arrange training for its staff (section 14 a) and the obligation to maintain records of radiation sources and to notify STUK of any changes in these records (section 14 b). Further specifications were also made to dosimetric service approval procedures (section 32 a). These amendments will not modify current practices, as corresponding requirements had already been imposed in ST Guides or in separate decisions of STUK.

The Ministry of Social Affairs and Health was also assisted in preparing a directive on optical radiation.

6 Research

The aim of research work conducted by STUK is to provide information that will improve expertise, support regulatory activities and enhance preparedness to respond to radiological and nuclear emergencies.

6.1 Ionizing Radiation

Research and development work on ionizing radiation formed part of the following projects:

Improved optimization in the use of computed tomography appliances

The number of computed tomography (CT) examinations has risen continually and new areas of use have been discovered for this technique as the appliance technology has developed. Even though CT scans constitute only 5 per cent of all X-ray examinations, they give rise to about 40 per cent of the total X-ray dose sustained by patients for diagnostic purposes. The quality criteria and reference levels issued by the European Union are partially out of date, and optimization of the use of new multislice appliances in respect of image quality and dose has often laid too much emphasis on good image quality. The aims of the research project of STUK are:

- to prepare recommendations for improving optimization
- to update the reference levels for CT scans and to issue such levels for paediatric examinations
- to develop a suitable routine inspection method
- to update the quality control guide for CT scans.

The CT appliance measurements were completed during 2005 and assessment of clinical image quality began. The image quality assessment will be performed by radiologists from the Hospital District of Helsinki and Uusimaa (HUS).

The measurements indicate that the average doses from CT scans (volume averages of CT dose) are generally greater for multislice appliances than for single-slice appliances. Differences were found between doses at various hospitals that evidence a need for better optimization. The doses were in part larger and in part clearly smaller than the current reference levels for patient radiation exposure. The reference levels for CT scans will also be revised on the basis of these findings in 2006. A joint Nordic patient dose survey will form the basis for issuing reference levels for paediatric CT scans as well. A summary compiled from quality assurance work will be used in preparing a new guide to quality control methods in X-ray examinations. The method of measuring examination-specific doses used in the investigation will be employed in inspections of the use of radiation. The final report of the research project will be completed during 2006, and an article on the findings will also be prepared for international publication.

Examination-specific radiation doses of staff in interventional radiology

The aim of the study is:

- to investigate the radiation doses of staff in each separate examination, and to relate these to patient doses in corresponding examinations
- to investigate the proportion of the dose to staff sustained at various stages of work (fluoroscopy/imaging).

The dosemeters to be used in the project were tested and the effect of a protective apron on the effective dose sustained by radiologists was also investigated. The measurement of examination-specific individual doses at the HUS cardiology clinic was also studied in the course of the project. The project will continue in 2006 and will partially join in the European Union SENTINEL project (see below).

Irradiation equipment for biological research

This project designed and manufactured an irradiation appliance based on an alpha source for the purpose of biological research. The project was implemented in association with the Radiation Biology Laboratory (SBL) of the Department of Research and Environmental Surveillance (TKO) of STUK and forms part of research conducted by SBL into the bystander effect.

The irradiation appliance was completed and a scientific article was published on its technology and dosimetry.

The SENTINEL project

"Safety and efficacy for new techniques and imaging using new equipment to support European legislation" (SENTINEL) is a project related to the diagnostic use of radiation, which was launched in 2005 and is co-ordinated by the European Union. The project comprises eight work modules covering nearly the entire field of diagnostic use of radiation with the exception of computed tomography. STUK is primarily involved in the following subject areas:

- performance standards/mathematical assessment of fluoroscopic image quality
- cardiology/collation of patient doses in heart examinations
- interventional radiology/collation of patient doses in interventional radiology
- staff doses in interventional radiology
- mammography examinations.

Follow-up research into patient and staff doses in interventional radiology began in 2005 and project meetings were attended. The project is scheduled to end in the first half of 2007.

Academic thesis work

The results of academic thesis work may be used in the activities of STUK or will help to improve radiation safety in Finland.

Patient radiation exposure in measurements of bone mineral density

This work developed measuring methods for determining the radiation exposure sustained by a patient during measurements of bone mineral density based on X-ray imaging. The thesis work was completed in 2005.

The doses arising from various appliances are different due to varying appliance operating modes, differences in radiation quality and the variety of measurement programmes employed. However, patient radiation exposure may be reduced by one third without changing the appliance by optimizing examinations and reducing the number of parts of the body selected for imaging. While the effective doses of patients were less than 0.5 µSv in measurements of the peripheral skeleton, the doses administered in measurements of the central skeleton varied between 0.1 and 78 µSv, chiefly in line with the parts chosen for measurements and the number of them. No significant deficiencies were observed in the use or quality control of fixed appliances.

Patient radiation exposure in X-ray examinations

The aim of this work was to determine a suitable procedure for national monitoring of patient radiation exposure in X-ray examinations. The investigation was performed on an experimental basis using a few selected X-ray examination units and X-ray examinations.

The findings indicated that good practices in monitoring patient radiation exposure are still developing at many radiography units. Capacities and arrangements for determining patient radiation exposure vary greatly, and both resource direction and training in the subject have yet to be arranged. For the most part, it would appear necessary to implement the information gathering required for a patient dose register on a sampling basis, and it would be expedient to assign to STUK, as a central agency, the duty of calculating the effective dose to a patient. A report of the investigation will be completed at the beginning of 2006.

6.2 Non-Ionizing Radiation

Most of the research and development work on non-ionizing radiation was done in the course of the jointly financed research projects set out below.

Health risk evaluation of mobile communications (HERMO)

One of the purposes of the HERMO project is to investigate the effect of mobile phone radiation on swine brain functioning. The exposure equipment and provisional dosimetry were largely completed during the preceding year. In tests with live swine the apparatus was found to work well. A phantom simulating the head of a swine will be completed at the beginning of 2006, whereupon it will be possible to make SAR measurements.

Another function of the HERMO project was a determination of the radio frequency power absorbed in juvenile rats (whole body SAR) used in animal tests at the University of Kuopio. The SAR was determined by measuring temperature rises in a homogenous rat phantom.

Research into methods of determining exposure arising from mobile phones and base stations (AMEST)

This project develops testing and measuring methods for determining exposure to electromagnetic fields caused by mobile phones and their base stations.

People working in the vicinity of base station antennae are exposed to RF radiation emanating from these antennae, and the degree of exposure can even exceed the prescribed maximum exposure levels. The electric and magnetic fields that arise in the vicinity of a typical base station antenna and the SAR value were measured using the SAR testing system of STUK. The findings indicated that an exposure estimate based on power density is considerably more conservative than one based on an SAR determination. The SAR limit may be exceeded at a distance of 20 cm from the antenna where the power density limit is already exceeded at a range of about 70 cm. The SAR measurement results were compared with the results of calculations derived using a formula developed by the electromagnetic laboratory at Helsinki University of Technology. The differences were insignificant.

Other research activities

Besides jointly financed research projects into non-ionizing radiation, research and technical development work also continued as part of the basic activities of the NIR Laboratory.

Magnetic imaging

The problem with the open magnetic appliances that are becoming common in magnetic imaging is that medical and nursing staff are particularly exposed to magnetic fields during interventional radiology examinations. Based on provisional measurements of stray fields, it would appear that exposure to static and radio frequency magnetic fields approaches the guideline values of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and may even exceed these values. The problem will increase in future as appliances are introduced that use increasingly powerful magnetic fields. The investigation is due to continue in 2006 in association with the Finnish Institute of Occupational Health.

Academic thesis work

Effects of UV-A radiation

A summary of a doctoral thesis on the effects of UV-A radiation on melanoma in mice was completed.

Induction currents caused by battery currents in GSM mobile phones

This work for a Master's thesis developed a model for calculating the induction currents caused by battery currents in GSM mobile phones in the brain of a mobile phone user. The induced currents were calculated using an ELF solver developed for the work. The source data came from the magnetic field generated by the GSM mobile phone and the findings were compared with calculations made at Helsinki University of Technology. The calculations indicated that the currents induced by the mobile phone were trivially small from the point of view of radiation exposure.

Exposure to the stray RF field of high frequency heaters

This Master's thesis calculated the currents induced and RF power (SAR) absorbed in the body of a worker exposed to the stray RF field of high frequency heaters. The currents and measured electric fields were compared with measurements made using an experimental heater model. The findings were a close match. One particularly interesting finding was that the research seems to show that it is possible to assess whether SAR limits will be exceeded based on measurements of body currents at workplaces.

7 International Co-operation

Representatives of STO and the NIR Laboratory are involved in several international organizations, commissions and expert groups dealing with regulatory control and with the development of safety regulations and measuring methods, as well as with standardizing activities in the field of radiation (IAEA, NACP, EURADOS, EUROMET, ESTRO, ESOREX, ICRU, NEA, AAPM, NOG, IEC, ISO, CEN, CENELEC, ICNIRP).

Participation in meetings of international working groups

During 2005, representatives of STUK took part in meetings of the following international organizations and working groups:

- Nordic dosimetry working group
- Nordic diagnostics working group (use of ionizing radiation in health care)
- Ionizing radiation working group of the European Collaboration on Measurement Standards (EUROMET)
- Clinical auditing working group (radiotherapy) of the European Society for Therapeutic Radiology and Oncology (ESTRO)
- Nordic sealed source working group (NORGUSS)
- Radiation Safety Standards Committee (RASSC) working group of the IAEA
- Working group on harmonizing individual worker dose measurement methods of the European Radiation Dosimetry Group (EURADOS)
- EURADOS working groups on harmonizing individual dose measurement methods for workers and on radiation protection measurements of health care staff
- European committee CENELEC TC61 for harmonizing safety of domestic electrical appliances
- Standardization working groups on electromagnetic fields: CENELEC TC106X/WG1 and CENELEC TC106X/WG9
- UV radiation standardization working group TC61/MT16 of the International Electrotechnical Commission (IEC)
- Nordic ozone and UV working group NOG.

Participation in other international conferences

Representatives of STO and the NIR Laboratory took part in several international conferences and congresses in the field of radiation safety and gave presentations and lectures at these events (organizers included IAEA, EANM, ESTRO, EUROMET, CIPM and the European Commission).

Other international co-operation

STUK took part in the European ESOREX project (European Study on Occupational Radiation Exposures). A project report on monitoring of radiation exposure in Finland was updated in 2005. The project also compiled dose statistics for workers engaged in radiation work over the period 2001–2004.

Specialists from STO took part in two projects financed by the European Union, one of which sought to improve the quality management system of Latvian radiation safety authority (the Phare project), while the other assessed radiation protection regulations in Romania.

Representatives from STO assisted in preparing the EURADOS IM 2005 conference on individual radiation dose measurement in Vienna.

STUK was responsible for preparing the joint opinion of Nordic radiation protection authorities on sunbed equipment and facilities. This work began in 2004 and the opinion was published in

2005. According to the opinion, the use of sunbed equipment for tanning or other purposes that have no medical justification should be avoided and it would be particularly important to ensure that such equipment is not used at all by persons under the age of 18 years and those with sensitive skin. The opinion expresses the hope that the European Commission will expedite the preparation of European Union recommendations on sunbed use.

The work of the ICNIRP permanent committee of experts (SC 3, Science and technology) involved participation in preparing a literature survey on radio frequency fields and revision of guideline values for low frequency fields.

8 Co-operation in Finland

Representatives of STO and the NIR Laboratory are involved in several Finnish commissions and expert groups dealing with regulatory control of and research into the use of ionizing and non-ionizing radiation and with standardizing activities in the field of radiation (such as the Advisory Committee on Metrology, the Radiation Safety Conference committee, Eurolab-Finland, SESKO).

Finnish conferences arranged by STUK

STUK organized the following conferences in 2005:

- Conference of radiotherapy physicists
- Training conference on radiation safety and quality in X-ray diagnostics
- Training conference on radiation safety and quality in X-ray technology
- Training conference on radiation safety and quality in nuclear medicine
- Radiation Safety Conference in association with the Radiological Society of Finland
- Radiation safety conference for industry
- Negotiation and training session on worker dosimetry together with dosimetric services performing measurements of individual doses caused by external radiation
- Seminar for training organizations on radiation safety training for radiation safety officers in industry, research and trading, and in installation and servicing practices
- Joint negotiations between the National Agency for Medicines and STO and the NIR Laboratory
- Joint negotiations with the National Research and Development Centre for Welfare and Health (STAKES) on registering the number of examinations and establishing a liaison working group.

Participation in meetings of Finnish working groups

The SK 106 committee on radiation safety standardization of electromagnetic fields held two meetings and the SK 61 committee on standardization of domestic electrical appliances held three meetings, which were attended by the representatives of STUK and which considered corresponding standards proposals from the International Electrotechnical Commission (IEC) and the European Committee for Electrotechnical Standardization (CENELEC). Comments and opinions were issued on 14 standards proposals in the final vote. The negative final vote on a proposed amendment (CLC/TC 61(SEC)1535) to the CENELEC sunbed standard EN 60335-2-27 is particularly noteworthy. This standard permits unsupervised use of appliances that are too powerful, the annual ultraviolet radiation dose from sunbeds is too high, and vagueness in the classification of appliances will hamper regulatory control at places of use.

Participation in other Finnish conferences

Representatives of STO and the NIR Laboratory took part in several Finnish conferences in the field of radiation safety and gave presentations and lectures at these events.

Other co-operation in Finland

Collaboration with paediatric radiologists led to publication of the guidebook “Lasten röntgentutkimusohjeisto” (Guidelines for paediatric X-ray examinations) (STUK bulletin, 1/2005). This guidebook seeks to call particular attention to radiation safety in X-ray imaging of children.

Inspectors from STO's Office of Radiation in Health Care met representatives of Qualisan Oy engaged in clinical auditing for the first time in 2005.

STUK assisted the Ministry of Social Affairs and Health in preparing amendments to the Radiation Act and the Radiation Decree, and in preparing a directive on optical radiation (see item 5.2).

STO and the NIR Laboratory supervised academic thesis work by students in higher education (see items 6.1 and 6.2).

9 Information Activities

Books, bulletins and reviews

STUK publishes the Radiation and Nuclear Safety book series including a total of seven books. The situation with respect to books edited at the NIR Laboratory in 2005 was as follows:

- Most of the layout work was completed for the "Non-ionizing Radiation – Electromagnetic Fields" book (no. 6 in the book series).
- More than half of the manuscript was completed for the "Non-ionizing Radiation – Ultraviolet and Laser Radiation" book (no. 7 in the book series).

An updated reprinting of the review "Non-ionizing Radiation and Man" was completed.

Public information on current affairs

STUK took part in work to update its website. The Finnish language sections of the site were revised, a project was launched to develop extranet services for users of radiation and the English language website material was rewritten.

STUK continued the practice, started in the year 2000, of publishing the UV radiation index on its website between April and September.

An ultraviolet information session was arranged in spring 2005 in association with Finnish Cancer Organisations and the Finnish Meteorological Institute. The topic covered by STUK at the session was sun lotions.

Press releases were prepared on the following subjects:

- Finnish workers exposed to radiation in Chile.
- Only physicians may refer patients for X-ray examination.
- Alara magazine: Shortcomings exposed by radiation source inventory.
- STUK issues instructions for radiation safety of flight crews.
- Growing use of radiopharmaceuticals in cancer diagnosis.
- Worker radiation doses remain sufficiently low.
- No radioactive shipments found at borders.
- Sunbed tanning does not protect the skin from burning.
- Sun lotions must be used liberally.
- Nordic official opinion: sunbed use should be avoided.
- Radiation levels of mobile phones tested by STUK remain within recommended limits.

Other information activities:

- Information on radiation protection, on new regulations, and on the background thereto was actively disseminated to responsible parties and users of radiation at conferences, seminars and training events.
- Media interviews were given on questions of exposure to ionizing and non-ionizing radiation.
- Guidance on radiation protection problems was provided in the form of both telephone and Internet-based services to private individuals, enterprises and the public sector.
- Press articles and other written contributions were prepared.
- Articles were written for the Alara magazine published by STUK.

Educational lectures

The Director of the NIR Laboratory gave a course of lectures at Helsinki University of Technology on the subject "Biological effects and measurements of electromagnetic fields and optical radiation" (course equivalent to 2 study credits).

Representatives of STO and the NIR Laboratory gave lectures at a radiation training course for journalists held on the premises of STUK in April.

10 Metrology

STUK serves as the national standard laboratory for radiation quantities and maintains standards to ensure the accuracy and traceability of radiation measurements taken in Finland. STUK calibrates its own standards at regular intervals at the International Bureau of Weights and Measures (BIPM) or other primary laboratories. In the field of radiation metrology, STUK is involved in the work of the Advisory Committee on Metrology and of the EUROMET organization.

Standard laboratory activities are the responsibility of the Dosimetry Laboratory (the DOS Laboratory) at STO for ionizing radiation and the NIR Laboratory for non-ionizing radiation.

10.1 Ionizing Radiation

Development work on measurement and irradiation equipment and methods

A new X-ray appliance was obtained for the DOS Laboratory in 2005, the reliability of individual dosemeter calibration was improved by also determining the radiation quality characteristics of the X-ray beams used by the Laboratory at low radiation qualities of less than 30 kV, and a calibration procedure was introduced for the DLP meters used in computed tomography X-ray examinations. An external assessment was also made of the standard activities of the Laboratory. Standard activities were also the subject of two internal audits at STUK. No significant shortcomings were revealed in the assessment or audits of activities.

A guide to radiotherapy dosimetry was published to ensure the reliability of radiation measurements taken by users of radiation.

Meter and measurement comparisons

The DOS Laboratory took part in three EUROMET calibration comparisons:

- comparison of air kerma with X-radiation
- comparison of dose equivalent with X-radiation
- comparison of absorbed dose to water with ^{60}Co gamma radiation.

The results of these comparisons are not yet available.

STUK also took part in the annual IAEA TLD measurement comparison of absorbed dose with ^{60}Co gamma radiation and linear accelerator photon radiation (6 MV). STUK's result differed from the reference value by 0.2 per cent with ^{60}Co gamma radiation and by 0.6 per cent for linear accelerator photon radiation. Both of these results were well within the 3.5 per cent acceptable range of results.

In the 2004 IAEA comparisons STUK's results differed from the reference value by 0.8 per cent (^{60}Co gamma radiation) and 0.3 per cent (linear accelerator photon radiation, 15 MV).

Figure 12 shows the deviations in the measurement results of STUK from the reference value in IAEA measurement comparisons over the period from 1990 to 2005.

10.2 Non-Ionizing Radiation

Development work on measurement and irradiation equipment and methods

The optical laboratory of the NIR Laboratory took part in a pilot comparison of broadband UV-A meter calibration co-ordinated by the Metrology Research Institute of Helsinki University of Technology, in which the ultraviolet radiation laboratories of TUBITAKUME (the standards laboratory of Turkey), the University of Dundee, and Guy’s & St Thomas’s Hospital were also involved. A comparison showed that the results of all participants were within ± 5 per cent of one another, which was less than in previous comparisons. STUK's results deviated by less than one per cent from the comparison reference value.

On assignment by the Swiss accreditation laboratory (METAS) in 2004 the radio laboratory of the NIR Laboratory calibrated two SAR-measurement probes manufactured by SPEAG of Switzerland at several frequencies. The calibrations by STUK and by SPEAG were analyzed in 2005 and the findings matched within the notified uncertainty ranges. STUK took part in an international testing comparison of mobile phones arranged by SPEAG in which the SAR value of a certain mobile phone model was measured at several laboratories. The findings of this comparison will be determined in 2006.

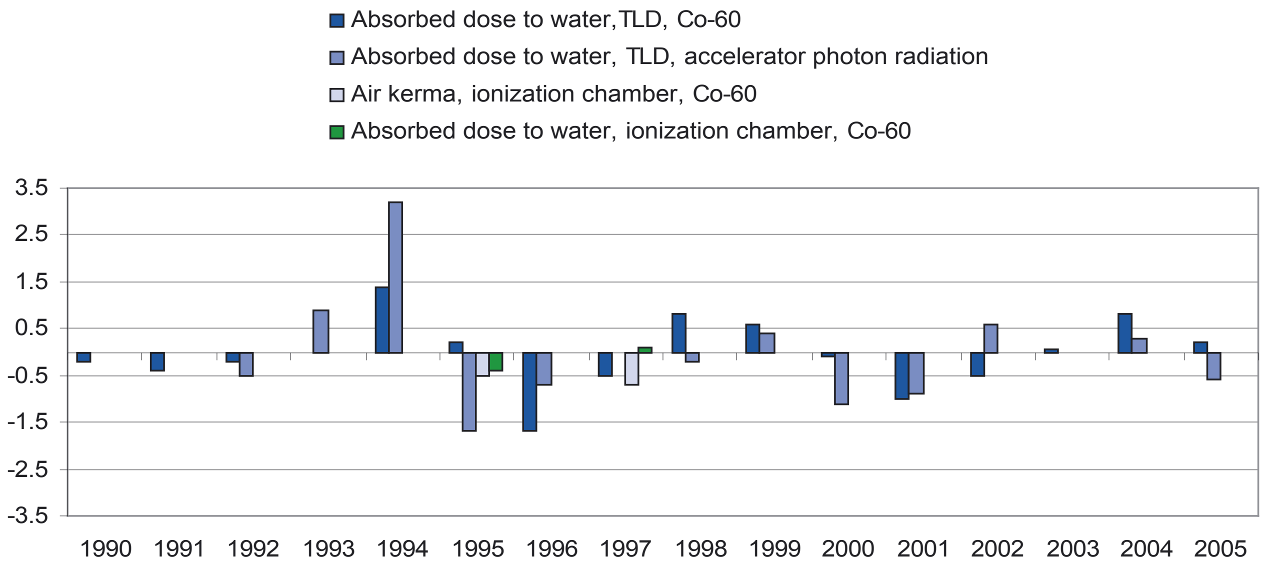

Figure 12. Deviations (per cent) in measurement results of STUK from the reference value in IAEA measurement comparisons, 1990–2005.

11 Services

Calibration, testing and irradiation

The DOS Laboratory performed radiation meter calibrations on request. 58 radiation meter calibration certificates and 46 irradiation certificates were issued. About one quarter of the calibrations and about half of the irradiations were performed for STUK's own measuring instruments and samples.

The NIR Laboratory performed a total of 25 radiation meter calibrations and tests and 31 safety assessments and radiation measurements. The service work of the NIR Laboratory between 2000 and 2005 is shown in Table XVIII of Appendix 1. The volume of calibration and testing work has remained roughly constant in recent years.

12 Other Activities

NIR Laboratory customer satisfaction survey

The findings of the customer satisfaction survey conducted in 2004 were analyzed. The clients had not criticized the laboratory in any way. The survey was extended by sending a questionnaire to customers with every service certificate or regulatory control document. No analysis was performed for 2005 due to the small volume of data and because the findings were broadly in line with those of 2004. A digest of the 2005 survey will be combined with the results for 2006.

APPENDIX 1 TABLES

Table I. Radiation practices referred to in safety licences for the use of radiation in health care at the end of 2005.

Use of radiation	Number of practices
X-ray examination	416
Dental X-ray examination*)	11
Veterinary X-ray examination	199
Use of unsealed sources	45
Use of sealed sources	22
Radiotherapy	11
Other uses of radiation	19

*) Licence granted for dental X-ray appliances that are nevertheless mainly used for purposes other than dental X-ray practices.

Table II. Radiation sources and appliances used in health care and in veterinary X-ray practices, and radionuclide laboratories at the end of 2005.

Appliances/laboratories	Number
X-ray diagnostic appliances (generators)*)	**1552**
X-ray tubes	1715
• mammography (not screening)	103
• screening mammography	95
• computer tomography	80
• angiography (not DSA)	28
• digital subtraction angiography (DSA)	81
• bone mineral density measurement	86
Dental X-ray appliances	**5200**
• conventional dental X-ray appliances	4606
• panoramic X-ray appliances	594
Radiotherapy appliances	**88**
• accelerators	30
• afterloading appliances	11
• X-ray therapy appliances or radiographic appliances	21
• radiotherapy simulators	8
• BNCT therapy unit	1
• other appliances	17
Appliances containing radioactive substances	**104**
• attenuation correction units	32
• flood sources	23
• calibration sources	21
• other appliances	28
Veterinary X-ray appliances	**235**
Radionuclide laboratories	**70**
• B-type laboratories	18
• C-type laboratories	50
• other laboratories	2

*) An X-ray diagnostic appliance comprises a high voltage generator, one or more X-ray tubes and one or more examination stands.

Table III. Radiation practices referred to in safety licences for the use of radiation in industry, research and education at the end of 2005.

Use of radiation	Number of practices
Use of sealed sources (excluding gamma radiography)	631
Use of X-radiation (excluding radiography)	191
Installation, test operation and servicing	133
Use of unsealed sources	130
Import, export and trade	128
X-ray radiography	77
Gamma radiography	7
Production of radioactive substances	5
Other uses of radiation	50

Table IV. Radiation appliances and sources used in industry, research and education, and radionuclide laboratories at the end of 2005.

Appliances/laboratories	Number
Appliances containing radioactive substances	**6238**
• level switches	2329
• continuous level gauges	1071
• density gauges	995
• basis weight meters	568
• weight scales	514
• fluorescence analyzers	125
• moisture and density gauges	122
• thickness gauges	84
• radiography appliances	19
• other appliances	411
X-ray appliances and accelerators	**975**
• radiography appliances	334
• fluoroscopic appliances	301
• diffraction and fluorescence analyzers	213
• thickness gauges	40
• ash meters	18
• particle accelerators	16
• other analytical appliances	52
Radionuclide laboratories	**163**
• A-type laboratories	2
• B-type laboratories	28
• C-type laboratories	117
• other laboratories	16

Table V. Radionuclides most commonly used in sealed sources in industry, research and education, and number and activities of sources at the end of 2005.

Radionuclide	Number of radiation sources	Total activity*) (GBq)
Activity < 400 GBq		
Cs-137	3884	10 281
Co-60	1475	1237
Kr-85	412	5118
Am-241 (gamma sources)	358	2846
Pm-147	169	4573
Fe-55	145	400
Am-241 (AmBe neutron sources)	114	879
Sr-90	63	197
Cd-109	59	32
Cm-244	30	196
Activity > 400 GBq		
Cs-137	27	666 320
Ir-192	11	46 540
Co-60	7	100 175 **)
H-3	1	3700

*) Sum of the nominal activities notified on commissioning. The activity of short-lived radionuclides (e.g. Ir-192) is much lower than the nominal activity.
**) Activity on 31 December 2005

Table VI. Inspections of the use of radiation in 2005.

Type of inscpection	Number of inspections		
	Industry, research, education, trade, installation, maintenance	Health care	
		Licensed practices	Notifiable licence-exempt dental X-ray practices
Initial inspections	31	151	1
Periodic inscpections	107	160	8
Repeat inspections	0	3	0
Other inspections or measurements	3	3	53
Total	**141**	**317**	**62**

Table VII. Inspections of licensed practices in 2005.

Type of practice	Number of inspections
Use of radiation in health care	
• X-ray diagnostics	247
• dental X-ray diagnostics	4
• veterinary X-ray diagnostics	24
• nuclear medicine	11
• radiotherapy	30
• other uses of radiation	1
Use of radiation in industry, research and education, and in trade, installation and maintenance of radiation sources	
• use of sealed sources (excluding radiography)	65
• use of unsealed sources	18
• trade and maintenance	4
• use of X-radiation (excluding radiography)	40
• gamma and X-ray radiography	12
• other uses of radiation	2
Total	**458**

Table VIII. Imports and exports of sealed sources in 2005.

Radionuclide	Imports		Exports	
	Activity (GBq)	Number	Activity (GBq)	Number
Ir-192	40 935	19	4585	9
H-3	13 475	5216	16 505	5570
Kr-85	1342	93	1066	73
Pm-147	304	41	169	18
Fe-55	214	63	98	40
Cs-137	122	109	< 1	5
Po-210	26	32	- *)	-
Am-241	24	360	8	1434
Gd-153	24	33	< 1	2
Co-60	22	24	-	-
Cd-109	18	37	14	29
Am-241**)	8	4	1	1
Sr-90	5	24	1	4
Ni-63	4	7	-	-
others total ***)	5	674	2	45
Total	**57 528**	**6736**	**22 449**	**7230**

*) The "-" symbol indicates no imports/exports.
**) AmBe neutron sources.
***) Imports, nuclides: Ba-133, C-14, Co-57, Eu-152, Ge-68, I-125, I-129, Na-22 and Sr-85.
Exports, nuclides: Eu-152, Cm-244 and Ge-68.

Table IX. Imports and exports of unsealed sources in 2005.

Radionuclide	Activity (GBq)	
	Imports	Exports
Mo-99	48 961	12 306
I-131	6672	1679
P-32	710	< 1
I-123	116	29
Tl-201	114	-*)
I-125	89	4
S-35	88	-
Y-90	41	-
In-111	35	-
H-3	25	< 1
C-14	14	< 1
Sm-153	7	< 1
F-18	-	24
others total **)	13	< 1
Total	**56 885**	**14 042**

*) The "-" symbol indicates no imports/exports.
**) Imports, nuclides: Ca-45, Cl-36, Co-57, Cr-51, Fe-55, Ga-67, I-129, Na-22, P-33, Ra-226, Rb-86, Re-186, Se-75 and Sr-85.
Exports, nuclides: I-129 and Pu-236.

Table X. Manufacturing of radioactive substances (unsealed sources) in 2005.

Radionuclide	Activity (GBq)
O-15	26 200
C-11	13 140
F-18	8615
Br-82	2738
Ru-103	16
La-140	6
Na-24	6
Au-198	4
others total*)	4
Total	**50 729**

*) Nuclides: Cd-109, Cr-51, Cu-64, Pu-236, I-123 and Sm-153.

Table XI. Number of workers subject to individual monitoring in 2001-2005.

Year	Number of workers in various occupational category						
	Health care		Veterinary medicine	Industry	Research and education	Use of nuclear energy*)	Total**)
	Exposed to X-radiation	Exposed to other radiation sources					
2001	4576	919	288	1128	1362	2753	10 899
2002	4697	891	296	1180	1209	3055	11 190
2003	4741	906	305	1114	1109	2862	10 901
2004	4759	915	328	1070	1025	3124	11 082
2005	4837	896	355	1172	995	3584	11 698

*) Finns working at nuclear power plants in Finland and abroad and foreign workers working at Finnish facilities.
**) The figure shown in certain rows of this column is not necessarily the same as the sum of the figures in other columns of the same row, as some health care staff are exposed to both X-radiation and other forms of radiation, and there are workers in industry who also work in the use of nuclear energy.

Table XII. Total doses (sums of $H_p(10)$ values) in various occupational categories in 2001–2005.

Year	Total dose (Sv)						
	Health care		Veterinary medicine*)	Industry	Research and education	Use of nuclear energy**)	Total
	Exposed to X-radiation*)	Exposed to other radiation sources					
2001	1.68	0.11	0.06	0.22	0.10	2.58	4.75
2002	1.69	0.13	0.07	0.24	0.09	4.12	6.36
2003	1.55	0.12	0.07	0.20	0.09	2.38	4.41
2004	1.48	0.12	0.06	0.23	0.09	4.16	6.15
2005	1.48	0.14	0.06	0.19	0.09	3.42	5.38

*) $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the use of radiation in health care and veterinary X-ray practices, in which workers use personal protective shields and in which the dose is measured by a dosemeter on the exposed side of the shield. The effective dose is then obtained by dividing the $H_p(10)$ value by a factor between 10 and 60.
**) Finns working at nuclear power plants in Finland and abroad and foreign workers working at Finnish facilities.

Table XIII. Data ($H_p(10)$ values) on certain occupational groups in 2005.

Group	Number of workers	Total dose (Sv)	Average dose (mSv)		Largest dose (mSv)
			Workers*) whose dose ecxeeds recording level	All workers subject to individual monitoring	
Cardiologists**)	167	0.59	4.4	3.5	26.5
Radiologists**)	553	0.39	2.5	0.7	24.3
Interventional radiologists**)	20	0.21	11.2	10.6	42.2
Surgeons**)	242	0.08	2.2	0.3	19.2
X-ray assistants**)	2642	0.11	0.5	0.0	2.8
Industrial radiographers	376	0.09	0.9	0.2	5.7
Researchers	769	0.04	1.2	0.0	3.7
Nuclear power plant workers					
• mechanical duties	776	1.25	2.1	1.6	11.9
• cleaning	253	0.36	2.4	2.4	9.5
• material testing	232	0.24	1.3	1.0	12.1
• insulation work	93	0.33	4.0	3.5	13.5
• radiation protection	85	0.15	2.0	1.7	7.7
• operating staff	272	0.08	0.7	0.3	5.4

*) The recording level is 0.1 mSv per month for persons working in nuclear power plants and 0.1 mSv per month or 0.3 mSv per quarter for other workers depending on the duration of the measurement period.

**) $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the dose sustained by these worker groups. Workers engaged in the use of radiation (X-rays) in health care and veterinary X-ray practices use personal protective shields, and the dose is measured by a dosemeter on the exposed side of the shield. The effective dose is then obtained by dividing the $H_p(10)$ value by a factor between 10 and 60.

Table XIV. The principal low-level radioactive waste in the national storage facility (December 2005).

Radionuclide	Activity (GBq) or mass
H-3	16 540
Cs-137	2221
Pu-238	1621
Kr-85	1230
Am-241	1194
Sr-90	262
Ra-226	231
Co-60	199
Cm-244	77
U-238	687 kg

Table XV. Low-level radioactive waste received by STUK in 2005.

Radionuclide	Activity (GBq)
Am-241	283
Kr-85	66
H-3	57
Pm-147	18
Cs-137	12
Fe-55	4
Co-60	2
Cl-36	1.9
Sr-90	0.6
Ni-63	0.5
Ra-226	0.5
Tl-204	0.023

Table XVI. Organizations having instruments approved for determining worker exposure to radon.

Organization	Instrument	Calibration valid until	Notes
Gammadata Mätteknik i Uppsala AB/ Gammadata Finland Oy, Helsinki	Alpha track detector	1 Jan 2007	Alpha track detector can determine the average radon concentration over an extended period. The method is not suitable for determining variations in radon concentration over time. The method is also approved for radon measurements in homes.
• City of Lahti • Turku Polytechnic • Tampere Polytechnic	• Pylon AB-5 • Pylon AB-5 • Pylon AB-5 and AlphaGuard	• 11 Jun 2006 • 11 Jun 2006 • 22 Sep 2006 23 Sep 2006	Continuously monitoring instruments that can record variations in radon concentration over time. These instruments are suitable for measuring radon concentration during working hours.

Table XVII. Number of air crew members subject to individual monitoring of radiation exposure and total dose of crew members (sum of effective doses) in 2001–2005.

Year	Number of workers		Total dose (Sv)	
	Pilots	Cabin crew	Pilots	Cabin crew
2001	677	1751	1.14	3.03
2002	692	1799	1.07	2.93
2003	739	1746	1.09	3.02
2004	739	1801	1.19	3.45
2005	739	1861	1.31	3.80

Table XVIII. Work of the NIR Laboratory.

Year	Regulatory control inspections	Decisions	Statements	Calibrations and tests	Safety assessments and radiation measurements	Total
2000	17	0	7	31	1	56
2001	23	2	16	27	9	77
2002	36	1	4	31	13	85
2003	49	0	3	23	11	86
2004	55	3	1	30	12	101
2005	66	1	1	25	31	124

Table XIX. Inspections of sunbed facilities.

Year	Number
2000	14
2001	17
2002	36
2003	31
2004	30
2005	36

Table XX. Mobile phone SAR tests.

Year	Number
2003	12
2004	18
2005	15

APPENDIX 2 Publications in 2005

The following publications completed in 2005 were authored by one or more employees of STO or the NIR Laboratory:

International publications

Ilvonen S, Sihvonen A-P, Kärkkäinen K, Sarvas J. Numerical Assessment of Induced ELF Currents in the Human Head Due to the Battery Current of a Digital Mobile Phone. Bioelectromagnetics 2005; 26: 648–656.

Nishizawa K, Yoshinaga S, Karppinen J, Vehmas T. Radiation exposure and risk assessment in HRCT. In book: Kusaka Y, Hering KG, Parker JE (eds). International classification of HRCT for occupational and environmental respiratory diseases. Tokyo: Springer-Verlag; 2005.

Pastila R, Leszczynski D. Ultraviolet A exposure alters adhesive properties of mouse melanoma cells. Photodermatology, Photoimmunology & Photomedicine 2005; 21: 183–190.

Pastila R, Leszczynski D. Ultraviolet A exposure might increase metastasis of mouse melanoma: a pilot study. Photodermatology, Photoimmunology &, Photomedicine 2005; 21: 234–241.

Ylianttila L, Schreder J. Temperature effects of PTFE diffusers. Optical Materials 2005; 32: 1811–1814.

Ylianttila L, Visuri R, Huurto L, Jokela K. Evaluation of a single-monochromator diode array spectroradiometer for sunbed UV-radiation measurements. Photochemistry and Photobiology 2005; 81: 333–341.

Conference papers and lectures at conferences

International

Annanmäki M, Oksanen E, Venelampi E, Markkanen M. Radon in Finnish mines – regular monitoring since 1972. Proceedings of the Seventh International Symposium on the Natural Radiation Environment (NRE-VII), 20–24 May 2002, Rhodes, Greece. In book: Baxter MS (ed.). Radioactivity in the Environment. Volume 7. Oxford: Elsevier Ltd.; 2005. p. 657–664.

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Regular Meeting of the Nordic Society for Radiation Protection, NSFS, 27–31 August 2005, Rättvik, Sweden. SSI Rapport 2005:151–154. Stockholm: Statens Strålskyddsinstitut; 2005.

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Parkkinen R, Sipilä P. Verification of implementation of the IAEA TRS 398 for external beams in Finland. 8th Biennal ESTRO Meeting on Physics and Radiation Technology for Clinical Radiotherapy, 24–29 September 2005, Lisboa, Portugal. Radiotherapy & Oncology 2005; 76 Suppl 2: S76.

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Lehtinen M. Uutta STUKin ohjeista ST 1.1, ST 7.1, ST 7.2 ja ST 7.5 (New guides from STUK: ST 1.1, ST 7.1, ST 7.2 and ST 7.5). In the book: Lectures. XXIX Radiation Safety Conference at Tampere Hall, Tampere 3–4 November 2005. Tampere: Lege Artis Oy; 2005. p. 76–78.

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ST 12.3 Radioactivity of Household Water, 9 August 1993
ST 12.4 Radiation Safety in Aviation, 20 June 2005.