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# Radiation practices

## Annual report 2006

Erkki Rantanen (ed.)

Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

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# Radiation practices

## Annual report 2006

Erkki Rantanen (ed.)

STUK • SÄTEILYTURVAKESKUS
STRÅLSÄKERHETSCENTRALEN
RADIATION AND NUCLEAR SAFETY AUTHORITY

Osoite/Address • Laippatie 4, 00880 Helsinki
Postiosoite / Postal address • PL / P.O.Box 14, FIN-00881 Helsinki, FINLAND
Puh./Tel. (09) 759 881, +358 9 759 881 • Fax (09) 759 88 500, +358 9 759 88 500 • www.stuk.fi

Translation. Original text in Finnish.

The following people were involved in preparing this report:
Siiri-Maria Aallos
Timo Ansaranta
Ritva Bly
Ritva Havukainen
Kari Jokela
Hannu Järvinen
Eero Kettunen
Jarno Koikkalainen
Antti Kosunen
Maaret Lehtinen
Eero Oksanen
Eija Venelampi
Reijo Visuri

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# Abstract

1733 safety licences for the use of radiation were current at the end of 2006. 1877 responsible parties were engaged in notifiable licence-exempt dental X-ray activities. Use of radiation was controlled through regular inspections performed at places of use, test packages sent by post to dental X-ray facilities and maintenance of a Dose Register. Radiation safety guides were also published and research was conducted in support of regulatory control.

STUK conducted 421 inspections of licensed practices and 31 inspections of notifiable licence-exempt dental X-ray practices in 2006. 194 repair orders and recommendations were issued. Use of six appliances was prohibited.

A total of 12 039 radiation workers were subject to individual monitoring in 2006. 140 000 dose entries were made in the Dose Register maintained by STUK. 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. 126 workplaces including a total of 266 work areas were subject to regulatory control during 2006. 3484 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 2006 focused particularly on mobile phones, sunbeds and lasers. 15 mobile phone types were tested in market surveillance of mobile phones. 25 sunbed facilities were inspected. One toy laser was taken off the market. Three statements were issued to planning authorities regarding land use in the vicinity of power lines. Research work focused especially on developing testing and measuring methods for determining exposure to electromagnetic fields. A doctoral thesis was completed on the effects of UV-A radiation on melanoma in mice.

There were 13 abnormal incidents involving the use of radiation in 2006. Ten of these incidents concerned the use of radiation in industry, research or transportation, and the other three concerned the use of radiation in health care. None of these incidents had serious consequences.

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# Management foreword

Eero Kettunen
Director
Department of Radiation Practices Regulation (STO)

Kari Jokela
Head of Laboratory
Laboratory for Non-ionizing Radiation Surveillance (NIR)

The Department of Radiation Practices Regulation (STO) of the Radiation and Nuclear Safety Authority (STUK) serves as a regulatory authority for the use of ionizing radiation, conducts research into the medical use of radiation, and maintains metrological standards for ionizing radiation. Regulatory control involves safety licence, approval and registration procedures, inspections of places when radiation is used, and monitoring of worker radiation doses. Investigations focus particularly on practices that cause substantial exposure to radiation, such as CT scans and interventional radiology. Metrological activities ensure the accuracy and traceability of radiation measurements to international metrological standards. This work also involves calibrating radiation meters used in Finland to ensure the reliability of radiation measurements made in Finland.

Radiotherapy practices are growing rapidly in Finland. In particular the number of linear accelerators used for radiotherapy is increasing. At many radiotherapy centres, however, the number of patients undergoing radiotherapy per accelerator has increased to an even greater extent. The number of these appliances can be expected to grow still further in future years.

The number of CT examinations and CT appliances in Finland has also increased continually. New applications for these examinations have also been found with advances in appliance technology. Conventional CT appliances are nowadays combined with single photon emission tomography (SPET) or positron emission tomography (PET). Five dental CT appliances have also been taken into use. Studies by STUK have found that the transition from single slice to multislice CT scanning increases patient radiation doses by 30%. Differences were also found between doses at various hospitals that evidence a need for better optimization. The reference levels for patient doses must also be updated as appliance technology and examination methods improve.

According to a study published in 2006, 3.9 million X-ray examinations and procedures were performed in 2005, compared to 4.1 million in 2000. While 7% fewer conventional X-ray examinations with no contrast medium were performed than in 2000, the number of CT scans increased correspondingly by 30%. CT scans accounted for only about 7% of all X-ray examinations, but were responsible for about 40% of the total radiation dose arising from all X-ray examinations. Optimization of examination methods and image quality is particularly important in these examinations. STUK is involved in research projects investigating optimization in practice, patient doses and quality control in CT scans.

The aim is to update patient dose reference levels and quality control instructions. Research projects have also been undertaken in association with public authorities in other Nordic countries.

The number of appliances containing radioactive substances for the use of radiation in industry has not changed substantially in recent years. By contrast the number of X-ray appliances and accelerators has increased by 50% over the last decade. New X-ray screening appliances have been introduced for security checks and product inspections, and the use of X-radiation has also increased in analytical equipment.

During last year STO launched a project to revise the regulatory control registers that will require special effort for several years to come. The aim is to unify the safety licence, radiation appliance and dose registers to enable more efficient collection, analysis and combination of information. This will facilitate better planning and monitoring of operations. It will become possible to gather better statistical information on radiation use and to focus regulatory control and research on sites that are important from the point of view of radiation safety.

Even though special care is taken in the use of radiation in Finland, more than ten abnormal incidents occur in this area every year. Serious consequences have nevertheless been avoided in these cases. Summaries of these incidents are included in this annual report and discussed in detail at expert seminars with a view to avoiding corresponding future incidents.

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.

During 2006 STUK played an active role in association with Nordic radiation safety authorities with a view to establishing European sunbed standards. Deficiencies affecting the safety of sunbed users were found at almost all of the establishments inspected. Regulatory control of lasers entailed ordering the removal from the market of a laser toy that could cause eye damage. Three statements were issued to planning authorities regarding land use in the vicinity of power lines. The radiation values of mobile phones tested in the course of market surveillance did not exceed the prescribed maximum value.

The main topics of investigation for non-ionizing radiation were the development of testing and measuring methods for determining the exposure caused by electromagnetic fields from mobile phones and their base stations, environmental radiation caused by radio transmitters operating in the 80–3000 MHz frequency band, and exposure of workers to stray RF radiation from high frequency heaters. A doctoral thesis was completed on the effects of UV-A radiation on melanoma in mice.

STUK was involved internationally in both an erythema-weighted comparison of UV radiometers and a test comparison of mobile phones between 21 measurement laboratories. The results demonstrated the high standard of STUK’s quality system.

# 1 General

The expression “use of radiation” refers to the use and manufacture of, and trade in radiation equipment and radioactive substances, and to associated activities such as possession, safekeeping, servicing, repair, installation, import, export, storage, transportat, and the process of rendering radioactive waste harmless. The expression “radiation practices” refers to the use of radiation and also to any activity 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 in 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.

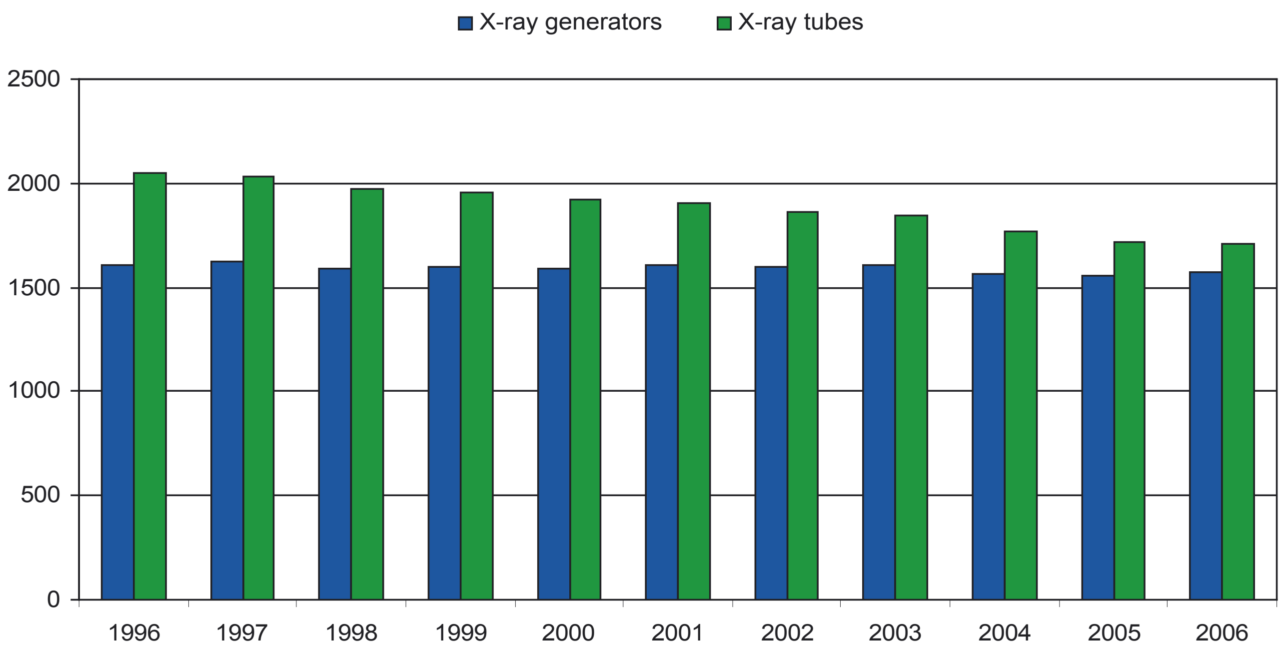


**Figure 1.** Licensed X-ray generators and tubes in health care, 1996–2006.

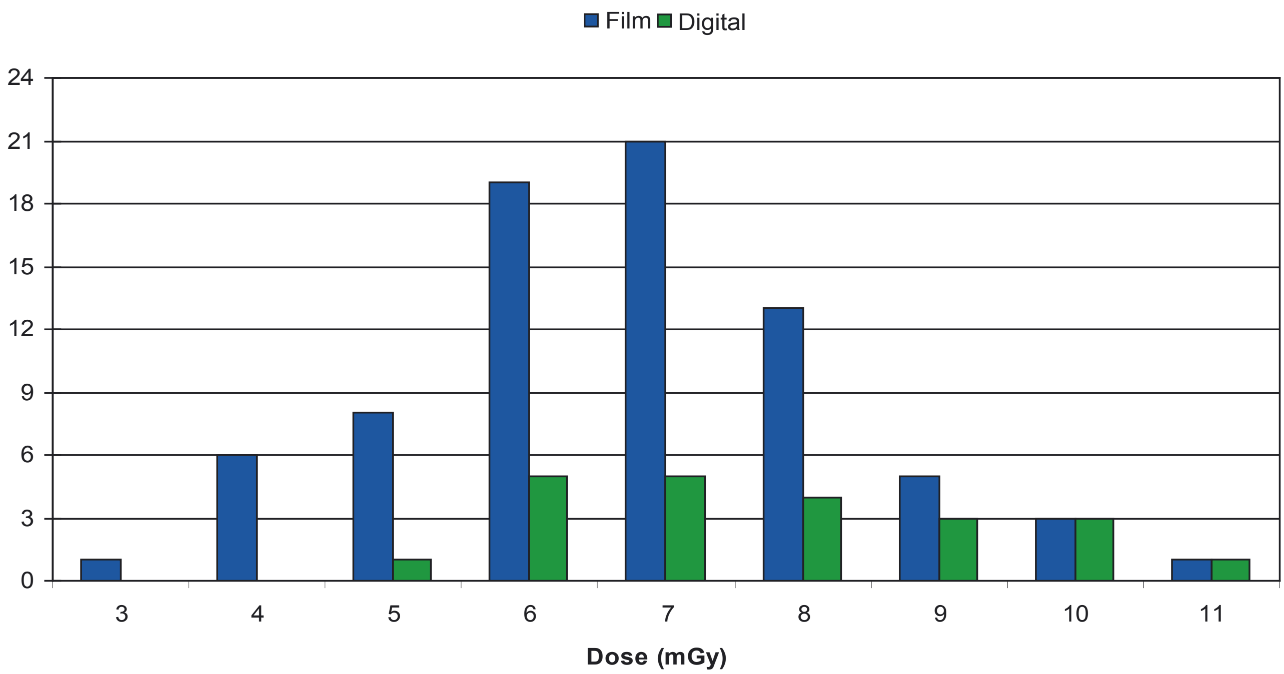


**Figure 2.** Patient (mammography) dose distributions measured in the course of inspections by STUK in 2005–2006. Reference level 10 mGy.

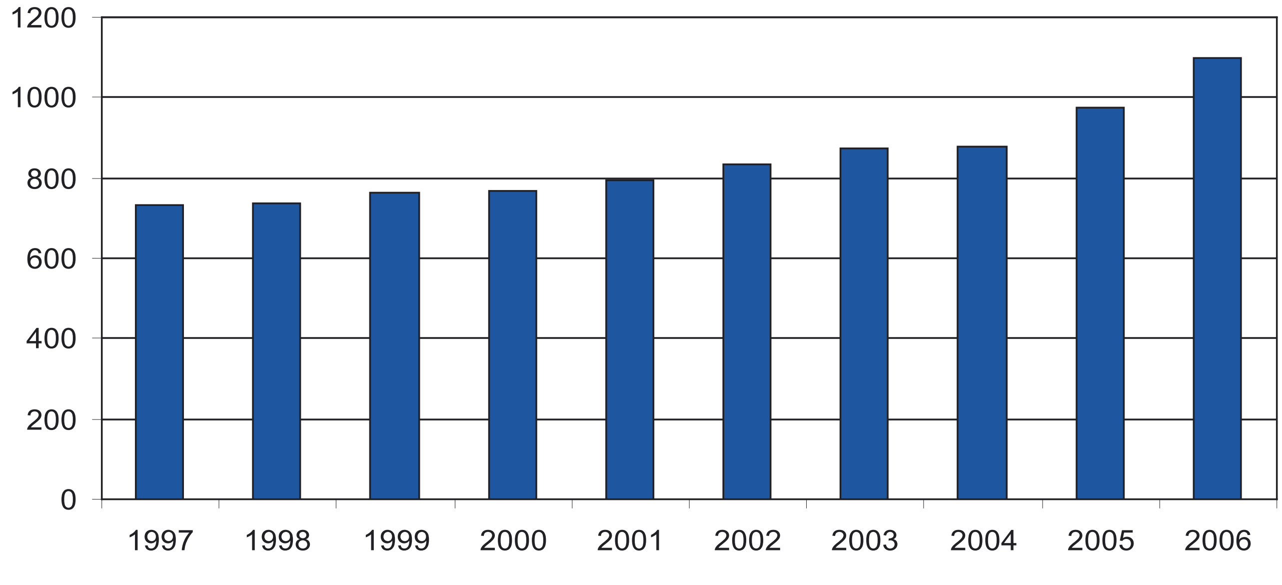


**Figure 3.** X–ray appliances and accelerators in industry, research and education, 1997–2006.

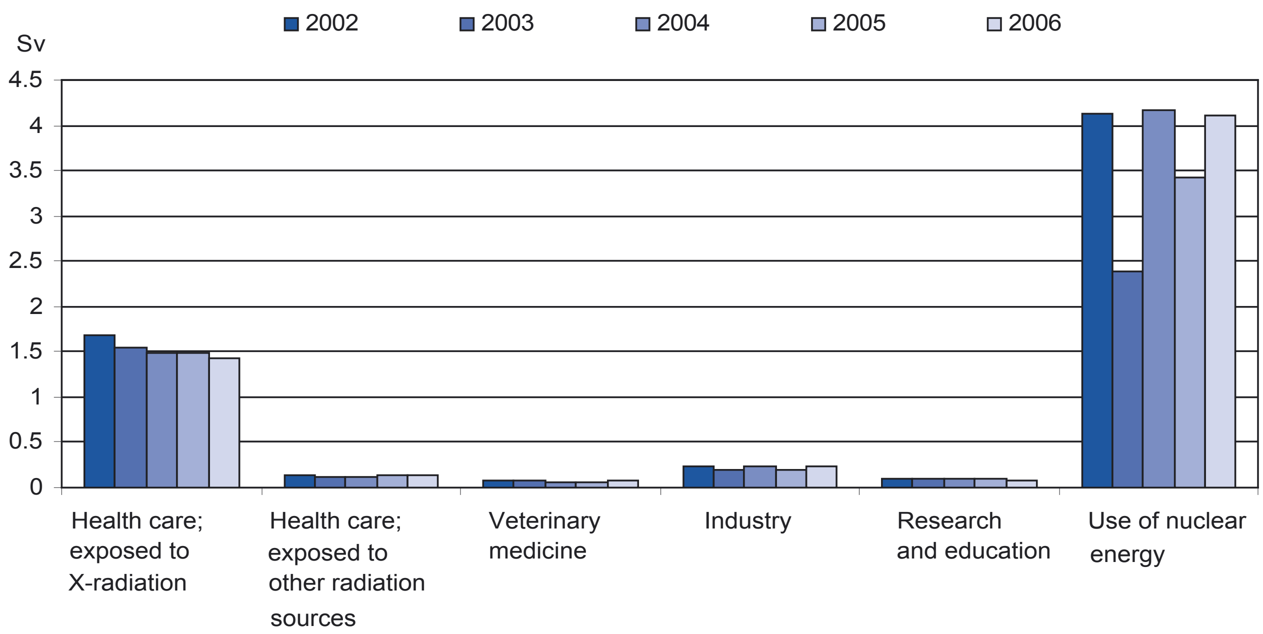


**Figure 4.** Combined doses ($H_p(10)$) of workers subject to individual monitoring in various sectors in the use of radiation and nuclear energy, 2002–2006.

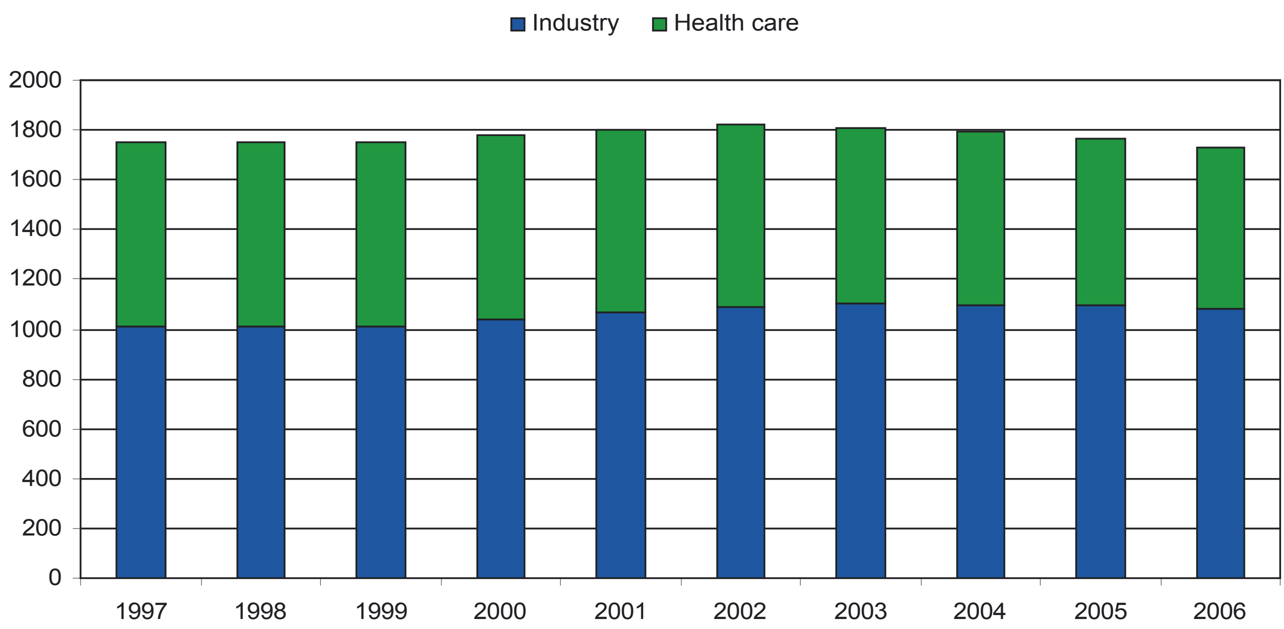


**Figure 5.** Current safety licences, 1997–2006.

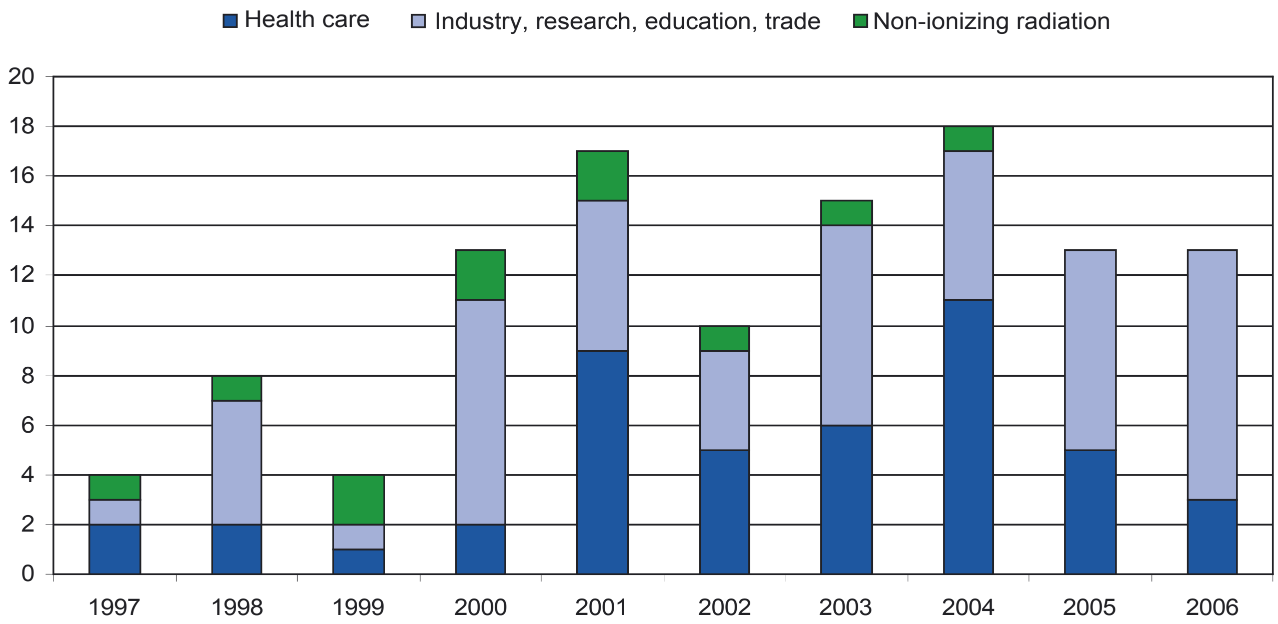


**Figure 6.** Abnormal incidents, 1997–2006.

# 2 Regulatory control of the use of ionizing radiation

## 2.1 Use of radiation in health care

### Safety licences

652 safety licences for the use of radiation in health care were current at the end of 2006. 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 (see Figure 5 in item 1.1). The total number of licences is falling. Radiotherapy practices are growing rapidly and safety licences were issued to two new radiotherapy centres. The increase in combined positron emission tomography and computed tomography scannings (PET-CT) is particularly associated with cancer therapy, and a safety licence was issued to a second imaging centre for the use of such an appliance in Finland.

### Radiation appliances and sources, and laboratories

The number of computed tomography (CT) appliances is increasing. At the end of 2006 there were 84 such appliances, 72 of which were used for conventional CT imaging. Nine appliances were combinations with single photon emission tomography (SPET) and two were combinations 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 ten CT appliances were also used for radiotherapy simulation. These appliances also are also used as part-time or backup machines for diagnostic imaging.

In particular the number of linear accelerators used for radiotherapy is increasing. This number has increased by nearly 30% since 1996, with 31 such appliances in use by the end of 2006 (see Figure 7). This number is expected to rise to 40 over the next five years. Figure 8 shows that even though the number of radiotherapy appliances has grown, the average number of patients undergoing radiotherapy per accelerator nevertheless increased to an even greater extent at most radiotherapy centres over the period 2000–2005.

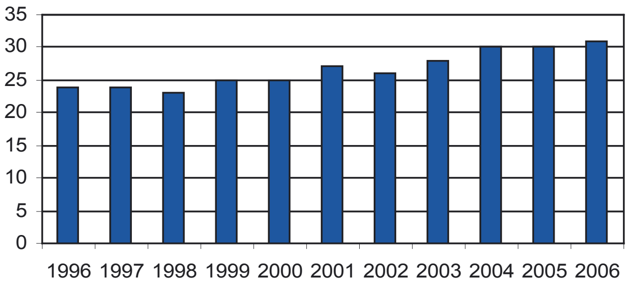


**Figure 7.** Linear accelerators in radiotherapy, 1996–2006.

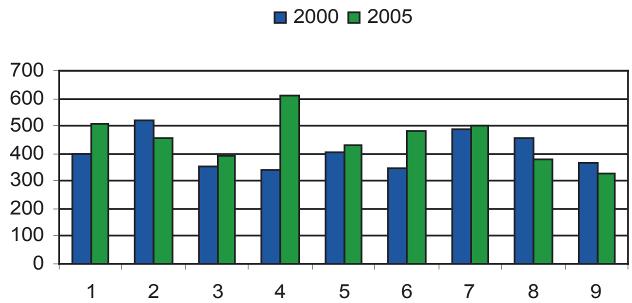


**Figure 8.** Average number of radiotherapy patients per linear accelerator at each of nine radiotherapy centres in 2000 and 2005.

In accordance with recommendations in Guide ST 2.1 of STUK, a radiotherapy specialist should treat an average of no more than 250 radiotherapy patients annually. Under section 24 of the Decree of the Ministry of Social Affairs and Health (423/2000), a radiotherapy specialist means a cancer specialist or other specialist qualified for radiotherapy in his specialism. Figure 9 indicates that the ratio of radiotherapy patients to radiotherapy specialists is a good deal higher than this at nearly all radiotherapy centres. Some radiotherapy centres do not distinguish radiotherapy specialists from cancer specialists, and so statistical estimates of the number of radiotherapy specialists are imprecise.

The same recommendation specifies that one hospital physicist is required for each 400 patients and a further hospital physicist is required where special therapy techniques are used, as in all university radiotherapy clinics, together with one hospital physicist for brachytherapy and one for radionuclide therapy. Only three central hospitals complied with this recommendation, while elsewhere the number of patients treated per hospital physicist was clearly higher. The shortage was most acute at university hospitals due to the use of increasing special therapy techniques. New techniques seek to improve the results of therapy by preserving more healthy tissue and thereby reducing the side effects of therapy.

Under the recommendation, there should be at least two radiographers operating a linear accelerator whenever up to 25 patients are treated each day. There should be four radiographers when more than 50 patients are treated each day using a single accelerator. Figure 9 indicates that the number of patients per radiographer is nearly the same at all radiotherapy centres. There are 4–6 radiographers for each accelerator. At some radiotherapy centres one of these serves in dose planning.

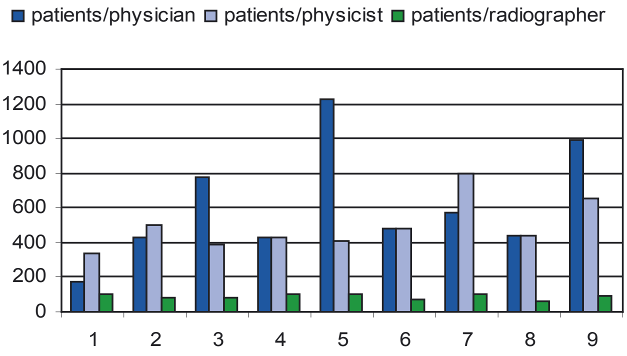


**Figure 9.** Radiotherapy patient to staff ratios in 2005.

Most dental X-ray appliances are used at dental surgeries, whereupon these appliances may be governed by a registration procedure. A safety licence must be obtained when dental X-ray appliances are used for more diverse examinations or, for example, are involved in scientific research. There were 4575 conventional dental X-ray appliances (see Figure 10) and 673 panoramic X-ray appliances in Finland (see Figure 11) at the end of 2006.

No dental X-ray imaging may be performed before a dentist or medical practitioner has made an individual assessment of the need for imaging (assessment of justification). A person who has been trained in dental X-ray imaging may thereafter perform dental X-ray imaging according to the instructions of a physician. Any mass screening involving dental X-ray imaging, for example of a certain age group, must be separately justified and submitted for evaluation to the National Research and Development Centre for Welfare and Health (STAKES).

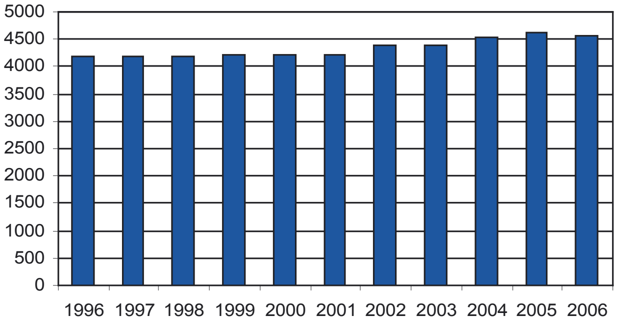


**Figure 10.** Conventional dental X-ray appliances, 1996–2006.

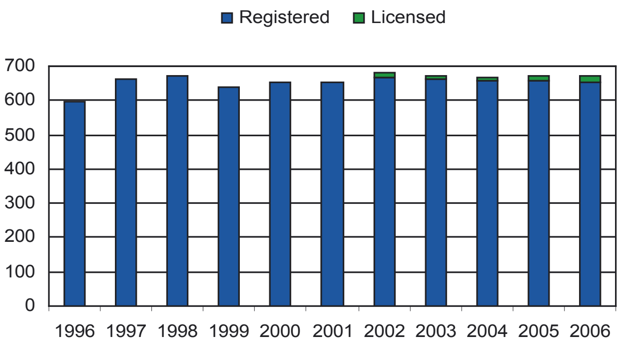


**Figure 11.** Panoramic X-ray appliances, 1996–2006.

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 2006. The number of licensed X-ray generators and tubes in health care in 1996–2006 is shown in Figure 1 (see item 1.1).

## Patient doses and number of examinations

The changes in patient doses arising from the transition from single slice to multislice CT scanning were investigated in a published study (STUK-A220). A 30% increase in patient doses was found. An updating of reference levels was prepared on the basis of the study. Optimization of patient doses was stressed at training seminars.

The number of radiological examinations in 2005 was investigated in a survey and the results were published in report STUK-B-STO 62. Responses to the survey on examination numbers were received from all responsible parties performing X-ray practices. 3.9 million X-ray examinations and procedures were performed in 2005, compared to 4.1 million in 2000. While 7% fewer conventional X-ray examinations were performed than in 2000, the number of CT scans increased correspondingly by 30%. The results will be used to determine the population dose in 2007.

### Reference levels

Measurements taken in the course of inspections revealed that the reference levels issued for X-ray examinations of adults were exceeded at six inspected sites in 2006. Nuclear medicine examination reference levels are surveyed every three years. The next survey will be based on data from 2006.

## 2.2 Use of radiation in industry, research and education

### Safety licences

1081 safety licences for the use of radiation in industry, research, education, trade and servicing operations were current at the end of 2006. The number of safety licences increased by about 10% between the mid-1990s and 2003, but has thereafter remained almost unchanged (see 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.

In 2006 STUK issued a decision exempting installation and servicing of smoke detectors containing radioactive substances from the obligation to obtain a safety licence. This decision led to discontinuation of 30 licences or radiation practices referred to in licences.

47 new safety licences were granted and 205 applications for amendments to existing licences were processed during 2006. 82 of these amendments concerned a change in the radiation safety officer and 123 concerned other changes such as commissioning of new equipment. A further 116 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 12 shows the number of appliances containing radioactive substances over the last ten years. There has been no substantial change in the number of appliances in recent years.

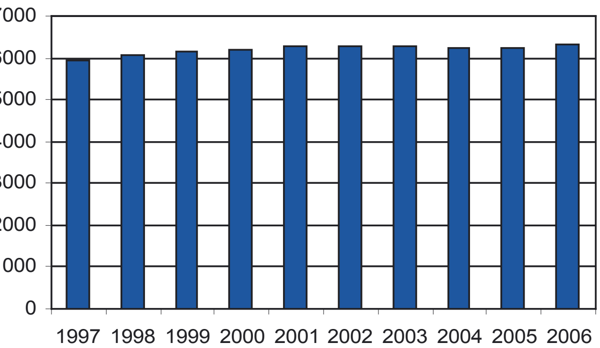


**Figure 12.** Appliances containing radioactive substances entered in safety licences for the use of radiation in industry, research and education, 1997–2006.

The number of X-ray appliances and accelerators used over a ten-year period is shown in Figure 3 (see item 1.1). This number increased by 50% during the period under review. New X-ray screening 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 gives 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 2006.

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

## 2.3 Inspections of licensed radiation practices

271 inspections were made of the use of radiation in health care. These inspections resulted in 122 repair orders or recommendations issued to responsible parties. Use of five unlicensed X-ray appliances was also prohibited.

150 inspections were made of the use of radiation in industry, research, education and trade.

These inspections resulted in 65 repair orders or recommendations. Most defects arose in warning lights and signs, and in other corresponding safety systems.

Table VI in Appendix 1 shows the number of inspections itemized by type of inspection. Table VII in Appendix 1 shows the number of inspections in health care itemized by type of practice.

## 2.4 Inspections of notifiable dental X-ray practices

1877 responsible parties were engaged in dental X-ray practices. Patient radiation exposure due to dental X-ray imaging was measured in 1281 appliances. The average dose was 2.3 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 34 imaging appliances.

31 inspections of notifiable dental X-ray practices were made. These inspections led to seven repair orders or recommendations issued to six responsible parties and one order prohibiting the use of an unregistered appliance.

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 2006 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 179 734 such devices were imported with a combined activity of about 7.5 GBq.

## 2.6 Radiation doses of workers

A total of 12 039 workers engaged in radiation work were subject to individual monitoring in 2006. Including doses falling below the registration threshold, about 140 000 dose records were entered in the Dose 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 recorded was 1.97 Sv in the use of radiation and 4.11 Sv in the use of nuclear energy. These recorded total doses were 0.2% larger in use of radiation and 20% larger in use of nuclear energy than in the preceding 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 $H_p(10)$ was 32.8 mSv recorded in the case of a surgeon. This corresponds to an effective dose of about 0.5–3.3 mSv. The largest effective dose in industry was a dose of 8.4 mSv sustained by a person who had used several radiation sources, while the largest effective dose in research was 17.7 mSv sustained by a person who had used unsealed sources.

The largest recorded dose to the fingers was 260.5 mSv, sustained by a laboratory assistant using unsealed sources.

Effective doses arising from exposure to internal radiation were recorded in the case of seven nuclear power plant workers, and for three people working in industry and two people working in research. The combined dose sustained by these workers from internal exposure was 1.3 mSv. The dose sustained from internal radiation is included in the calculation of total dose.

Table XI of Appendix 1 shows the number of workers in various sectors in the use of radiation and nuclear energy subject to individual monitoring over the last five years. The combined doses of workers in these sectors are shown in Figure 4 (in item 1.1) and in Table XII. Table XIII shows the doses in 2006 of worker groups sustaining high levels of exposure or being large in number. 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 radiation in X-ray practices in health care and veterinary medicine, in which workers use personal protective shields, and in which the dose is measured by a dosimeter on the exposed side of the shield. The effective dose is then estimated by dividing the measurement result ($H_p(10)$ value) by a factor between 10 and 60.

## 2.7 Approval decisions and verification of competence

### Training organizations providing radiation safety training for radiation safety officers

In Radiation Safety Guide ST 1.8 STUK has stipulated the minimum qualifications of the radiation safety officers who are responsible for the safe use of radiation. Training organizations that arrange training and competence examinations for radiation safety officers must apply to STUK for the right to arrange such examinations. Five applications from training organizations were reviewed and decided in 2006. 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 2006 there were 226 responsible practitioners in Finland, 18 of whom were accredited during 2006.

## 2.8 Radioactive waste

195 waste packages had been transported to the national storage facility for low-level radioactive waste maintained by STUK by the end of 2006. 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 44 batches of low-level radioactive waste in 2006, comprising a total of 127 packages. Table XV of Appendix 1 shows the activities or masses of the waste that was consigned to STUK in 2006.

## 2.9 Abnormal incidents

Under section 17 of the Radiation Decree (1512/1991), STUK must be notified of any abnormal event involving the use of radiation that is substantially detrimental to safety at the place where the radiation is used or in its environs. Any disappearance, theft or other loss of a radiation source such that it ceases to be in the possession of the licensee must likewise be notified, as must any other abnormal observation or information of essential significance for the radiation safety of workers, other persons or the environment.

There were 13 cases in 2006 in which abnormal incidents or situations occurred or were suspected in the use of ionizing radiation. Ten of these cases concerned the use of radiation in industry, research or transportation, and the other three concerned the use of radiation in health care. The number of abnormal incidents that occurred between 1997 and 2006 are shown in Figure 6 (item 1.1).

The case histories set out below specify the abnormal incidents that occurred in 2006 and the reasons for them, together with the measures taken on account of each incident.

***Incident 1***

During a servicing stoppage at an industrial plant fitters working in a silo were exposed to the beams from radiation sources. According to instructions, the radiation source shutters should have been closed before entering the silo, but due to human error this was not done. The silo contained three $^{60}$Co radiation sources with activities of approximately 80 MBq. The radiation doses sustained by the fitters were less than 0.03 mSv. The incident led to a change in the instructions for silo work, requiring the person authorizing such work to personally ensure that the radiation source is closed before the work commences.

***Incident 2***

A customer who had ordered some scrap lead noticed that the consignment included a lead housing bearing a radiation hazard warning sign and notified STUK of this observation. An inspection and radiation measurements performed at the site of the discovery revealed that there was no radioactive substance in the housing or in the glass bottle within it. The glass bottle had previously contained a phosphorus isotope ($^{32}$P) used in research. The radiation warning signs remaining on the housing and bottle had not been removed when the package was discarded. The package was several years old and, due to its short half-life (14.3 days), the radioactive substance would have decayed in any case by the time of the find.

***Incident 3***

A notification was received from an airport regarding damage sustained during cargo handling by a transportation package containing radioactive substance. The package contained a liquid iodine isotope ($^{123}$I) of activity 185 MBq destined for hospital use. An on-site inspection at the airport found that although the cardboard transportation crate of the package and its expanded polystyrene lining were damaged, the actual package containing the radioactive substance was intact and not leaking. The damaged package was removed from the working area of the freight depot and separated from other goods. The importer of the consignment subsequently collected and transferred the package to its own stores. The incident caused no extraordinary radiation exposure to workers or to the general public.

***Incident 4***

A notice was received from the Brazilian radiation safety authority (CNEN) that radiation sources sent from Finland had not reached their destination. The consignment contained two $^{85}$Kr sources of total activity 29.6 GBq. These radiation sources were beta sources used in industrial gauges that measure the thickness of paper. When properly packaged the sources pose no danger to the surroundings. The package was despatched to Brazil via Germany. The latest information indicates that the sources were found in Brazil this year after being delivered to the wrong recipient.

***Incident 5***

A radiation source containing Americium ($^{241}$Am) was melted down in a steel foundry. The source reached the foundry as part of a recycled metal consignment from abroad. The foundry is equipped with modern recycled metal radiation measurement systems to detect possible radiation sources. No source was detected, however, as the low-energy gamma radiation (59 keV) emitted by $^{241}$Am readily attenuates when the source is concealed under other metal items. Americium vaporises at a temperature of about 2600 °C. As the temperature in the foundry was considerably less than this (about 1600 °C), the americium remained liquid, and aside from minute quantities of dust and spray, it was not released, for example, to the air breathed by foundry workers. Molten americium will bind to the foundry slag. One member of the work shift at the time of the incident visited STUK for whole body counting and urine samples were collected from two other workers for radionuclide analysis. No americium was detected in these measurements. On the basis of other measurements taken (dust settling on surfaces and respiratory filters) it was estimated that the order of magnitude of worker exposures could have been no greater than some tens of microsieverts. The most important consequence of the incident was the slag batch in which the americium is bound. The activity concentration of the slag is about 200 Bq/g and the total size of the batch is about 120 tonnes. The slag is now stored in the foundry area and the responsible party is currently investigating various options for its final disposal. No americium was detected in the steel from the foundry batch in question.

***Incident 6***

Four industrial workers were exposed to X-radiation in an industrial facility when radiography was performed on an upper floor of their route through the facility. Although the radiographers used lead shields to attenuate the X-radiation, the shielding and access restrictions were not entirely adequate. The doses sustained by the exposed workers were between 0.8 and 2.6 mSv. Foremen of all contractors performing X-ray examinations were reminded of their duty to ensure radiation safety in their operations.

***Incident 7***

A radiation meter in the national radiation monitoring network set off an alarm (dose rate 99 µSv/h) when hit by radiation scattered from an embankment in X-ray imaging of a welded joint in a district heating pipe. The radiographers were unaware of the radiation meter, as it had been installed on the roof of a public office storehouse. Such meters are generally installed in fire stations. Nobody was exposed to radiation, as care had been taken to ensure that the storehouse was vacated before the imaging took place.

***Incident 8***

Gantries were constructed in a power station coal silo for the purpose of interior resurfacing work and workers used them for several days before an on-site inspection by STUK revealed that the radiation source ($^{137}$Cs, 3700 MBq) for the lowest level gauge in the silo had not been closed. The work was discontinued until the source had been closed. The highest dose sustained by any worker did not exceed 0.9 mSv. The STUK inspector issued regulations and instructions for safe working in an inspection protocol. In a memorandum the responsible party has notified STUK of the measures that it has taken to improve radiation safety.

***Incident 9***

$^{18}$F gas was released to the air of a radionuclide laboratory. This incident was due to a modification, of which the users were unaware, made during servicing work on the ventilation gear of a fume cupboard. The fume cupboard ventilation was mistakenly switched off, so that emissions from isotope handling were not channelled to the fume cupboard ventilation, and instead escaped to the air of the working area with the normal ventilation. By calculation, the largest possible dose to any worker was estimated at 0.33 mSv. However, the estimated dose to an individual worker based on whole body counting was less than one tenth of this. The responsible party revised its working instructions to prevent any future corresponding incident.

***Incident 10***

The spectrometers of a STUK laboratory vehicle detected a momentary increase in the dose rate of external radiation on Trunk Road 4. Spectral analysis indicated that the radiation was emitted by a bromine isotope ($^{82}$Br). The gamma spectrum suggested that the radiation source was almost unshielded. The dose rate at a distance of one metre from the radiation source was estimated at 50–200 μSv/h. This result indicated that the radioactive substance was not being transported in accordance with transport regulations. An investigation indicated that a private company vehicle performing indicator tests had passed the STUK laboratory vehicle at the precise point where the observation was made. This company had performed flow measurements for a customer using $^{82}$Br. The radiation was due to contamination of the apparatus used for applying the indicator. STUK inspected the company and instructed it to ensure that radioactive material was purged from its apparatus after measurements and that transportation of apparatus otherwise complied with transport regulations.

***Incident 11***

A patient was mistakenly given a radiopharmaceutical injection intended for another patient at a radionuclide laboratory. The patient was supposed to receive 600 MBq of $^{99m}$Tc tetrophosmine for a cardiac perfusion scan, but instead received 600 MBq of $^{99m}$Tc HMDP radiopharmaceutical intended for skeletal examinations. The excessive dose administered to the patient was about 4.8 mSv. The patient was advised to drink more liquid than usual over a 24-hour period. The planned cardiac perfusion scan was deferred. An internal bulletin was issued stressing the importance of due care and attention.

***Incident 12***

An update to a radiotherapy dose planning system failed to include an adjustment for tissue unhomogeneity. The error was detected one month after the update and a compensatory adjustment was made to ensure that the doses of patients in care complied with objectives. The worse case scenario, had the error remained undetected, would have been a 16% overdose to the bronchial area of one patient. As the error was detected enabling compensation of doses, none of the radiotherapy doses sustained by patients exceeded the planned total dose. The incident was discussed with the staff immediately after the error was detected and reconsidered at a subsequent staff training event.

***Incident 13***

The collimator rotation of one therapy field of a radiotherapy accelerator used in 'half-field' therapy deviated by 8–9 degrees from the value indicated by the appliance. This incident was probably due to slippage in the chain that turns the collimator, with consequent damage to one potentiometer. This caused an incorrect display of collimator angle, partial overlapping of therapy fields, and an additional dose of 2% in a small area compared to the planned target dose of 50 Gy. The incident posed no health hazard to the patient. The appliance manufacturer was notified of the incident to prevent future corresponding problems.

# 3 Regulatory control of practices causing exposure to natural radiation

## 3.1 Radon at workplaces

During 2006 STUK received 278 radon measurement notifications concerning either a radon concentration exceeding the action level of 400 Bq/m$^3$ measured in a work area, or further investigations of previously reported excessive levels. 122 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 55 work areas, and a measurement at another time of year in order to determine an annual average in 24 work areas. Radon concentrations were successfully reduced in 22 work areas during the year. STUK discontinued regulatory control in 26 work areas on the basis of further investigations (measurement during working hours or determination of annual averages). 266 work areas at 126 workplaces were subject to regulatory control by STUK during the year.

Regular radon inspections were performed at six underground mines, in one of which the average radon concentration slightly exceeded the action level in a measurement taken in summer. A decision was taken to perform repeat measurements at the mine at another time of year to determine the annual average radon concentration. 12 underground excavation sites were inspected, and the radon concentration was found to exceed the action level at three of these. Repair orders were issued for these work sites in order to reduce the radon concentration.

Radon exposure of workers was monitored by regular radon measurements and monitoring of working hours at one conventional workplace and one excavation site where the radon concentration exceeded the action level. A total of 23 workers were subject to radon exposure monitoring during 2006.

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 household water, construction materials and other materials. Inspection reports on six activity measurements of construction materials and one activity measurement of household water were prepared in 2006. A statement was also issued on the use of drilled well water as household water. On the basis of radioactivity measurements submitted to STUK, an order was issued for removal of radioactive substances from the water in question.

## 3.3 Cosmic radiation

The employees of six Finnish airlines were exposed to cosmic radiation to such a degree that radiation exposure monitoring was required for the employees. The doses sustained by the 3484 employees in question were recorded in the Dose Register.

The largest individual doses of cosmic radiation sustained by pilots and cabin crew members were 4.0 mSv and 5.3 mSv, respectively. The average doses sustained were 1.6 mSv for pilots and 1.8 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 activities that give 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 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 and radar stations.

The work of the NIR Laboratory in regulatory control of the use of non-ionizing radiation between 2000 and 2006 is shown in Table XVIII of Appendix 1. Most regulatory inspection work takes place at sunbed facilities and in market surveillance 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 2006 chiefly consisted of inspection consultancy services, for example when determining the radiation characteristics of ultraviolet lamps in use and the compliance of equipment with safety standards.

On-site 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. The 25 facilities inspected in 2006 included a total of 39 clam shell type sunbed appliances. Only one inspected site included ceiling-installed tanning equipment (12 appliances). Deficiencies affecting the safety of sunbed users were found at almost all facilities. About one third of the clam shell type sunbed appliances did not belong to the appliance class approved in Finland (UV type 3), which is slightly more than in the preceding year. Although about half of the appliances complied with requirements by including radiation safety instructions, these appliances also included information contrary to requirements on such matters as the health impact of sunbeds, or inadequate technical operating instructions. For example, only about half of the operating instructions referred to the recommendation limiting annual use of sunbed appliances (5 $kJ/m^2$, corresponding to about 20 tanning sessions) and to the 18-year age limit recommendation included in the Decree of the Ministry of Social Affairs and Health on the Limitation of Public Exposure to Non-ionizing Radiation (294/2002). Half of the sunbed appliances inspected also lacked the required timer that enables the user to select recommended exposure times and switches the appliance off after the set period has elapsed. The times for first tanning sessions recommended for these appliances were also too long. The use of ceiling-installed tanning lamps was discontinued entirely due to lack of compliance with safety requirements on such aspects as unrestricted use of appliances by children. Sunbed appliances were used for medical phototherapy at one facility by permission of the State Provincial Office.

### Other regulatory control

A wholesaler's website indicated that it supplied sunbed lamps that were too powerful. After the wholesaler was contacted marketing of these lamps for tanning was discontinued and lamps of the type in question were removed from the product catalogue.

Two laser light shows were arranged in April without notifying STUK. Following enquiries into this matter the organizers announced that they would stop using laser appliances. In December a Finnish event organizer used lasers of foreign origin in a show that was not notified to STUK and at which laser radiation was directed at the audience in a manner contrary to instructions issued by STUK. This case is still under investigation.

A fixed light display installation at one nightclub directed radiation from low-power laser appliances towards members of the public. After STUK called attention to this the nightclub announced that it would stop using laser appliances.

An order was issued for withdrawal of a laser projector from the market and a RAPEX notification to the European Commission was made regarding this consumer product that could damage the eyes. The Danish importer had marketed the appliance in Finland as a class 1 laser for use as a toy. However, measurements made by the Finnish Institute of Occupational Health and by STUK indicated that the appliance actually belonged to class 3R, and could not be used as a toy.

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

The ultraviolet radiation of an air filter was measured and exposure due to stray radiation was estimated.

## 4.3 Electromagnetic fields

### Market surveillance of mobile phones

Market surveillance of mobile phones began in 2003. Radiation tests have been performed on a total of 60 mobile phones to date (see Table XX of Appendix 1). Fifteen GSM-type mobile phones in general use were tested in 2006. No phone exceeded the maximum value of 2 W/kg specified in a Decree of the Ministry of Social Affairs and Health (294/2002). The highest measured value was 1.3 W/kg.

### Other regulatory control

STUK issued three statements to planning authorities specifying its views regarding land use in the vicinity of power lines. While a favourable opinion was issued to Inkoo district executive board concerning a golf course planned under 400 kV and 110 kV power lines in the village of Ingarskila, it was recommended that no residential buildings should be sited in the area of the power lines or in their immediate proximity. A statement issued to the City of Espoo city planning department saw no need for substantially amending planning proposals concerning a new golf course on the former Mankkaa dump next to 110 kV power lines. In another statement issued to the City of Espoo STUK recommended that a motor vehicle parking lots should not be located under 400 kV power lines.

The labour protection department of the Ministry of Social Affairs and Health requested the views of STUK on how a forthcoming government resolution "on protection of workers from hazards arising from electromagnetic fields" should ensure the occupational health and safety of persons working in the vicinity of magnetic imaging appliances. In its statement STUK noted that the exposure limits specified in the Decree should not apply to medical and nursing staff, provided that the risks caused by exposure are otherwise prevented and exposure is limited in accordance with the ALARA principle (As Low As Reasonably Achievable). Tests on volunteer test subjects that are required in technical R&D and production settings should be performed on the same principles as medical tests on healthy test subjects, for which an appropriate statement is required from the Board of Ethics.

Radiation exposure caused by radar and radio equipment was estimated for construction work to be undertaken in the vicinity of a radar station and at two public broadcasting stations. Base station transmitters were also inspected.

## 4.4 Abnormal incidents

The abnormal incident reporting required by section 17 of the Radiation Decree 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 2006.

# 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 2006:

- ST 1.3 Warning signs for radiation sources
- ST 3.3 X-ray examinations in health care

These Finnish language guides were also translated into Swedish and English.

## 5.2 Other regulation work

Pursuant to section 17 of the Radiation Act, STUK issued decision no. 19/300/06 exempting from the duty to obtain a safety licence the servicing and installation of smoke detectors containing the radioactive isotope $^{241}$Am of activity not exceeding 40 kBq.

By decision no. 12/310/06 STUK confirmed the acceptability criteria for operating radiography and fluoroscopy equipment and computed tomography appliances in health care. These acceptability criteria were confirmed pursuant to section 30 of the Decree of the Ministry of Social Affairs and Health on the Medical Use of Radiation (423/2000), and were appended to Guide ST 3.3.

STUK assisted the Ministry of Social Affairs and Health in national implementation of a labour protection Directive on electromagnetic fields and a forthcoming 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 examinations (CT scans) has risen continually and new areas of use have been discovered for this technique with advances in appliance technology. Even though CT scans constitute only 7% of all X-ray examinations, they give rise to about 40% of the total X-ray dose sustained by patients for diagnostic purposes. The quality criteria and reference levels issued by the European Union are partly outdated, and optimization of the use of new multislice appliances in respect of image quality and dose has often overemphasized good image quality. STUK research projects have investigated the realization of optimization, patient doses and quality control in CT scans, with a view to updating reference levels for patient doses and quality control instructions. The results were published in report STUK-A220, and an article on the findings will also be prepared for international publication in 2007.

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 indicate 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. In many cases reference levels must be revised downwards on the basis of the results, though in some cases upward revisions are needed. 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 survey will be employed in inspections of the use of radiation.

### Examination-specific radiation doses of staff in interventional radiology

The aim of the study is:

- to investigate examination-specific staff radiation doses and the dependency between staff doses and the doses sustained by patients in corresponding examinations
- to investigate doses to various parts of the body (hands, legs, eyes and whole body) from interventional radiology/cardiology.

The operation of dosemeters to be used in the project was tested and measurements were taken at two hospitals for the cardiology studies. The effect of a protective apron on the effective dose sustained by radiologists was also investigated. An international research publication was prepared on the effect of the protective apron. This project will continue in 2007.

### 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 cardiac studies
- interventional radiology/collation of patient doses in interventional radiology
- staff doses in interventional radiology
- mammography examinations.

A report on X-ray image quality assessment was completed during 2006 and provisional results were obtained on patient doses in interventional radiology. A review of individual doses of persons working in interventional radiology and cardiology was also performed. A conference on special issues in paediatric X-ray examinations was also arranged at STUK. The project will end in the first half of 2007.

### IAEA code of practice on dosimetry in X-ray diagnostics

An International Atomic Energy Agency (IAEA) research project to test a code of practice on diagnostic dosimetry began in 2006 (Coordinated Research project 2006–2007: Testing of the Implementation of the Code of Practice on Dosimetry in X-ray Diagnostic Radiology). STUK is particularly involved in this project in testing work on dose-area-product meters, in testing calibration and measurement methods for the meters used in CT dosimetry, and in mammography dosimetry. This project will continue in 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.

#### Measurement of small direct currents

A master's thesis on measurement of small direct currents was completed in association with the Centre for Metrology and Accreditation. Current measurement is a fundamental element of radiation metrology when using ionization chambers. The thesis created a reliable summary of the bases for measurements of small ionization currents and of uncertainty estimates for various measuring methods.

#### Calibration of an ionization chamber for use in CT appliance dosimetry

In dosimetry of computed tomography equipment for X-ray diagnostics (CT appliances) the dose is determined in a long and narrow volume using a special ionization chamber that measures the product of dose and length. This master's thesis work studied various practical implementation models for calibrating such ionization chambers and determined the measuring uncertainties for these methods. The work gave rise to a source document on calibration methods for CT appliance dosemeters for use by the Dosimetry Laboratory at STO.

## 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)

This study is part of the subproject of the Tampere University of Technology HERMO project, which seeks to investigate the effect of mobile phone radiation on swine brain function. To improve the accuracy of dosimetry, the SAR (specific absorption rate) was measured in a liquid phantom representing the head of a pig. The SAR for the corresponding situation was determined numerically at the Technical Research Centre of Finland – VTT. These results differed by less than 2%, which was a good outcome. The results will be reported in a scientific article currently under preparation.

The HERMO-SKIN study is investigating the impact of mobile phone radiation on the proteins of skin in vivo. The NIR Laboratory assembled the apparatus required for irradiation, arranged the technical quality control and safety of this irradiation, and determined the SAR of the test subjects. The findings were reported in a scientific article, which was submitted to the journal Bioelectromagnetics for review.

## Software development for simulating electromagnetic fields (EMSOFT)

In association with the Electromagnetics laboratory of Helsinki University of Technology (HUT) an investigation was performed into how accurately exposure to base station radiation can be determined by computation. STUK was assigned to provide information on measured field strengths for the computation model and to verify the computed results of HUT empirically. In accordance with the project plan, field strengths were measured for one base station antenna and the SAR was determined using a slab phantom representing a human being.

## 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.

### High frequency heaters

The practical work of this investigation was already completed at the end of 2005. The findings indicated that absorbed thermal power could be estimated using the current induced in the body of the user of a high frequency heater. A scientific article on this subject was prepared during 2006 and will be sent to the journal Health Physics for review.

### Background radio frequency (RF) radiation

This investigation sought to gather information on radiation in the environment caused by radio transmitters operating in the 80–3000 MHz frequency band for the purpose of informing the public of the risks of this radiation. Studies focused particularly on fields generated by new wireless communication devices. The materials were collated and largely processed during the year under review. Outlines of the technical report and publication were completed.

## Academic thesis work

### Effects of UV-A radiation on mouse melanoma

An academic thesis was completed under the title: “Effect of long-wave UV radiation on mouse melanoma: An in vitro and in vivo study”.

# 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 2006 representatives of STUK took part in meetings of the following international organizations and working groups:

- Expert Group on Article 31 of the Treaty establishing the European Atomic Energy Community
- Working group on harmonizing individual worker dose measurement methods of the European Radiation Dosimetry Group (EURADOS)
- EAN working group on radiation protection of workers in the use of radiation and in exposure to natural radiation (European ALARA Network)
- Clinical auditing working group of the European Society for Therapeutic Radiology and Oncology (ESTRO)
- Standardization working group on electromagnetic fields CENELEC TC106X/WG9.
- Standardization working group on ultraviolet radiation IEC TC61/MT16.
- Nordic ozone and UV working group NOG.
- Nordic working group on the use of sealed sources (NORGUSS).
- TG ELF working group of the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Work also continued on the ESOREX (European Study on Occupational Radiation Exposure) project by collating exposure data for workers engaged in radiation practices.

## Participation in other international conferences

Representatives of STO 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

The DOS Laboratory helped to organize a training event for the staff of Nordic ionizing radiation calibration laboratories. The main theme of this event was measurement techniques for small ionization currents and the reliability of such measurements. The event took place at SSI (the Swedish Radiation Protection Authority – Statens Strålskyddsinstitut) in Sweden.

STUK organized a meeting of the Nordic dosimetry working group at its premises in Helsinki. A report prepared by the working group on the capacity of Nordic laboratories was completed.

As part of the EMF-NET co-ordination project under the sixth European Union framework programme, representatives of the NIR Laboratory visited Arbetslivsinstitut (the Swedish National Institute for Working Life) in Umeå, Sweden, to discuss collaboration on magnetic fields generated by welding equipment.

In association with other Nordic radiation protection authorities, STUK commented on the draft report of the European Union Scientific Committee on Consumer Products (SCCP), which discussed the safety of ultraviolet radiation from sunbed appliances.

# 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 National Board for Metrology, the Radiation Safety Conference committee, Eurolab-Finland, and SESKO).

## Finnish conferences arranged by STUK

STUK organized two conferences in 2006: A co-operation seminar with hospital physicists working in X-ray diagnostics, and a co-operation seminar with representatives of Qualisan Oy engaged in clinical auditing.

## Participation in meetings of Finnish working groups

Representatives from STUK took part in a meeting of a steering group appointed by the Ministry of Social Affairs and Health to promote patient safety.

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 two meetings, which were attended by representatives of STUK and which considered standards proposals from the International Electrotechnical Commission (IEC) and the European Committee for Electrotechnical Standardization (CENELEC) falling within the competence of these committees. Comments and opinions were issued on 13 standards proposals (two statements for SK 61 and 11 statements for SK 106) in the final vote. Particularly noteworthy was the negative opinion in the final vote regarding a proposed amendment (61/3027/RVC) to the sunbed standard of the IEC (IEC 60335-2-27). 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. The CENELEC sunbed standard (EN 60335-2-27) should also be revised. The new standard should take note of the views on safety in using sunbeds that were published in July by the European Union Scientific Committee on Consumer Products (SCCP).

## 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

STUK assisted the Ministry of Social Affairs and Health in national implementation of a labour protection Directive on electromagnetic fields and a forthcoming Directive on optical radiation (see item 5.2).

# 9 Information activities

## Books, bulletins, reviews

STUK publishes the Radiation and Nuclear Safety book series comprising a total of seven books. A five volume series of books on ionizing radiation was published between 2002 and 2004 under the titles: “Radiation and its Detection”, “Radiation in the Environment”, “Health Impacts of Radiation”, “Nuclear Safety” and “Use of Radiation”. A sixth volume was added to the series in 2006 under the title: “Electromagnetic Fields”. About two-thirds of the manuscript for a final volume on optical radiation was completed by the end of the year.

## Public information on current affairs

STO and the NIR Laboratory took part in work to improve STUK's website. The Finnish language pages of the site were updated.

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

During the year the NIR Laboratory received many questions from members of the public, radiation users, the media, and other parties interested in non-ionizing radiation. Responses depend increasingly on the Public Information unit of STUK and the publications editor, as research personnel would otherwise spend a great deal of time preparing answers to enquiries. The UUDIN project will seek to find ways of reducing the burden of outside enquiries. In addition to answers, parties submitting enquiries were also provided with publicity bulletins. Visiting groups were also given a tour of the NIR Laboratory and a presentation of its work.

An ultraviolet information session was arranged in spring 2006 in association with Finnish Cancer Organisations and the Finnish Meteorological Institute. The session issued a joint bulletin entitled: “it’s always worth protecting yourself from ultraviolet radiation”. STUK addressed the event on the subject of clothing and creams to protect the skin, and especially the child’s skin, from sunlight.

Press releases were prepared on the following subjects:

- No radioactive shipments found at borders.
- Radiation levels of mobile phones tested by STUK remain within recommended limits.
- Amendment to the Radiation Act imposes new requirements on possessors of radiation sources.
- Workers sustain lower radiation doses.
- Nordic radiation safety authorities cast doubt on sunbed use.
- Protecting the skin from ultraviolet radiation could prevent nine out of ten melanomas.
- UV-A radiation may cause greater health hazards than previously believed.
- Workers exposed to powerful electromagnetic fields.
- CT scanners increasingly used for X-ray examinations.

Other information activities:

- Information on radiation protection, on new regulations, and on the background thereto was actively provided to responsible parties and radiation users 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

STO arranged the following training events:

- Radiation safety and quality in X-ray diagnostics
- Radiation safety conference for industry
- Radiation protection course for trainers
- Conference of radiotherapy physicists

Lectures were also given at the annual Radiation Safety Conference in Tampere.

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.

A general training and information event on implementation of the new labour protection Directive limiting electromagnetic fields was arranged in association with the Finnish Institute of Occupational Health in Tampere.

A lecture on the new worker Directive and its background biology was given at a current affairs conference arranged by the University of Vaasa (Low frequency electrical and magnetic fields in the environment). A lecture was given at an event arranged by the Magnet Technology Centre on the effects and measurement of electromagnetic fields and sources of low-frequency electromagnetic fields in industry.

A lecture was delivered at an occupational health and safety sector conference in Tampere on assessing the risks associated with electromagnetic fields at the workplace and the labour protection Directive on this subject.

A lecture on the metrology of measurements of exposure to electromagnetic fields was delivered at a seminar on high frequency measurements and their traceability organized by the Centre for Metrology and Accreditation.

A lecture on the effects of UV-A radiation on melanoma metastasis was delivered at a conference and training event arranged by the Norwegian Society for Photobiology and Photomedicine in Trondheim on 12 May 2006.

# 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. It 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

### Maintenance of metrological standards, and development work on irradiation equipment and methods of measurement

In 2006 the DOS Laboratory:

- Began using a new reference standard (ionization chamber) for measurements in X-ray diagnostics. The standard was calibrated at the PTB Laboratory (Physikalisch-Technische Bundesanstalt) in Germany.
- Began using IEC 61267 standard radiation qualities designed for X-ray diagnostics.
- Developed a calibration procedure for DAP meters (dose-area product) based on the use of two DAP meters. This procedure was presented to the IAEA International Conference on Quality Assurance and New Techniques in Radiation Medicine in Vienna, and was also noted in IAEA dosimetry guidelines for diagnostics.
- Began calibrating DLP meters (dose-length product) for use in CT dosimetry. A master's thesis was also prepared on validation of this method.

Standard dosimetry activities of the DOS Laboratory in 2006 incorporated two internal audits covering the appliance register, staff training, job descriptions, laboratory facilities, validation of measurement methods, testing of measuring equipment, handling of apparatus, reference measurement devices and quality assurance of results. Remedial measures arising from observations made during the audits have already been taken or will be taken during 2007.

Chapter 6 gives details of research projects on standard laboratory activities and dosimetry.

### Meter and measurement comparisons

The DOS Laboratory took part in the annual TLD comparison measurement of absorbed dose of $^{60}Co$ gamma radiation between calibration laboratories belonging to the laboratory network maintained by the IAEA/WHO. The STUK result differed from the reference value by less than 0.1%, which was well within the approval limit of 3.5%.

Figure 13 shows the deviations in the measurement results of STUK from the reference value in IAEA/WHO measurement comparisons over the period from 1990 to 2006.

## 10.2 Non-ionizing radiation

### Development work on measurement and irradiation equipment and methods

The cosine correction and diffuser reference level used in precision measurements of spectral ultraviolet irradiance have been amended so that the spectral irradiance in measurements of solar ultraviolet radiation is reduced by 3–4%.

STUK took part in an international comparison of erythema-weighted UV radiometers (COST PMOD) in Davos. The difference from the STUK calibration was 7%, which was well within the uncertainty range for the comparison (± 10.8%).

STUK participated in an international test comparison of mobile phones between 21 measurement laboratories arranged by the Swiss company Schmid & Partner Engineering AG (SPEAG) in 2005–2006. The results demonstrated the high standard of STUK's quality system for SAR testing. The results obtained by STUK generally deviated by less than the laboratory average, and even the maximum difference was less than 13%. The comparison confirmed that the uncertainty of SAR testing is within the estimated uncertainty (20.2%).

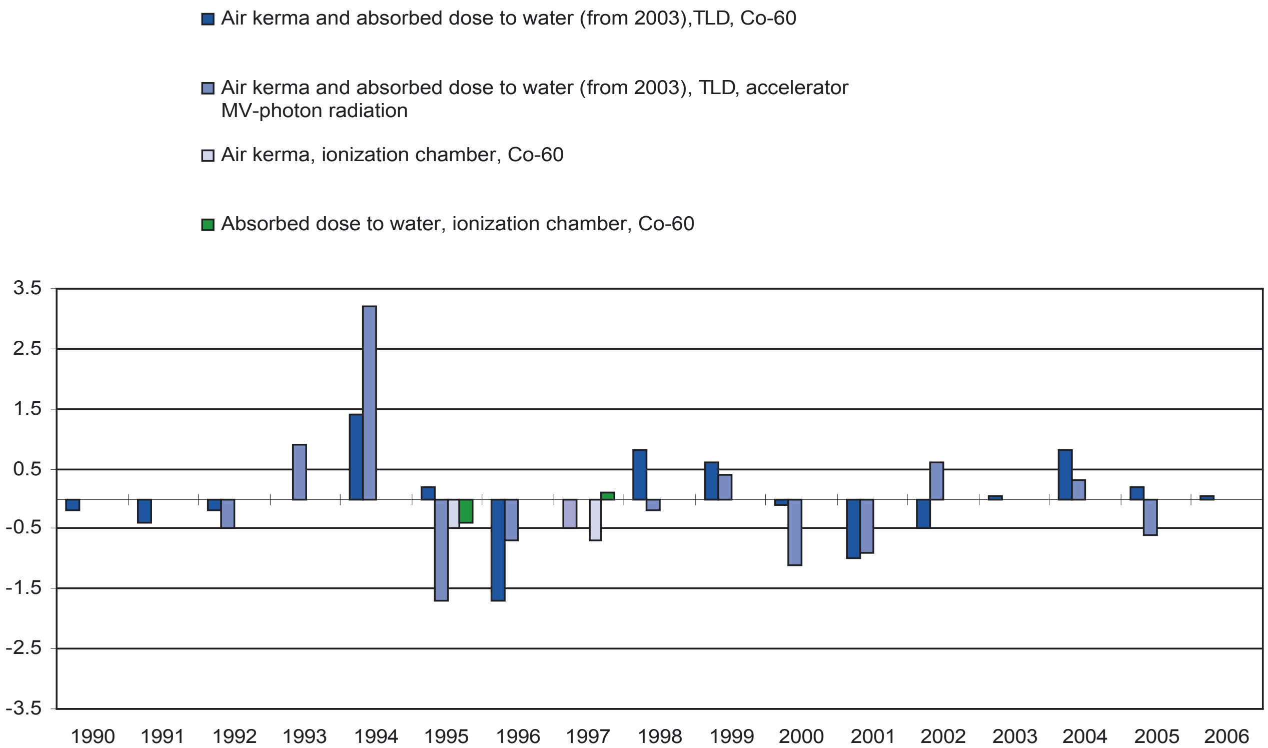


**Figure 13.** Deviations (%) in measurement results of STUK from the reference value in IAEA/WHO measurement comparisons, 1990–2006.

# 11 Services

## 11.1 Ionizing radiation

### Calibration, testing and irradiation

The DOS laboratory performed radiation meter calibrations on request. 91 radiation meter calibration certificates and 18 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.

### Other services

112 copies of the PCXMC measurement program developed at STUK were sold for dose calculation in X-ray diagnostics. Tests were also provided as a service to confirm the compliance of X-ray appliances with standards.

## 11.2 Non-ionizing radiation

### Calibration, testing and irradiation

The NIR Laboratory performed a total of 17 radiation meter calibrations and tests and seven safety assessments and radiation measurements. The service work of the NIR Laboratory between 2000 and 2006 is shown in Table XVIII of Appendix 1.

# 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 and 2006, due to the small volume of data and because the findings were broadly in line with those of 2004. A digest of the surveys for 2005 and 2006 will be combined with the results for 2007.

# APPENDIX 1 TABLES

**Table I.** Radiation practices referred to in safety licences for the use of radiation in health care at the end of 2006.

| Use of radiation | Number of practices |
|---|---|
| X-ray examination | 398 |
| Dental X-ray examination*) | 11 |
| Veterinary X-ray examination | 200 |
| Use of unsealed sources | 41 |
| Use of sealed sources | 22 |
| Radiotherapy | 13 |
| Other uses of radiation | 18 |

*) 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 2006.

| Appliances/laboratories | Number |
|---|---|
| **X-ray diagnostic appliances (generators)** *) | **1572** |
| **X-ray tubes** | 1711 |
| • mammography (not screening) | 113 |
| • screening mammography | 90 |
| • computer tomography | 84 |
| • angiography (not DSA) | 29 |
| • digital subtraction angiography (DSA) | 81 |
| • bone mineral density measurement | 86 |
| **Dental X-ray appliances** | **5248** |
| • conventional dental X-ray appliances | 4575 |
| • panoramic X-ray appliances | 673 |
| **Radiotherapy appliances** | **95** |
| • accelerators | 31 |
| • afterloading appliances | 6 |
| • X-ray therapy appliances or radiographic appliances | 25 |
| • radiotherapy simulators | 14 |
| • BNCT therapy unit | 1 |
| • other appliances | 18 |
| **Appliances containing radioactive substances** | **103** |
| • attenuation correction units | 22 |
| • flood sources | 23 |
| • calibration sources | 22 |
| • other appliances | 36 |
| **Veterinary X-ray appliances** | **239** |
| **Radionuclide laboratories** | **64** |
| • B-type laboratories | 18 |
| • C-type laboratories | 45 |
| • other laboratories | 1 |

*) 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 2006.

| Use of radiation | Number of practices |
|---|---|
| Use of sealed sources ((excluding gamma radiography) | 628 |
| Use of X-radiation (excluding radiography) | 235 |
| Import, export and trade | 127 |
| Use of unsealed sources | 125 |
| Installation, test operation and servicing | 115 |
| X-ray radiography | 79 |
| Gamma radiography | 7 |
| Production of radioactive substances | 5 |
| Other uses of radiation | 33 |

**Table IV.** Radiation appliances and sources used in industry, research and education, and radionuclide laboratories at the end of 2006.

| Appliances/laboratories | Number |
|---|---|
| **Appliances containing radioactive substances** | **6305** |
| • level switches | 2315 |
| • continuous level gauges | 1122 |
| • density gauges | 1006 |
| • weight scales | 566 |
| • basis weight meters | 558 |
| • moisture and density gauges | 124 |
| • fluorescence analyzers | 126 |
| • thickness gauges | 80 |
| • radiography appliances | 20 |
| • other appliances | 388 |
| **X-ray appliances and accerators** | **1098** |
| • X-ray screening appliances | 393 |
| • radiography appliances | 330 |
| • diffraction and fluorescence analyzers | 232 |
| • thickness gauges | 40 |
| • ash meters | 18 |
| • particle accelerators | 18 |
| • other analytical appliances | 67 |
| **Radionuclide laboratories** | **158** |
| • A-type laboratories | 2 |
| • B-type laboratories | 25 |
| • C-type laboratories | 116 |
| • other laboratories | 15 |

**Table V.** Radionuclides most commonly used in sealed sources in industry, research and education, and number and activities of sources at the end of 2006.

| Radionuclide | Number of radiation sources | Total activity*) (GBq) |
|---|---|---|
| **Activity < 400 GBq** | | |
| Cs-137 | 3980 | 11 007 |
| Co-60 | 1445 | 1182 |
| Kr-85 | 413 | 5194 |
| Am-241 (gamma sources) | 362 | 2595 |
| Pm-147 | 168 | 4635 |
| Fe-55 | 147 | 4172 |
| Am-241 (AmBe neutron sources) | 124 | 1076 |
| Co-57 | 71 | 17 |
| Sr-90 | 64 | 198 |
| Cd-109 | 59 | 25 |
| **Activity > 400 GBq** | | |
| Cs-137 | 27 | 666 320 |
| Ir-192 | 12 | 99 310 |
| Co-60 | 7 | 97 664 **) |
| 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 2006.

**Table VI.** Inspections of the use of radiation in 2006.

| Type of inspection | Number of inspections | | |
|---|---|---|---|
| | Industry, research, education, trade, installation, maintenance | Heatlh care | |
| | | Licensed practices | Notifiable licence-exempt dental X-ray practices |
| Initial inspections | 20 | 142 | 0 |
| Periodic inspections | 125 | 127 | 6 |
| Repeat inspections | 0 | 1 | 0 |
| Other inspections or measurements | 5 | 1 | 25 |
| **Total** | **150** | **271** | **31** |

**Table VII.** Inspections of licensed practices in health care in 2006.

| Type of practice | Number of inspections |
|---|---|
| • X-ray diagnostics | 191 |
| • dental X-ray diagnostics | 3 |
| • veterinary X-ray diagnostics | 46 |
| • nuclear medicine | 4 |
| • radiotherapy | 26 |
| • other uses of radiation | 1 |
| **Total** | **271** |

**Table VIII.** Imports and exports of sealed sources in 2006.

| Radionuclide | Imports | | Exports | |
|---|---|---|---|---|
| | Activity (GBq) | Number | Activity (GBq) | Number |
| Ir-192 | 49 108 | 11 | 4278 | 9 |
| H-3 | 7400 | 2500 | 894 | 526 |
| Cs-137 | 853 | 211 | 57 | 62 |
| Am-241 | 709 | 47 | 4 | 558 |
| Pm-147 | 353 | 27 | 279 | 22 |
| Kr-85 | 198 | 122 | 1027 | 70 |
| Fe-55 | 80 | 63 | 90 | 38 |
| Gd-153 | 48 | 13 | 4 | 3 |
| Cd-109 | 14 | 27 | 9 | 19 |
| Co-60 | 7 | 15 | -*) | - |
| Co-57 | 3 | 15 | - | - |
| Ni-63 | 2 | 4 | 2 | 3 |
| Am-241**) | 1 | 1 | - | - |
| others total ***) | 3 | 25 | 6 | 41 |
| **Total** | **58 779** | **3081** | **6650** | **1351** |

*) The “-” symbol indicates no import/exports.
**) AmBe neutron sources.
***) Imports, nuclidies Ba-133, Bi-207, Ge-68, Eu-152, Po-210 and Sr-90.
Exports, nuclides: Cm-244, Ge-68, Po-210 and Sr-90.

**Table IX.** Imports and exports of unsealed sources in 2006.

| Radionuclide | Activity (GBq) | |
|---|---|---|
| | Imports | Exports |
| Mo-99 | 41 164 | 7487 |
| I-131 | 6080 | - *) |
| Tc-99m | 2617 | - |
| Ho-166 | 345 | - |
| P-32 | 132 | < 1 |
| H-3 | 128 | 2 |
| Tl-201 | 111 | - |
| Y-90 | 74 | - |
| Sm-153 | 63 | - |
| I-125 | 60 | 5 |
| I-123 | 49 | 24 |
| In-111 | 40 | < 1 |
| S-35 | 35 | - |
| Co-60 | 34 | - |
| C-14 | 7 | < 1 |
| F-18 | - | 125 |
| others total **) | 10 | < 1 |
| **Total** | **50 949** | **7643** |

*) The "-" symbol indicates no imports/exports.
**) Imports, nuclidies: Co-57, Cr-51, Cs-137, Ga-67, I-129, Na-22, P-33, Po-210, Ra-226, Rb-86, Se-75,Sr-85 and U-238.
Expors, nuclides: Eu-152, Sr-85 and U-238.

**Table X.** Manufacturing of radioactive substances (unsealed sources) in 2006.

| Radionuclide | Activity (GBq) |
|---|---|
| O-15 | 19 650 |
| C-11 | 11 867 |
| F-18 | 13 406 |
| Br-82 | 2870 |
| I-123 | 2310 |
| Na-24 | 126 |
| Ru-103 | 43 |
| La-140 | 15 |
| others total *) | 15 |
| **Total** | **50 302** |

*) Nuclides: Ar-41, Cr-51, Cu-64, Au-198 and Np-235.

**Table XI.** Number of workers subject to individual monitoring in 2002–2006.

| Year | Number of workers in various sectors in the use of radiation and nuclear energy | | | | | | |
|---|---|---|---|---|---|---|---|
| | Health care | | Veterinary medicine | Industry | Research and education | Use of nuclear energy *) | Total **) |
| | Exposed to X-radiation | Exposed to other radiation sources | | | | | |
| 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 |
| 2006 | 4779 | 936 | 363 | 1281 | 948 | 3862 | 12 039 |

*) Finns working at nuclear power plants in Finland and abroad and foreign workers working at Finnish facilities.

**) The figure shown in a certain row 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 sectors in the use of radiation and nuclear energy in 2002–2006.

| 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 | | | | | |
| 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 |
| 2006 | 1.43 | 0.14 | 0.08 | 0.24 | 0.08 | 4.11 | 6.08 |

*) $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the use of X-radiation in health care and veterinary medicine 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 2006.

| 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**) | 163 | 0.53 | 3.7 | 3.2 | 15.0 |
| Radiologists**) | 541 | 0.39 | 2.5 | 0.7 | 24.7 |
| Interventional radiologists**) | 19 | 0.15 | 10.8 | 8.0 | 24.8 |
| Surgeons**) | 270 | 0.12 | 3.3 | 0.4 | 32.8 |
| Radiographers**) | 2626 | 0.11 | 0.5 | 0.0 | 3.8 |
| Industrial radiographers | 395 | 0.14 | 1.0 | 0.4 | 6.8 |
| Researchers | 734 | 0.05 | 2.1 | 0.1 | 12.8 |
| Nuclear power plant workers | | | | | |
| • mechanical duties | 886 | 1.41 | 2.1 | 1.6 | 13.9 |
| • cleaning | 250 | 0.49 | 2.8 | 1.9 | 13.3 |
| • material testing | 279 | 0.47 | 2.0 | 1.7 | 18.4 |
| • insulatin work | 106 | 0.44 | 4.8 | 4.1 | 13.6 |
| • radiation protection | 75 | 0.20 | 2.9 | 2.6 | 13.3 |
| • operating staff | 276 | 0.09 | 0.7 | 0.3 | 3.9 |

*) 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 medicine 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 2006).

| Radionuclide | Activity (GBq) or mass |
|---|---|
| H-3 | 15 857 |
| Cs-137 | 2323 |
| Pu-238 | 1608 |
| Kr-85 | 1250 |
| Am-241 | 1601 |
| Sr-90 | 257 |
| Ra-226 | 231 |
| Co-60 | 180 |
| Cm-244 | 109 |
| U-238 | 1055 kg |

**Table XV.** Low-level radioactive waste received by STUK in 2006.

| Radionuclide | Activity (GBq) or mass |
|---|---|
| Am-241 | 317 |
| Kr-85 | 51 |
| H-3 | 156 |
| Pm-147 | 38 |
| Cs-137 | 125 |
| Fe-55 | 33 |
| Co-60 | 5.5 |
| Cm-244 | 33 |
| Am-241*) | 7 |
| Sr-90 | 1.6 |
| Cd-109 | 0.4 |
| U-238 | 321 kg |

*) AmBe neutron sources.

**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 2008 | 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<br>• Tampere Polytechnic | • Pylon AB-5<br>• Pylon AB-5 and AlphaGuard | • 3 Aug 2008<br>• 25 Sep 2008<br>25 Sep 2008 | 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 2002–2006.

| Year | Number of workers | | Total dose (Sv) | |
|---|---|---|---|---|
| | Pilots | Cabin crew | Pilots | Cabin crew |
| 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 |
| 2006 | 1072 | 2412 | 1.73 | 4.35 |

**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 |
| 2006 | 48 | 1 | 7 | 17 | 7 | 80 |

**Table XIX.** Inspections of sunbed facilities.

| Year | Number |
|---|---|
| 2000 | 14 |
| 2001 | 17 |
| 2002 | 36 |
| 2003 | 31 |
| 2004 | 30 |
| 2005 | 36 |
| 2006 | 25 |

**Table XX.** Mobile phone SAR tests.

| Year | Number |
|---|---|
| 2003 | 12 |
| 2004 | 18 |
| 2005 | 15 |
| 2006 | 15 |

# Appendix 2 Publications in 2006

The following publications completed in 2006 were authored by one or more employees of STO or the NIR Laboratory.

## International publications

Aarnio P, Ala-Heikkilä J, Isolankila A, Kuusi A, Moring M, Nikkinen M, Siiskonen T, Toivonen H, Ungar K, Zhang W. Linssi – database for gamma-ray spectrometry. In: MARC VII Abstracts. p. 89–90.

Auvinen A, Toivo T, Tokola K. Epidemiological risk assessment of mobile phones and cancer: where can we improve? European Journal of Cancer Prevention 2006; 15 (6): 516–523.

Envall J, Ylianttila L, Moseley H, Coleman A, Durak M, Kärhä P, Ikonen E. Investigation of comparison methods for UVA irradiance responsivity calibration facilities. Metrologia 2006; 43: 27–30.

Hakanen A, Kosunen A, Pöyry P, Tapiovaara M. Determination of conversion factors from air kerma to operational dose equivalent quantities for low energy x-ray spectra. Radiation Protection Dosimetry 2006; doi: 10.1093/rpd/ncl386.

Hakanen A, Siiskonen T, Pöllänen R, Kosunen A, Turunen A, Belyakov O. Design, spectrum measurements and simulations for a $^{238}$Pu α-particle irradiator for bystander effect and genomic instability experiments. Applied Radiation and Isotopes 2006; 64: 864–867.

Heikkinen P, Ernst H, Huuskonen H, Komulainen H, Kumlin T, Mäki-Paakkanen J, Puranen L, Juutilainen J. No Effects of Radiofrequency Radiation on 3-Chloro-4-(dicholoromethyl)-5-hydroxy-2(*5H*)-furanone-Induced Tumorigenesis in Female Wistar Rats. Radiation Research 2006; 166: 397–408.

Höytö A, Sihvonen A-P, Alhonen L, Juutilainen J, Naarala J. Modest increase in temperature affects ODC activity in L929 cells: low-level radiofrequency radiation does not. Radiat. Environ. Biophys. 2006; 45: 231–235.

Jartti P, Pukkala E, Vartiainen E, Uitti J, Auvinen A. Cancer incidence among physicians occupationally exposed to ionizing radiation in Finland. Scandinavian Journal of Work, Environment & Health 2006; 32 (5): 368–73.

Kamenopoulou V, van Dijk JWE, Ambrosi P, Bolognese-Milsztajn T, Castellani CM, Currivan L, Falk R, Fantuzzi E, Figel M, Garcia Alves GA, Ginjaume M, Janzekovic H, Kluszczynski D, Lopez MA, Luszik-Bhadra M, Olko P, Roed H, Stadtmann H, Vanhavere F, Vartiainen E, Wahl W, Weeks A, Wernli Ch. Aspects of harmonisation of individual monitoring for external radiation in Europe: Conclusions of a EURADOS action. Radiation Protection Dosimetry 2006; 118 (2): 139–143.

Kapanen M, Tenhunen M, Hämäläinen T, Sipilä P, Parkkinen R, Järvinen H. Analysis of quality control data of eight modern radiotherapy linear accelerators: the short- and long-term behaviours of the outputs and the reproducibility of quality control measurements. Physics in Medicine and Biology 2006; 51 (14): 3581–3592.

Kapanen M, Tenhunen M, Parkkinen R, Sipilä P, Järvinen H. The influence of output measurement time interval and tolerance on treatment dose deviation in photon external beam radiotherapy. Physics in Medicine and Biology 2006; 51: 4857–4867.

Kortesniemi M, Kiljunen T, Kangasmäki A. Radiation exposure in body computed tomography examinations of trauma patients. Phys. Med. Biol. 2006; 51: 32690–3282.

Kosunen A, Komppa T, Toivonen M. Evaluation of methods to estimate the patient dose in interventional radiology. Radiation Protection Dosimetry 2005; 117 (1-3): 178–184.

Manninen P, Hovila J, Seppälä L, Kärhä P, Ylianttila L, Ikonen E. Determination of distance offsets of diffusers for accurate radiometric measurements. Metrologia 2006; 43: 120–123.

Meinander O, Kazadzis S, Ylianttila L, Johnsen B, Lakkala K, Koskela T, Josefsson W. Diurnal discrepancies in spectral solar UV-radiation measurements. Applied Optics 2006; 45:5346–5357.

Pöllänen R, Ketterer M, Lehto S, Hokkanen M, Ikäheimonen TK, Siiskonen T, Moring M, Martín Sánchez A, Rubio Montero MP. Multi-technique characterization of a nuclear bomb particle from the Palomares accident. Journal of Environmental Radioactivity 2006; 90: 15–28.

Pöllänen R, Siiskonen T. High-resolution alpha spectrometry under field conditions – fast identification of alpha-particle emitting radionuclides from air samples. Journal of Environmental Radioactivity 2006; 87: 279–288.

Pöllänen R, Siiskonen T. Minimum detectable activity concentration in direct alpha spectrometry from outdoor air samples: continuous monitoring versus separate sampling and counting. Health Physics 2006; 90: 167–175.

Siiskonen T, Pöllänen R. Alpha-electron and alpha-photon coincidences in high-resolution alpha spectrometry. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 2006; 558 (2): 437–440.

Tapiovaara M. Image quality measurements in radiology. Radiation Protection Dosimetry 2005; 117 (1-3): 116–119.

Verschaeve L, Heikkinen P, Verheyen G, Van Gorp U, Boonen F, Vander Plaetse F, Maes A, Kumlin T, Mäki-Paakkanen J, Puranen L, Juutilainen J. Investigation of Co-genotoxic Effects of Radiofrequency Electromagnetic Fields *In Vivo*. Radiation Research 2006; 165: 598–607.

## Conference papers and lectures at conferences

**International**

Jonsson H, Ennow K, Korpela H, Sigurdsson T, Unhjem JF. Survey of methods for radioiodine therapy of hyperthyroidism in the Nordic countries. Abstracts of the 9th Congress of World Federation of Nuclear Medicine and Biology. 22–27 October 2006, Seoul, Korea. World Journal of Nuclear Medicine 2006; 5 Suppl 1: S201.

Karppinen J, Järvinen H. A practical method to the users of radiation for the determination of patient doses in computed tomography. Book of extended synopses. IAEA-CN-146. International Conference on Quality Assurance and New Techniques in Radiation Medicine. 13–15 November, Vienna, Austria. p. 26–27.

Kiljunen T, Järvinen H, Parviainen T, Komppa T, Savolainen S. Patient doses and diagnostic reference levels in paediatric radiology in Finland: Phase I: The method. European Congress of Radiology (ECR 2006), 3–7 March 2006, Vienna, Austria. European Radiology 2006; 16 Suppl 1: B256–257.

Korpela H, Parkkinen R. Survey on QC measurements of nuclear medicine imaging equipment in Finnish hospitals. Book of extended synopses. IAEA-CN-146. International Conference on Quality Assurance and New Techniques in Radiation Medicine. 13–15 November, Vienna, Austria. p. 552–553.

Leszczynski D, Pastila R. UVA radiation may enhance tumor metastasis. 97th Annual Meeting of the American Association for Cancer Research, 1–5 April 2006, Washington, DC, USA.

Malicki J, Järvinen H, Scalliet P, Stankusova H, Leer JW, Bogusz-Osawa M, Ruebe C, Tait D, Macia M, Hallet JX, Taillet M. Clinical audit guidelines in radiotherapy – Preliminary results of the ESTRO working group. Book of extended synopses. IAEA-CN-146. International Conference on Quality Assurance and New Techniques in Radiation Medicine. 13–15 November, Vienna, Austria. p. 106–107.

Nordic dosimetric capabilities. Resources, needs and plans. Report on Nordic radiation protection co-operation No. 8. The radiation protection and nuclear safety authorities in Denmark, Finland, Iceland, Norway and Sweden. Østerås, Norway: Statens strålevern. Norwegian Radiation Protection Authority; 2006.

Padovani R, Faulkner K, Vano E, Bosmans H, Dowling A, Bochou C, Neofotistou E, Kosunen A. Assessment of the level of optimization of the interventional cardiology practice – The Sentinel Project. Book of extended synopses. IAEA-CN-146. International Conference on Quality Assurance and New Techniques in Radiation Medicine. 13–15 November, Vienna, Austria. p. 530–531.

Parkkinen R, Järvinen H. Implementation of QA in medical radiological practices: A national cooperation mode. Book of extended synopses. IAEA-CN-146. International Conference on Quality Assurance and New Techniques in Radiation Medicine. 13–15 November, Vienna, Austria. p. 114–115.

Pöyry P, Komppa T, Kosunen A. Tandem method for calibrating dose-area product meters. In: Abstract and program book of Physics in medicine in the 21st century: new techniques, challenges, problems and solutions. 21st Annual Symposium of the Belgian Hospital Physicist Association, 20–21 January 2006, Ghent, Belgium. p. 69.

Pöyry P, Komppa T, Kosunen A. A tandem calibration method for kerma-area product meters. Book of extended synopses. IAEA-CN-146. International Conference on Quality Assurance and New Techniques in Radiation Medicine. 13–15 November, Vienna, Austria. p. 290–291.

Pöyry P, Komppa T, Kosunen A. X-ray beam quality specification for kerma-area product meters. Book of extended synopses. IAEA-CN-146. International Conference on Quality Assurance and New Techniques in Radiation Medicine. 13–15 November, Vienna, Austria. p. 298–299.

Pöyry P, Zanca F, Bosmans H. Experimental investigation of the necessity for extra flat field corrections in quality control of digital mammography. International Workshop on Digital Mammography, 18–21 June 2006, Manchester, England. In book: Astley S. et al. (eds.). IWDM 2006, LNCS 4046. Berlin Heidelberg: Springer-Verlag; 2006. p. 475–481.

Salminen E, Sipilä P. Development of cancer care and use of radiotherapy equipment in a small country – The Finnish model. Book of extended synopses. IAEA-CN-146. International Conference on Quality Assurance and New Techniques in Radiation Medicine. 13–15 November, Vienna, Austria. p. 120–121.

Siiskonen T, Pöllänen R. Direct high-resolution alpha spectrometry for detecting transuranium elements from air samples. In: Book of Abstracts. International Conference on Monitoring, Assessments and Uncertainties for Nuclear and Radiological Emergency Response, 21–25 November 2005, Rio de Janeiro, Brazil.

Soimakallio S, Järvinen H, Ahonen A, Wigren T, Lyyra-Laitinen T, Kortelainen K, Ceder K, Sinervo T. Paunio M. Impact of clinical audit on the quality of radiological practices – Experiences from a national audit programme supported by a national steering committee. Book of extended synopses. IAEA-CN-146. International Conference on Quality Assurance and New Techniques in Radiation Medicine. 13–15 November, Vienna, Austria. p. 104–105.

Zanca F, Jacobs J, Pöyry P, Van Ongeval C, Carton AC, Deprez T, Marchal G, Bosmans H. Development and implementation of a user friendly and automated environment for creation of databases of digital mammograms with simulated microcalcifications. Proceedings of SPIE (The International Society for Optical Engineering), 17 March 2006. In book: Jiang Y, Eckstein MP. (Eds.). Image perception, observer performance, and technology assessment. Medical Imaging 2006.

**Finnish**

Järvinen H. STUKin opasluonnos laitteiden teknisestä laadunvalvonnasta – tavoitteet ja tilanne (STUK draft guidebook on technical quality control of appliances – objectives and current situation). In the book: Järvinen H (ed.). Säteilyturvallisuus ja laatu röntgendiagnostiikassa 2006 (Radiation safety and quality in X-ray diagnostics 2006). STUK-C5. Helsinki: Radiation and Nuclear Safety Authority; 2006. s. 21–23.

Karppinen J. Tietokonetomografialaitteiden käytön optimointi; potilasannokset TT-tutkimuksissa (Optimization in the use of computed tomography appliances; patient doses in CT scans). In the book: Luennot. XXX Sädeturvapäivät Tampere-talossa, Tampere 26.–27.10.2006 (Lectures. XXX Radiation Safety Conference at Tampere Hall, Tampere 26–27 October 2006). Tampere: Lege Artis Oy; 2006. p. 24–27.

Karppinen J. Tietokonetomografialaitteiden laadunvalvonta (CT appliance quality control). In the book: Järvinen H (ed.). Säteilyturvallisuus ja laatu röntgendiagnostiikassa 2006 (Radiation safety and quality in X-ray diagnostics 2006). STUK-C5. Helsinki: Radiation and Nuclear Safety Authority; 2006. p. 51–53.

Karppinen J. Tietokonetomografiatutkimusten potilasannokset (Patient doses in CT scans). In the book: Järvinen H (ed.). Säteilyturvallisuus ja laatu röntgendiagnostiikassa 2006 (Radiation safety and quality in X-ray diagnostics 2006). STUK-C5. Helsinki: Radiation and Nuclear Safety Authority; 2006. p. 46–50.

Kiljunen T. Vertailutasojen käyttö lasten röntgentutkimuksissa (Use of reference levels in paediatric X-ray examinations). In the book: Luennot. XXX Sädeturvapäivät Tampere-talossa, Tampere 26.–27.10.2006 (Lectures. XXX Radiation Safety Conference at Tampere Hall, Tampere 26–27 October 2006). Tampere: Lege Artis Oy; 2006. p. 100–103.

Markkanen M. Uutta säännöstöä (New regulations). In the book: Järvinen H (ed.). Säteilyturvallisuus ja laatu röntgendiagnostiikassa 2006 (Radiation safety and quality in X-ray diagnostics 2006). STUK-C5. Helsinki: Radiation and Nuclear Safety Authority; 2006. p. 11–15.

Parkkinen R. Säteilyturvakeskuksen päätökset (Decisions of the Radiation and Nuclear Safety Authority). In the book: Järvinen H (ed.). Säteilyturvallisuus ja laatu röntgendiagnostiikassa 2006 (Radiation safety and quality in X-ray diagnostics 2006). STUK-C5. Helsinki: Radiation and Nuclear Safety Authority; 2006. p. 9–10.

Pöyry P. Digitaalisten mammografialaitteiden laadunvalvonta (Quality control of digital mammography appliances). In the book: Järvinen H (ed.). Säteilyturvallisuus ja laatu röntgendiagnostiikassa 2006 (Radiation safety and quality in X-ray diagnostics 2006). STUK-C5. Helsinki: Radiation and Nuclear Safety Authority; 2006. p. 29–33.

Pöyry P, Komppa T. DAP-mittarin kalibrointi ja toimintakunnon seuranta (Calibration and operating condition monitoring of DAP meters). In the book: Järvinen H (ed.). Säteilyturvallisuus ja laatu röntgendiagnostiikassa 2006 (Radiation safety and quality in X-ray diagnostics 2006). STUK-C5. Helsinki: Radiation and Nuclear Safety Authority; 2006. p. 16–20.

Tenkanen-Rautakoski P. Uutta STUKin ohjeista ja päätöksistä (New guides and decisions from STUK). In the book: Luennot. XXX Sädeturvapäivät Tampere-talossa, Tampere 26.–27.10.2006 (Lectures. XXX Radiation Safety Conference at Tampere Hall, Tampere 26–27 October 2006). Tampere: Lege Artis Oy; 2006. p.92–95.

Vartiainen E. Kosminen säteily ja lentohenkilöstön altistuminen (Cosmic radiation and aircrew exposure). In the book: Ikäheimonen, T K (ed.). Ympäristön radioaktiivisuus Suomessa – 20 vuotta Tshernobylista (Environmental radioactivity in Finland – 20 years after Chernobyl). Symposium in Helsinki 25–26 April 2006. STUK-A217. Helsinki: Radiation and Nuclear Safety Authority; 2006. p. 115–119.

### STUK publications series

Pastila R. Effect of long-wave UV radiation on mouse melanoma: An in vitro and in vivo study. STUK-A216. Helsinki: Radiation and Nuclear Safety Authority; 2006.

Tapiovaara M. Relationships between Physical Measurements and User Evaluation of Image Quality in Medical Radiology – a Review. STUK-

A219. Helsinki: Radiation and Nuclear Safety Authority; 2006.

Karppinen J, Järvinen H. Tietokonetomografia-laitteiden käytön optimointi (Optimization in the use of computed tomography appliances). STUK-A220. Helsinki: Radiation and Nuclear Safety Authority; 2006.

Tenkanen-Rautakoski Petra. Radiologisten tutkimusten ja toimenpiteiden määrät vuonna 2005 (Number of radiological examinations and procedures in 2005). STUK-B-STO 62. Helsinki: Radiation and Nuclear safety Authority; 2006.

Järvinen H. (ed.). Säteilyturvallisuus ja laatu röntgendiagnostiikassa 2006 (Radiation safety and quality in X-ray diagnostics 2006). STUK-C5. Helsinki: Radiation and Nuclear Safety Authority; 2006.

### Books and articles in Finnish professional publications or textbooks

Jantunen M, Husgafel-Pursiainen K, Arvela H, Vähäkangas K, Zitting A, Pastila R, Saarela K. Suomalaisten altistuminen ulkoilman, sisäilman ja tupakansavun kemiallisille aineille ja säteilylle (Exposure of the public in Finland to chemical substances in outdoor and indoor air and in tobacco smoke and to radiation). Ympäristö ja Terveys 2006; 10: 32–45.

Jokela K. Biosähkömagnetiikan fysikaalisia perusteita (Physical foundations of bioelectromagnetism). In the book: Nyberg H, Jokela K (eds.). Sähkömagneettiset kentät (Electromagnetic Fields). Helsinki: Radiation and Nuclear Safety Authority; 2006. p. 27–57.

Jokela K. Dosimetria (Dosimetry). In the book: Nyberg H, Jokela K (eds.). Sähkömagneettiset kentät (Electromagnetic Fields). Helsinki: Radiation and Nuclear Safety Authority; 2006. p. 59–115.

Jokela K. Ionisoimaton säteily ja sähkömagneettiset kentät (Non-ionizing radiation and electromagnetic fields). In the book: Nyberg H, Jokela K (eds.). Sähkömagneettiset kentät (Electromagnetic Fields). Helsinki: Radiation and Nuclear Safety Authority; 2006. p. 11–25.

Jokela K, Korpinen L, Hietanen M, Puranen L, Huurto L, Pättikangas H, Toivo T, Sihvonen A-P, Nyberg H. Säteilylähteet ja altistuminen (Radiation sources and exposure). In the book: Nyberg H, Jokela K (eds.). Sähkömagneettiset kentät (Electromagnetic Fields). Helsinki: Radiation and Nuclear Safety Authority; 2006. p. 359–452.

Jokela K, Niittylä A. Altistumisen rajoittaminen (Limiting exposure). In the book: Nyberg H, Jokela K (eds.). Sähkömagneettiset kentät (Electromagnetic Fields). Helsinki: Radiation and Nuclear Safety Authority; 2006. p. 319–357.

Juutilainen J, Leszczynski D, Nylund R, Heikkinen P, Hietanen M, Haarala Björnberg C, Auvinen A, Huuskonen H, Toivonen T. Radiotaajuisten kenttien ja säteilyn vaikutukset (The effects of radio frequency fields and radiation). In the book: Nyberg H, Jokela K (eds.). Sähkömagneettiset kentät (Electromagnetic Fields). Helsinki: Radiation and Nuclear Safety Authority; 2006. p. 261–317.

Kauppinen T, Heikkilä P, Hietanen M, Jantunen M, Keskimäki I, Komulainen H, Lehtinen M, Louekari K, Muikku M, Pastila R, Peltonen K, Viluksela M. Suomalaisten altistuminen kemiallisille aineille ja säteilylle. Yhteenveto (Exposure of the public in Finland to chemical substances and radiation. Summary).Ympäristö ja Terveys 2006; 10: 8–23.

Komppa T. Säteilysuojelun kansainvälisiä suosituksia uudistetaan: Mikä muuttuu ja milloin? (Revised international recommendations on radiation protection: What will change and when?). Radiografia 2006; 1: 6–9.

Lang S, Jokela K. Biofysikaaliset vaikutukset (Biophysical impacts). In the book: Nyberg H, Jokela K (eds.). Sähkömagneettiset kentät (Electromagnetic Fields). Helsinki: Radiation and Nuclear Safety Authority; 2006. pp. 117–187.

Litmanen T, Kuustonen J, Jokela K. Sähkömagneettiset kentät terveysriskinä (Electromagnetic fields as a health risk). In the book: Nyberg H, Jokela K (eds.). Sähkömagneettiset kentät (Electromagnetic Fields). Helsinki: Radiation and Nuclear Safety Authority; 2006. p. 501–526.

Nyberg H, Jokela K (eds.). Sähkömagneettiset kentät (Electromagnetic Fields). Helsinki: Radiation and Nuclear Safety Authority; 2006.

Pastila R. Tuore UV-tohtori nauttii kesästä – maltilla (A new "ultraviolet" doctor enjoys the summer – in moderation). Alara 2006; 2: 24.

Puranen L. Altistumisen mittaus ja laskentamallit (Exposure measurement and computation models). In the book: Nyberg H, Jokela K (eds.). Sähkömagneettiset kentät (Electromagnetic Fields). Helsinki: Radiation and Nuclear Safety Authority; 2006. pp. 455–499.

Viluksela M, Sainio E-L, Venäläinen R, Pastila R, Louekari K. Suomalaisten altistuminen kotiympäristön ja kosmetiikan kemiallisille aineille ja säteilylle (Exposure of the public in Finland to chemical substances and radiation in the home and in cosmetics). Ympäristö ja Terveys 2006; 10: 58–71.

## Academic thesis work

Nieminen K. Tietokonetomografialaitteen annosmittauksissa käytettävän ionisaatiokammion kalibrointi (Calibration of an ionization chamber for use in CT appliance dosimetry). Pro Gradu -työ (Master's thesis). Helsinki University, Faculty of sciences, Department of physical sciences; 2006.

## Regulatory reports

Rantanen E. (toim.). Säteilyn käyttö ja muu säteilylle altistava toiminta (Use of radiation and other activities involving exposure to radiation). Vuosiraportti 2005 (Annual Report 2005). STUK-B-STO 60. Helsinki: Radiation and Nuclear Safety Authority; 2006.

Rantanen E. (ed.). Radiation Practices. Annual Report 2005. STUK-B-STO 61. Helsinki: Radiation and Nuclear Safety Authority; 2006.

## Regulatory guides

**Finnish language**

Säteilylähteiden varoitusmerkinnät (Warning signs for radiation sources). Ohje ST 1.3 (Guide ST 1.3). Radiation and Nuclear Safety Authority (16 May 2006).

Röntgentutkimukset terveydenhuollossa (X-ray examinations in health care). Ohje ST 3.3 (Guide ST 3.3). Radiation and Nuclear Safety Authority (20 March 2006).

**Swedish language**

Varningsmärkning av strålkällor (Warning signs for radiation sources). Direktiv ST 1.3 (Guide ST 1.3). Radiation and Nuclear Safety Authority (16 May 2006).

Röntgenundersökningar i hälsovården (X-ray examinations in health care). Direktiv ST 3.3 (Guide ST 3.3). Radiation and Nuclear Safety Authority (20 March 2006).

**English language (translations)**

Safety fundamentals in radiation practices. Guide ST 1.1. Radiation and Nuclear Safety Authority (23 May 2005).

Warning signs for radiation sources. Guide ST 1.3. Radiation and Nuclear Safety Authority (16 May 2006).

# APPENDIX 3

# ST GUIDES PUBLISHED BY STUK. SITUATION AS OF 31 DECEMBER 2006.

## General Guides

ST 1.1 Safety Fundamentals in Radiation Practices, 23 May 2005 (in Finnish)
ST 1.3 Warning Signs for Radiation Sources, 16 May 2006
ST 1.4 Radiation User's Organization, 16 April 2004
ST 1.5 Exemption of the Use of Radiation from the Safety Licence and Reporting Obligation, 1 July 1999
ST 1.6 Operational Radiation Protection, 29 December 1999
ST 1.7 Radiation Protection Training in Health Care, 17 February 2003
ST 1.8 Qualifications of Persons Working in Radiation User's Organization and Radiation Protection Training Required for Competence, 16 April 2004

## Radiation Therapy

ST 2.1 Quality Assurance in Radiotherapy, 22 May 2003
ST 2.2 Radiation Safety of Radiotherapy Equipment and Treatment Rooms, 2 February 2001.

## Diagnostic Radiology

ST 3.1 Use and Regulatory Control of Dental X-ray Installations, 27 May 1999
ST 3.2 Mammography Equipment and Their Use, 13 August 2001
ST 3.3 X-ray Examinations in Health Care, 20 March 2006
ST 3.6 Radiation Safety in X-ray Facilities, 24 September 2001.
ST 3.7 Breast Cancer Screening Based on Mammography, 28 March 2001

## Industry, Research, Education and Commerce

ST 5.1 Radiation Safety of Sealed Sources and Equipment Containing Them, 17 February 1999
ST 5.3 Use of Ionising Radiation in the Teaching of Physics and Chemistry, 17 February 1999
ST 5.4 Trade in Radiation Sources, 2 October 2000
ST 5.6 Radiation Safety in Industrial Radiography, 17 February 1999
ST 5.8 Installation, Repair and Servicing of Radiation Appliances, 17 February 1999

## Unsealed Sources and Radioactive Wastes

ST 6.1 Radiation Safety Requirements for Radionuclide Laboratories, 1 July 1999
ST 6.2 Radioactive Wastes and Discharges, 1 July 1999
ST 6.3 Use of Radiation in Nuclear Medicine, 18 March 2003

## Radiation Doses and Health Surveillance

ST 7.1 Monitoring of Radiation Exposure, 25 February 2000
ST 7.2 Application of Maximum Values for Radiation Exposure and Principles for the Calculation of Radiation Dose, 1 July 1999
ST 7.3 Calculation of the Dose Caused by Internal Radiation, 1 July 1999
ST 7.4 Registration of Radiation Doses, 25 February 2000
ST 7.5 Medical Surveillance of Occupationally Exposed Workers, 29 December 1999 (in Finnish)

## Non-Ionizing Radiation

ST 9.1 Radiation Safety Requirements and Regulatory Control of Tanning Appliances 1 December 2003 (in Finnish)
ST 9.2 Radiation Safety of Pulsed Radars, 2 September 2003 (in Finnish)
ST 9.3 Radiation Safety during Work on Masts at FM and TV Stations, 2 September 2003 (in Finnish)
ST 9.4 Radiation Safety of High Power Display Lasers, 8 October 1993 (in Finnish)

## Natural Radiation

ST 12.1 Radiation Safety in Practices Causing Exposure to Natural Radiation, 6 April 2000
ST 12.2 The Radioactivity of Building Materials and Ash, 8 October 2003
ST 12.3 Radioactivity of Household Water, 9 August 1993
ST 12.4 Radiation safety in aviation, 20 June 2005.