STUK-B 107 / SEPTEMBER 2009

Radiation practices

Annual report 2008

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 Havukainen
Kari Jokela
Hannu Järvinen
Eero Kettunen
Helinä Korpela
Antti Kosunen
Jorma Kuusisto
Maaret Lehtinen
Eero Oksanen
Eija Venelampi
Reijo Visuri

ISBN 978-952-478-470-2 (print) Edita Prima Oy, Helsinki/Finland 2009
ISBN 978-952-478-471-9 (pdf)
ISSN 0781-1713

RANTANEN Erkki (ed.). Radiation practices. Annual report 2008. STUK-B 107. Helsinki 2009. 34 pp. + apps. 14 pp.

Key words: use of radiation, radiation practices, safety licence, licence-exempt practices, inspections of the use of radiation, radiation sources, radioactive substances, radioactive waste, radiation doses of workers, natural radiation, non-ionizing radiation, measurement standards, regulation work, research, Finnish and international co-operation, information activities, services, abnormal incidents

Abstract

1775 safety licences for the use of radiation were current at the end of 2008. 1831 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 the Dose Register. Radiation safety guides were also published and research was conducted in support of regulatory control.

STUK conducted 424 inspections of licensed practices and 18 inspections of notifiable licence-exempt dental X-ray practices in 2008. 209 repair orders and recommendations were issued. Use of one appliance was prohibited.

A total of just over 11 500 workers were subject to individual monitoring in 2008, and about 140 000 dose entries were made in the Dose Register maintained by STUK.

Regulatory control of natural radiation focused on radon at workplaces and exposure of aircrews to cosmic radiation. 89 workplaces including a total of 201 work areas were subject to radon monitoring during 2008. Some 3700 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 2008 focused particularly on mobile phones, sunbeds and lasers. Ten mobile phone types and five baby monitors were tested in market surveillance of wireless communication devices. 25 sunbed facilities were inspected and nine laser display inspections were performed.

There were 22 abnormal incidents involving the use of radiation in 2008. Seventeen of these incidents concerned the use of radiation in industry, research or transportation, four concerned the use of radiation in health care, and one concerned the use of non-ionizing radiation. None of these incidents had serious consequences.

Contents

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 licensing, approval and registration procedures, inspections of places where 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.

Major changes in the use of radiation are continuing, and this is reflected in increased regulatory control work focusing on such changes. Hospital districts have been reorganized to meet productivity targets, and the work of private health service enterprises has expanded and evolved during the past year. Reforms have arisen in industry as large industrial concerns have reorganized with the consequent decommissioning of a significant number of measuring devices containing radiation sources. These decommissioned sources have either been returned to the appliance supplier or sent to the storage facility for low-level radioactive waste at STUK for final disposal. The regulatory control work of STUK has had to pay particular attention to the effectiveness of the radiation users´ organizations and to issues of responsibility and quality management in these cases.

Led by the World Health Organization (WHO) and the International Atomic Energy Agency (IAEA), international organizations have been concerned about the assessment of justification and optimization when radiation is used in health services. Reviews conducted in Sweden and Finland indicate that, for example, greater attention should be paid to assessing justification when referring patients for CT scans. Although new technologies are improving diagnostics and therapy, they are also imposing greater knowledge and skills requirements on the user. This challenge must be met by effective basic and supplementary training. STUK has sought to respond to this challenge by arranging several training and consultation events with users of radiation and organizations giving training in radiation protection. Persons involved in the use of radiation, their employers and training organizations will nevertheless play a crucial role in maintaining expertise.

Pioneering work has been done in Finland to improve quality control when using radiation in health services, and clinical audits have become a standard procedure in such practices. A project led by STUK and financed by the European Commission led to a proposal on clinical auditing practices in Europe. The participants in this project included specialists from Tampere University Hospital in Finland and international partners from several countries.

New requirements have taken effect governing the use and regulatory control of high activity sources. In-service securities have now been obtained for the largest sources. The licensing process also requires plans to be drawn up in advance for the eventual decommissioning of high activity radiation sources.

The importance of the security arrangements involved in the use and custody of radiation sources containing radioactive substances has increased during the current decade. During 2008 STO acquired further expertise in security arrangements, and began preparing guidelines for radiation users. Police representatives were also involved in work to specify the principles governing security arrangements.

Particle accelerators for several practical applications have been taken into use. Modern scanning appliances were commissioned for use in border control at Vuosaari Harbour, and licence applications were pending for accelerators used in manufacturing radioactive substances for medical use.

The exposure sustained in 2008 by workers engaged in radiation work remained within the prescribed dose limits. The total dose from radiation use recorded in the workers' Dose Register maintained by STUK was 2% lower than in the preceding year. The doses sustained by employees of six airlines were also entered in the Dose Register in 2008. A slight increase of about 6% was recorded in the total dose sustained by flight crews, which was due to an increase in long-haul air traffic.

STUK arranged monitoring of exposure to radon gas at 89 workplaces including a total of 201 work areas during the year. The monitoring reports required reductions in radon concentrations or an investigation of radon concentration during working hours in 40 work areas, and a measurement at another time of year in order to determine an annual average in 21 work areas. Radon concentrations were successfully reduced in 27 work areas during the year. Aside from a few minor exceptions, inspections found good radon gas conditions in subterranean mines and quarries.

STUK took part in the annual TLD comparison measurement of the absorbed dose of ^{60}Co gamma radiation between calibration laboratories belonging to the laboratory network maintained by the IAEA/WHO. The result of the comparison was well within the prescribed quality requirements. Metrological activities included research collaboration with the IAEA and preparations for replacing the radiation sources required for calibration. The new sources will ensure continued good quality.

STUK published a quality control guide for X-ray diagnostics, which was produced in association with specialists in the field. This guide took several years to prepare, and a similar collaboration format will be applied when preparing corresponding guidebooks in future.

During the year under review STO staff engaged in regulatory control of the use of radiation in health services and in metrological activities participated in training radiation protection authorities in Bulgaria and in improving radiation practices in the health services of that country through a project led by STUK and financed by the European Commission. This project involved several STUK specialists in time-consuming visits to Bulgaria, but also provided perspectives on the way that they discharge their regular duties in Finland.

Work at STO to revise regulatory control registers for the use of radiation was completed at the end of the year, and pilot operation of the new system began at the beginning of 2009. The objective has been to ensure operability of the registers for the next 10–15 years and eliminate the maintenance risks involved in using outdated technology. At the same time the system has been expanded to provide better access to the life cycle history of radiation sources. More advanced information management and reporting also enables better use of the results of regulatory control.

The Laboratory for Non-ionizing Radiation Surveillance (the 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, lasers and mobile phones. 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. Considerable effort has been applied in recent years to provide public information on the safety of electromagnetic fields and optical radiation.

Inspections were conducted at 25 sunbed facilities during the year. The most serious shortcomings were found in two appliances for use at self-service sunbed facilities emitting radiation exceeding the maximum value prescribed in the Decree of the Ministry of Social Affairs and Health (294/2002) by two and four times respectively. Two sunbed customers suffered skin blisters from using the more powerful of these appliances.

The main policy lines governing regulatory control of lasers sold to consumers were agreed at a conference arranged by the occupational health and safety department of the Ministry of Social Affairs and Health with representatives from this Ministry and from STUK, the Finnish Consumer Agency, the Safety Technology Authority and the Finnish Institute of Occupational Health. STUK serves as the regulatory authority for consumer sales of lasers other than toys, which are supervised by the Finnish Consumer Agency.

Advances in laser technology have enabled consumer marketing of inexpensive battery-operated diode lasers capable of causing ocular damage (laser class 3B). During 2008 STUK learned of some cases in which laser pointers had been used in a manner contrary to requirements for mischief and harassment. STUK issued a decision prohibiting online consumer sales of 30 mW class 3B green laser pointers. These devices emit about thirty times the ocular radiation safety limit, damaging the retina if the beam shines in the eye. Laser vendors were required to advise the purchaser of this hazard to the eye. Sales of 1–5 mW laser pointers were also discontinued until the vendor has demonstrated that these devices do not exceed the 1 mW power limit prescribed in a Decree of the Council of State (291/2008).

Market control of wireless communication devices is an important element in monitoring of electromagnetic fields. Tests were conducted in 2008 on ten mobile phone models, six of which were UMTS phones. Five baby monitors were also tested. The largest SAR value measured was 1.2 W/kg in mobile phones and 0.4 W/kg in baby monitors, meaning that the maximum value of 2 W/kg specified in the Decree of the Ministry of Social Affairs and Health (294/2002) was not exceeded.

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, transport, 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 is liable to cause detriment to health.

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

Regulatory control of safety in radiation use 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 1–3.

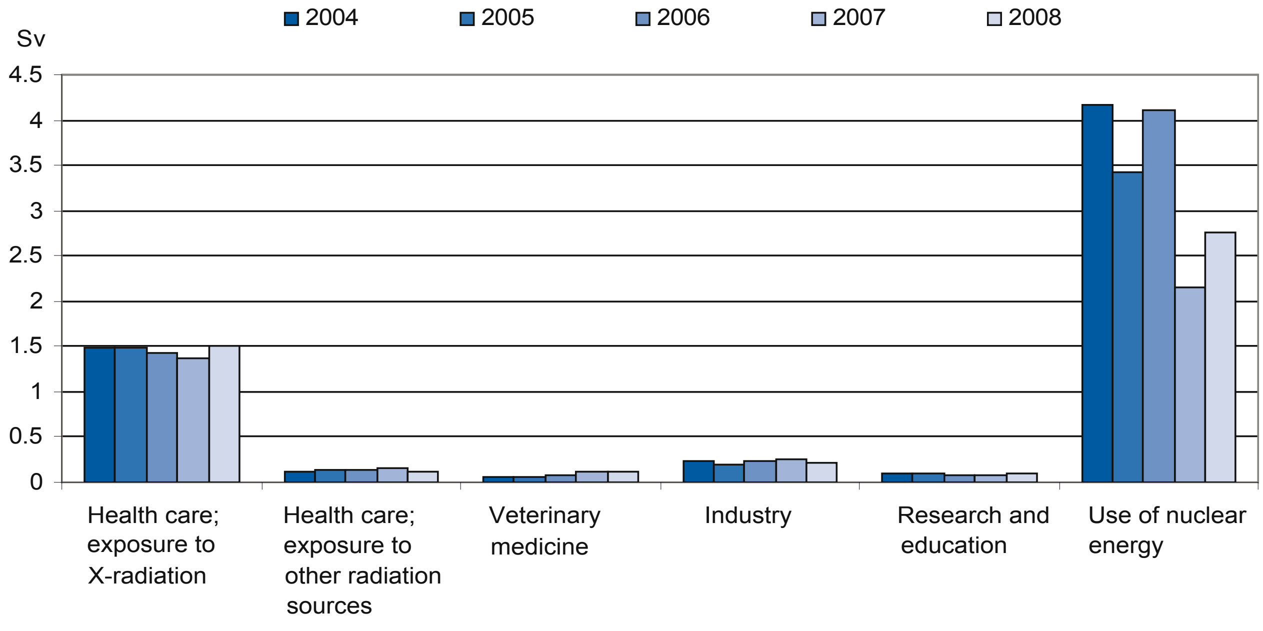

Figure 1. Combined doses ($H_p(10)$) of workers subject to individual monitoring by occupational category, 2004–2008. ($H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the use of X-rays in health care and veterinary practices, in which workers use personal protective shields and in which the dose is measured by a dosemeter on the exposed side of the shield. The effective dose is then obtained by dividing the $H_p(10)$ value by a factor between 10 and 60).

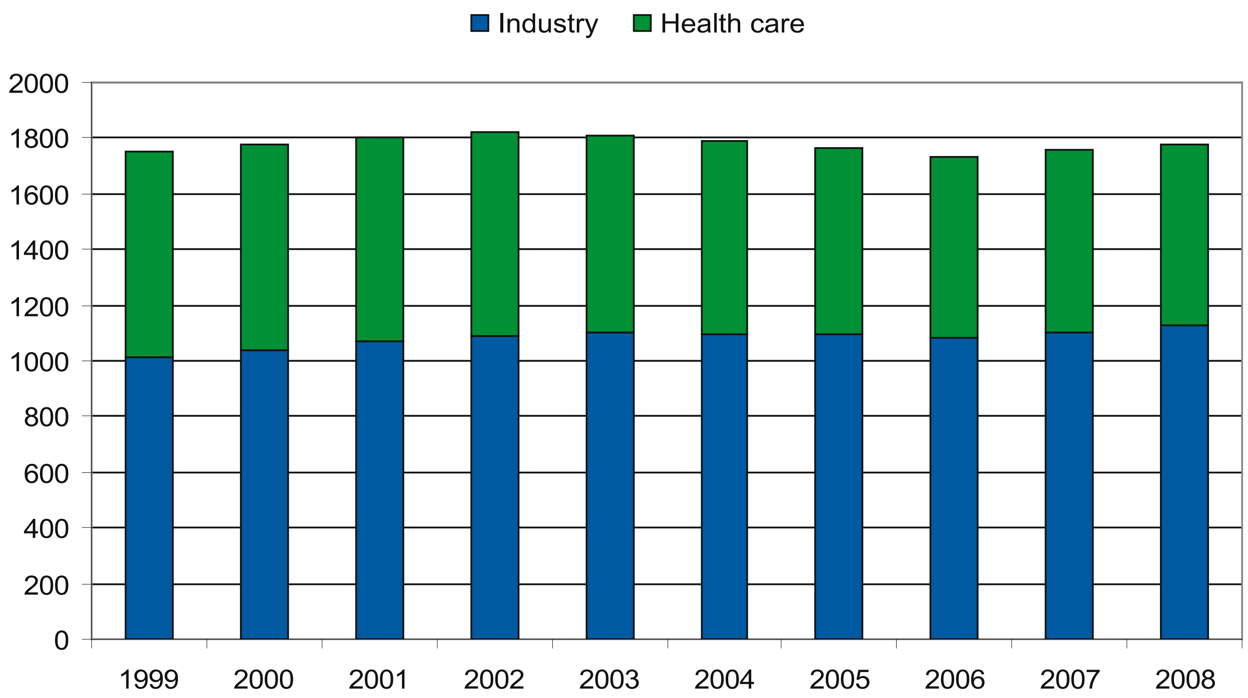

Figure 2. Current safety licences, 1999–2008.

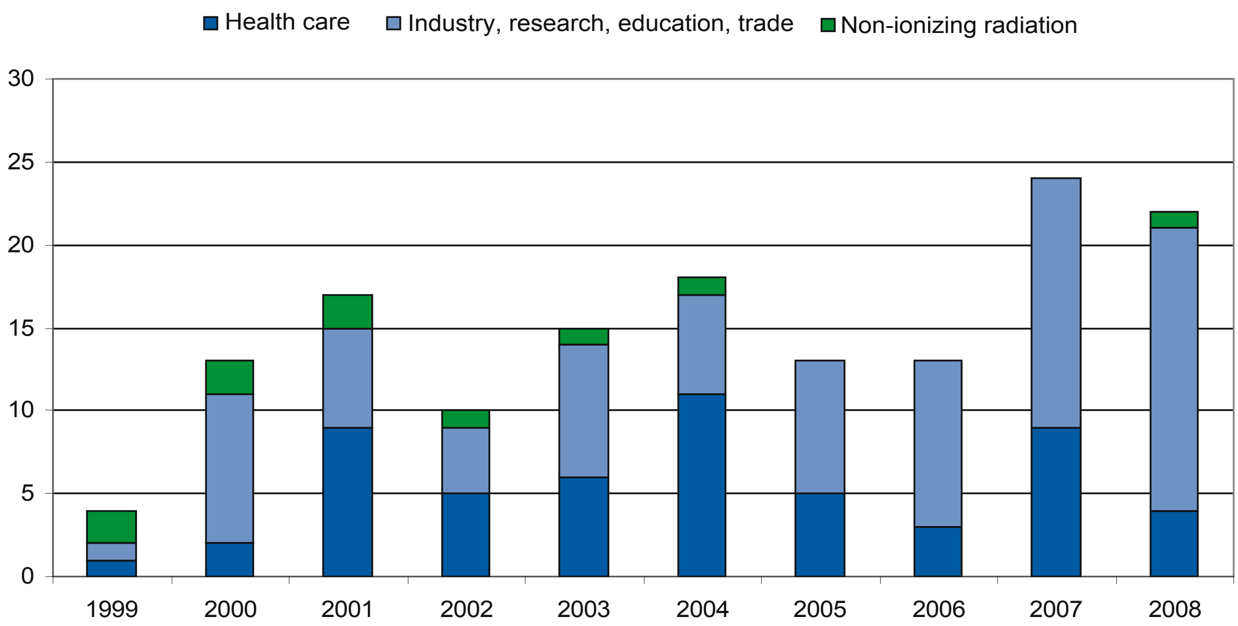

Figure 3. Abnormal incidents, 1999–2008.

2 Regulatory control of the use of ionizing radiation

2.1 Use of radiation in health care

Safety licences

650 safety licences for the use of radiation in health care were current at the end of 2008 (see also Figure 2). The numerical distribution of radiation practices referred to in these licences is shown in Table 1 of Appendix 1. There was no significant change in the total number of safety licences compared to the previous year.

Radiation appliances and sources and laboratories

Table 2 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 2008.

Figure 4 shows changes in the numbers of various types of radiotherapy appliance from the 1970s to the present decade.

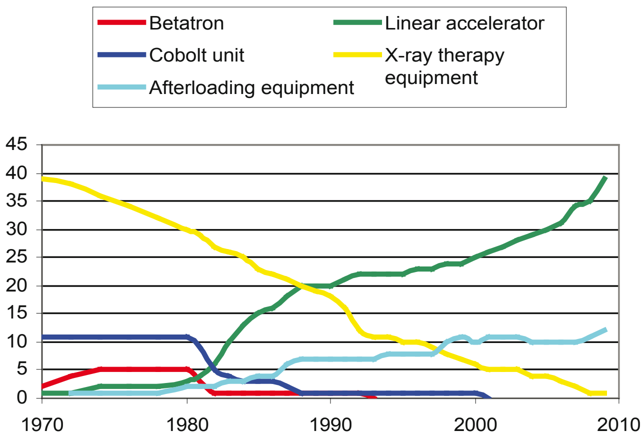

Figure 4. Various radiotherapy appliance types, 1970–2008.

2.2 Use of radiation in industry, research and education

Safety licences

There were 1125 current safety licences for the use of radiation in industry, research, education, trade and servicing operations at the end of 2008 (see also Figure 2).The numerical distribution of radiation practices referred to in these licences is shown in Table 3 of Appendix 1.

Radiation appliances and sources and laboratories

Figure 5 shows the number of X-ray appliances used in Finland over the last decade. The number of such appliances has increased by about one hundred a year since 2004. New X-ray appliances have been purchased for use particularly in scanning and analytical work.

Figure 6 shows the number of appliances containing radioactive substances over the last ten years. Unlike X-ray appliances, the number of devices of this kind has remained almost constant.

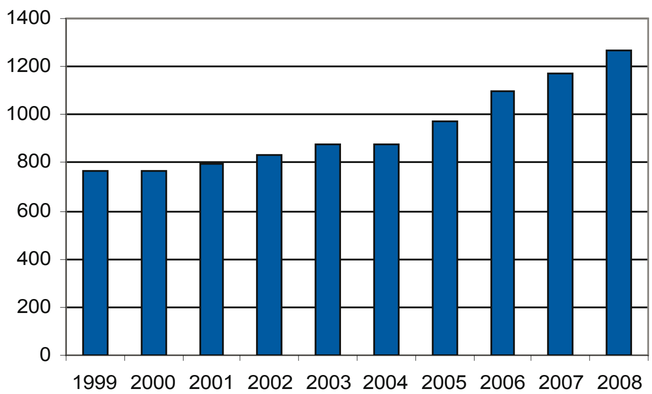

Figure 5. X-ray appliances entered in safety licences for use in industry, research and education, 1999–2008.

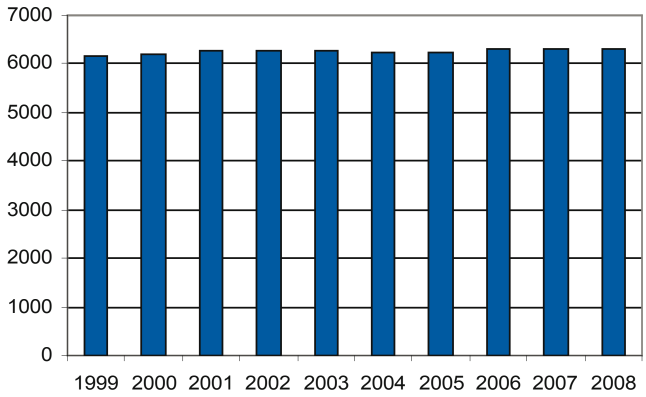

Figure 6. Appliances containing radioactive substances entered in safety licences for use in industry, research and education, 1999–2008.

Table 4 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 2008.

Table 5 in Appendix 1 shows the number and total activities of radionuclides used in sealed sources.

2.3 Inspections of licensed radiation practices

274 inspections were made of the use of radiation in health care. These inspections resulted in 118 repair orders or recommendations issued to responsible parties. Use of one appliance was prohibited.

150 inspections were made of the use of radiation in industry, research, education and trading. These inspections resulted in 83 repair orders or recommendations.

Table 6 in Appendix 1 shows the number of inspections itemized by type of inspection. Table 7 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

1831 responsible parties were engaged in dental X-ray practices. Patient radiation exposure due to dental X-ray imaging was measured in 1341 appliances. The average dose was 2.1 mGy. This dose corresponds to the dose absorbed at the surface of the cheek (entrance surface dose, ESD) when imaging a tooth. The reference level of 5 mGy was exceeded in 34 imaging appliances.

18 inspections of notifiable dental X-ray practices were made. Repairs were ordered in 5 inspections and recommended in 3 inspections.

Inspections of dental X-ray practices itemized by type of inspection are also shown in Table 6 of Appendix 1.

2.5 Import, manufacture and export of radioactive substances

Details of radionuclides imported to, manufactured in and exported from Finland in 2008 are shown in Tables 8–10 of Appendix 1. The figures in the tables are based on data gathered from radiation safety licensees engaged in importing, manufacturing and exporting. 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 8 of Appendix 1 excludes smoke detectors and fire alarm system ion detectors containing americium (^{241}Am). A total of 160 000 such devices were imported with a combined activity of about 5.6 GBq.

2.6 Radiation doses of workers

A total of just over 11 500 workers were subject to individual monitoring in 2008. 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 dose limit of 500 mSv.

The total dose recorded was 1.9 Sv in the use of radiation and 2.8 Sv in the use of nuclear energy. The total recorded dose was 2% lower in use of radiation and 28% smaller in use of nuclear energy than the corresponding figures for the previous year. Total doses in the use of nuclear energy vary considerably each year depending on the duration of annual servicing and the duties performed in servicing work.

The largest $H_p(10)$ was 45 mSv, recorded in the case of a veterinarian performing X-ray examinations. This corresponds to an effective dose of about 0.8–4.5 mSv. The largest $H_p(10)$ in health services was 26 mSv recorded in the case of a cardiologist. This measured dose corresponds to an effective dose of about 0.4–2.6 mSv. The largest effective dose in industry was 15 mSv sustained by a person performing tracer tests, while the largest effective dose in research was 8 mSv sustained by a person using unsealed sources.

The largest dose to the fingers was 336 mSv, recorded in the case of a person using unsealed sources in health care.

Table 11 of Appendix 1 shows the number of workers by occupational category subject to individual monitoring over the last five years. The combined doses of workers by occupational category are shown in Figure 1 (in item 1.1) and in Table 12. Table 13 shows the doses in 2008 of persons sustaining high levels of exposure or of numerically large worker groups. The measurement results ($H_p(10)$ values) shown in the figures and tables are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the use of radiation in health care and veterinary X-ray practices, in which workers use personal protective shields, and in which the dose is measured by a dosemeter on the exposed side of the shield. The effective dose is then 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 Guide ST 1.8 STUK has stipulated the 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. No new approval applications were lodged in 2008. A total of 23 approval decisions were current. There is a list of approved training organizations on the STUK website.

Responsible medical practitioners

STUK verifies the competence of medical practitioners responsible for medical surveillance of category A workers. At the end of 2008 there were 266 responsible practitioners in Finland, 21 of whom were accredited during 2008.

2.8 Radioactive waste

203 waste packages had been transported to the national storage facility for low-level radioactive waste maintained by STUK by the end of 2008. The activities or masses of the most significant waste held in the storage facility are shown in Table 14 of Appendix 1.

Waste is initially held in an interim storage unit at STUK's premises in Helsinki pending transportation to the national storage facility. This interim storage unit received 42 consignments of low-level radioactive waste in 2008, comprising a total of 78 packages. Table 15 in Appendix 1 shows the activities of the waste that was surrendered to STUK in 2008.

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. The disappearance, theft or other loss of a radiation source such that it ceases to be in the possession of the licensee must likewise be reported. Any other abnormal observation or information of essential significance for the radiation safety of workers, other persons or the environment must also be notified.

There were 21 cases in 2008 in which abnormal incidents or situations occurred or were suspected in the use of ionizing radiation. Seventeen of these cases concerned the use of radiation in industry, research or transportation, and the other four concerned the use of radiation in health care (see also item 4.4 on abnormal incidents in the use of non-ionizing radiation). Figure 3 (in item 1.1) shows abnormal incident numbers between 1999 and 2008.

The case histories set out below specify the abnormal incidents in the use of ionizing radiation that occurred in 2008 and the reasons for them, together with the measures taken on account of each incident.

Incident 1
The wrong radiopharmaceutical product was administered to an isotope examination patient and the examination had to be repeated. This incident was due to human error. The confusion was detected immediately and the incident was discussed with the patient and the attending medical practitioner, and was entered in the patient's medical record. The incident was also discussed with other workers involved in the case. The excessive dose sustained by the patient was about 2 mSv.

Incident 2
A patient was referred for two isotope examinations (gamma imaging of an inflammation site and skeletal gamma imaging). The inflammation site gamma imaging was performed first (imaging 1/2, 4 and 24 hours after injection). The skeletal gamma imaging began dynamically on the next morning and the patient was injected with the radiopharmaceutical for this purpose. However, the patient was taken for surgery before the actual imaging took place. The inflammation site gamma imaging report was also not yet available at this time. This meant that the requested examinations were unnecessary, as the decision to operate was taken without the information that they provided.

The patient sustained an effective dose of about 6 mSv from these unnecessary examinations. The radiation dose sustained by persons involved in the surgery due to the incident was negligible.

Incident 3
When administering a radiopharmaceutical labelled with ^{123}I to a patient by injection the syringe disengaged from the cannula in the final stages of the injection. A small amount of the radiopharmaceutical was sprayed over the patient, the hands of a nurse and the surrounding area. The patient washed the facial area, changed clothes, and was instructed to wash the contaminated clothing. A contaminated chair and treatment table were taken to a store for radioactive waste and the most active areas of the floor were covered with lead plates. The premises and furnishings were restored to normal use when radioactive decay had reduced their activity to background level.

Incident 4
When administering a radiopharmaceutical labelled with ^{99m}Tc to a patient by injection the syringe disengaged from the cannula in the middle of the injection, and the substance in the syringe sprayed over a nurse and onto the floor. The nurse was wearing spectacles, preventing the substance from reaching the eyes. The nurse washed the facial area and hair, and changed clothes and shoes. The contaminated area was isolated. The nurse sustained no significant radiation dose due to the incident.

Incident 5
An enterprise conducted X-ray imaging in outdoor premises belonging to another enterprise. On imaging in an upward direction a dose rate of 20 µSv/h was caused at a workstation in an adjacent industrial hall due to aerially scattered radiation. Following instructions from STUK a decision was taken to move the workstation to a more remote location. A decision was also taken to move the imaging site over the weekend to a more suitable place that was not in the vicinity of any workstation. The dose sustained by the exposed workers remained minimal, even though the limiting value prescribed in ST Guides (7.5 µSv/h) was momentarily exceeded. STUK also instructed the practitioner performing the imaging to plan this work in a manner ensuring that the prescribed dose and dose rate limits were not exceeded under any circumstances.

Incident 6
A wire supporting the radiation source (^{137}Cs, 18.5 GBq) of a level meter and density gauge in a production tower of an industrial plant snapped, and the source fell to the bottom of its protective tube. A detailed plan was prepared for extracting the source from the pipe. The source was extracted from the protective tube as planned and was fastened to an undamaged wire. The incident caused no human exposure to plant staff, and careful planning of repair measures also ensured minimal radiation exposure of the servicing crew. The supporting wires of all corresponding sources were subsequently replaced to ensure durability under plant operating conditions.

Incident 7
A worker in an industrial plant found a radiation source and its associated locking device (^{137}Cs,

370 MBq) on a grille platform after it had become detached from its housing. The source served as a blockage detector for peat conveyor systems. The attaching screws of the source locking device had sheared due to vibration on the conveyor system and the source and locking device had fallen onto the grille platform below. The time of this detachment was not known, but the source could not have been on the grille platform for longer than three months. There were no details of persons sustaining radiation exposure during this period. No persons used the grille platform under normal conditions. The radiation appliance keeper wrapped the device in a lead apron and delivered it to the radiation source store. The keeper thereby sustained a radiation dose of 5–10 µSv.

Incident 8

When using a mobile scanning device installed in a vehicle a customs worker was briefly near by the radiation beam of the device. This incident was due to an error by the appliance operator in starting both a scanning operation and the return of the scanner vehicle to its initial position. The reading of the worker's personal dosemeter indicated that the incident had caused no excessive radiation dose. The operating and warning systems of the appliance were repaired to ensure that corresponding incidents could no longer occur.

Incident 9

A ^{226}Ra radiation source (activity 2.22 MBq) used for training at a military installation disappeared during radiation protection exercises, and could not be found despite a search. The source was normally kept in a lead shield. The gamma radiation emitted by the source can only be detected at close range when the source is unshielded. STUK instructed the responsible party to review and rectify the procedures relating to use of radiation sources to ensure that corresponding losses may be prevented.

Incident 10

An ^{241}Am radiation source was melted down with scrap metal in a steel foundry. Most of the americium was captured in the slag from the smelting process and a minimal quantity was released in exhaust gas dust. Measurements taken at the plant indicated that worker exposure was negligible at the time of the incident and immediately thereafter. No americium was released to the surroundings of the plant. The americium-contaminated slag and dust were stored in separate vessels within the plant area.

Incident 11

A fire occurred at an industrial plant. The plant radiation safety officer notified STUK of this event and requested an inspection of the radiation appliances that had been in the vicinity of the fire. The inspection found the appliances to be intact, and with one exception their shutters functioned perfectly. The responsible party repaired the defective appliance immediately.

Incident 12

Two workers of an outside enterprise were performing X-ray imaging of welded joints in the yard of an industrial plant. They discontinued this work on observing an employee of the industrial plant walking past the imaging site. However, the employee suspected some exposure to radiation had occurred. To avoid similar incidents, STUK issued instructions requiring the use of warning signs around the imaging site.

Incident 13

Two workers of an outside enterprise were surfacing woodchip hoppers at an industrial plant. The shutter of a radiation source (^{137}Cs, 370 MBq) in a hopper level meter had remained open, and the surfacing workers were both exposed to radiation for about 10 hours. The effective dose to each worker was estimated at approximately 100 µSv.

As another incident causing radiation exposure of workers had occurred at the same industrial plant about one year prior to this, STUK asked the plant to give an account of how use of radiation is organized at the plant, of the division of responsibilities and duties between responsible persons, and of quality control in radiation safety functions. The plant rendered the requested account and took steps to improve radiation safety, such as enhancing supervision and clarifying responsibilities.

Incident 14

A child managed to climb onto a baggage conveyor at an airport and was scanned together with items of baggage. The child was taken off the conveyor after operators noticed the incident. At about 1.5 µSv, the radiation dose sustained by the child was quite small. As a result of this incident the responsible party evaluated its causes and ways of most effectively preventing corresponding situations in future. Although the planned corrective measures seek in particular to minimize the risk of physical injury, they may also reduce the likelihood of exposure to radiation.

Incident 15

A batch of scrap metal arriving from a defence forces installation caused a radiation alarm at the gates of a metal collection point. The reading and balancing disks of decommissioned artillery guns that had been painted with fluorescent radioactive material (^{226}Ra) were observed to be the cause of the alarm. The artillery decommissioning process was discontinued. The defence forces found and detached the irradiating parts of the guns and agreed with STUK on their disposal as radioactive waste.

Incident 16

An ^{241}Am source that arrived at a steel foundry in a consignment of scrap metal was accidentally melted down. The incident was detected when radiation detectors monitoring the slag pots sounded the alarm. On hearing the alarm the plant workers donned respiratory filters when moving within the foundry premises.

It is known from previous corresponding incidents that most of the americium is captured in the slag from the smelting process and a minimal quantity is released in exhaust gas dust. The case caused no release of radioactive material to the surroundings, and the radiation dose sustained by the workers was negligible.

Incident 17

According to information received from France, a consignment of lift buttons had been sent to Finland that could contain radioactive cobalt (^{60}Co). STUK took some measurements at a few lift installation sites but no radioactive buttons were found. However, the lift manufacturer recalled all of the buttons in the suspected batch. The recalled buttons were tested and it was found that they did not contain cobalt or any other radioactive substances. The metal parts of the buttons containing cobalt had originated in India. Radioactive buttons were subsequently found in other European countries.

Incident 18

The shutter mechanism of a belt weigher radiation source (^{60}Co, 370 MBq) from a log sorting system in a paper mill was damaged. The indicator light showed green, indicating that the radiation source housing was closed. An inspector touring the plant observed a worker under the belt weigher. The inspector measured a dose rate of 80–100 µSv/h at the point where the worker was working and asked the worker to leave the vicinity of the radiation appliance at once. The worker did not remain within the primary beam for longer than two minutes and so exposure to radiation was minimal. The plant inspected the operation of all belt weighers containing radiation sources.

Incident 19

An abnormal radiation measurement result was observed in sampling at a steel foundry. The matter was reported to STUK, which asked the plant to send samples of metal castings, exhaust gas dust, slag, and dust from within the indoor premises of the plant to STUK for testing. However, nothing abnormal was detected in the tests conducted at STUK. Neither were any further abnormal observations made in verification measurements taken by the plant.

Incident 20

An ^{123}I radiation source (activity 185 MBq) that arrived in Finland by air freight disappeared for a few days. The source arrived in Helsinki, from which it was due to be forwarded by air to the consignee. An investigation and search for the source began when the consignee did not receive it on time. The source was found after a few days in the air freight department at the consignee's local airport, where it had been mistakenly loaded in the wrong place. This was due to a breakdown in communications between the airline and the party in charge of the cargo. The airline is improving communications to prevent recurrence of such an incident. Nobody was exposed to radiation due to this incident.

Incident 21

A transport package of radioactive material in transit through Finland to a destination abroad was found to be damaged at a Finnish airport. The damage only affected the outermost packaging, and so no radioactive materials escaped to the environment. This was also verified by measurements taken in accordance with instructions from STUK. The materials were repackaged in Finland and forwarded to their destination.

3 Regulatory control of practices causing exposure to natural radiation

3.1 Radon at workplaces

During 2008 STUK received 197 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. 84 inspection reports were sent to enterprises on the basis of radon measurements. The reports required reductions in radon concentrations or an investigation of radon concentration during working hours in 40 work areas, and a measurement at another time of year in order to determine an annual average in 21 work areas. Radon concentrations were successfully reduced in 27 work areas during the year. STUK discontinued regulatory control in 9 work areas on the basis of further investigations (measurement during working hours or determination of annual averages). Regulatory control was discontinued at a total of 99 work areas for other reasons (e.g. short working periods or discontinued use of premises). 201 work areas at 89 workplaces were subject to regulatory control by STUK during the year.

A statutory radon inspection was conducted at five subterranean mines, at all of which the average radon concentration fell below the action level of 400 Bq/m^3, with the exception of a few individual workstations at one mine. STUK ordered radon concentration reduction measures at these workstations.

Eleven underground excavation sites were inspected, at one of which the radon concentration exceeded the action level. A radon concentration reduction repair order was issued for this site.

Radon exposure of workers was monitored by regular radon measurements and monitoring of working hours at two conventional workplaces and one excavation site where the radon concentrations exceeded the action level. A total of 14 workers were subject to radon exposure monitoring during 2008.

The measuring instruments or methods used for establishing radon concentrations when determining worker exposure to radiation must be approved by STUK. In 2008 STUK issued Guide ST 1.9, which also specified regulations for measuring inhaled air radon concentrations. After this Guide took effect STUK sent an enquiry to 55 approved practitioners requesting notification of the intention to continue radon concentration measurements, or of any already implemented or planned discontinuation of measurement operations. Respondents were also asked whether their current methods and equipment met the requirements of Guide ST 1.9 and how future measurements would comply with the new Guide. Through this procedure STUK sought to ensure that all workplace radon measurements in Finland comply with the requirements of Guide ST 1.9.

The enquiry revealed that 16 approved practitioners did not intend to continue measurement operations. Eight practitioners announced their intention to continue such operations, but no response of any kind was received from a further 28 practitioners. Some approved practitioners could not be contacted. Practitioners seeking to continue operating, but lacking methods or equipment satisfying the requirements of Guide ST 1.9, were advised of the new requirements and of the associated instrumentation features, at which point some of these practitioners decided to discontinue measurements. A final decision on this question is still pending in some of these cases. A follow-up letter was sent to practitioners that failed to respond to the original enquiry, notifying them that approval of measuring equipment would lapse unless the details requested in the enquiry were submitted to STUK by a stipulated deadline. Processing of responses and the search for contact addresses of approved practitioners continues in 2009.

Table 16 of Appendix 1 provides a list of organizations providing instruments that were approved in 2008 in accordance with the new requirements of Guide ST 1.9. 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. Regulatory control at one point of use of household water was discontinued in 2008 following connection to the public water network. Fifteen inspection reports on the radioactivity of construction materials were prepared during the year. These reports imposed restrictions on the use of materials where necessary. A statement was also prepared on use restrictions affecting an area used for heaping peat combustion ash containing radioactive caesium (^{137}Cs and ^{134}Cs) originating as fallout from the Chernobyl incident.

3.3 Cosmic radiation

In 2008 one airline submitted its plans for a method of determining radiation exposure. This method was found to comply with requirements.

A total dose for 2007 of 6.6 mSv was recorded for one pilot in January 2008. However, this merely indicated that an erroneous, and subsequently corrected, dose notification had been received from the airline. The corrected dose was substantially smaller than the dose constraint of 6 mSv.

The doses sustained by employees of six airlines were entered in the Dose Register in 2008. The largest individual annual dose of cosmic radiation sustained by a pilot was 4.3 mSv. The largest individual annual dose sustained by a cabin crew member was 5 mSv. The average annual dose sustained by pilots in 2008 was 2.0 mSv and the average annual dose of cabin crew members was 2.3 mSv. The average doses over the period 2004–2008 are shown in Figure 7. The number of workers subject to individual monitoring of radiation exposure and their combined effective doses are shown in Table 17 of Appendix 1.

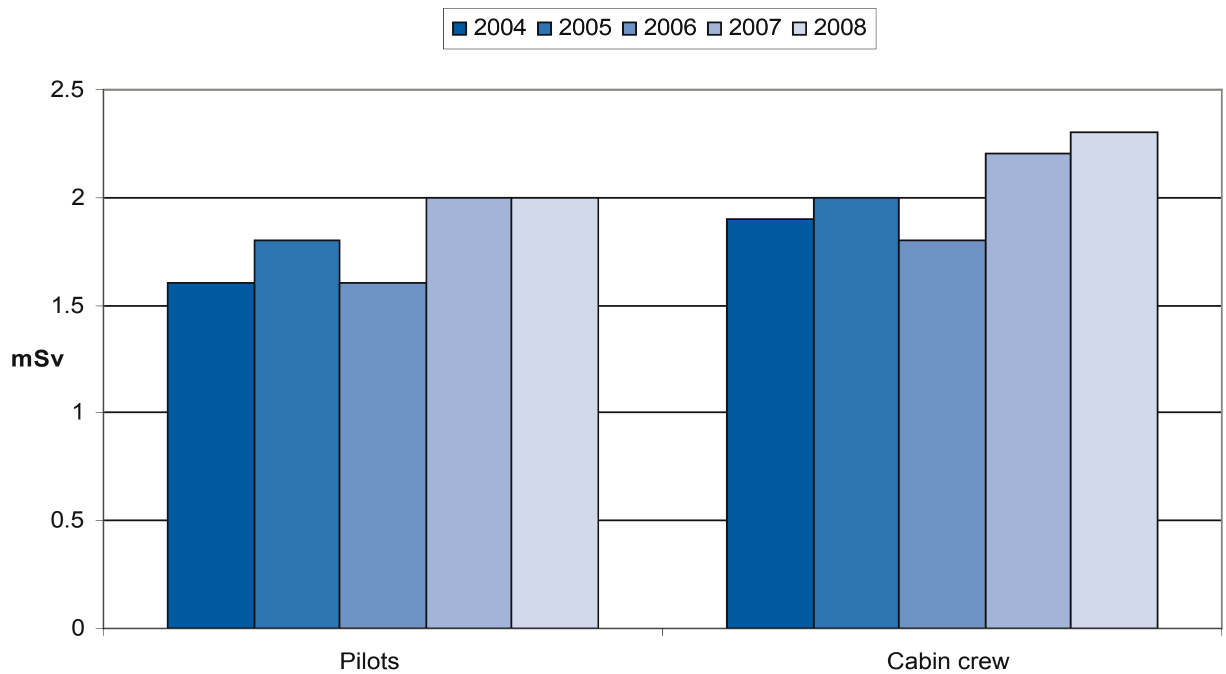

Figure 7. Average doses of air crews, 2004-2008.

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) and falling prices. There has also been an increase in the use for harassment of non-compliant laser pointers that are hazardous to the eye.

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 2008 is shown in Table 18 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

Initial inspections were made at 21 sunbed establishments with a total of 40 clam shell type and 2 upright sunbed appliances. A total of 5 repeat inspections were performed at 4 establishments, owing to lamps of excessive power observed in the initial inspections (see Table 19 in Appendix 1). Three of these repeat inspections were associated with initial inspections performed in 2007. Four of the sunbed establishments inspected (25 locations) were self-service establishments.

Deficiencies affecting the safety of sunbed users were found at almost all establishments. Only one such establishment cleared the initial inspection without criticism. About one fifth of the sunbed appliances inspected did not belong to the appliance class approved in Finland (UV type 3). This is about the same proportion as in 2007. Use of one appliance inspected at a self-service establishment was prohibited, as its erythema effective irradiance was more than twice the maximum value of 0.3 W/m^2 prescribed in the Decree of the Ministry of Social Affairs and Health (294/2002). The lamps of another self-service appliance that caused skin blisters had already been changed before the initial inspection (see item 4.4 Abnormal incidents). Although most appliances included radiation safety instructions, half of these guidelines included information that was generally contrary to requirements on such matters as the health impact of sunbeds, or inadequate technical operating instructions. Only about one quarter of the operating instructions referred to the regulation limiting annual use of sunbed appliances (5 kJ/m^2, corresponding to about 20 tanning sessions) under the Decree of the Ministry of Social Affairs and Health (294/2002), and to the recommendation of Guide ST 9.4 concerning starting times (5 minutes) for sunbed use. The 18-year age limit recommendation included in the Decree only appeared in half of the operating instructions. Nearly 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.

Premises of use were inspected in seven districts, with local health inspectors also involved in four districts. These inspectors were trained in inspecting radiation safety aspects. Other collaboration with health inspectors consisted of general consultancy regarding inspections, for example when determining the radiation characteristics of ultraviolet lamps in use and the compliance of equipment with safety standards.

A European Union sunbed market surveillance project was launched in September. A representative of the NIR Laboratory participated in a project training event at Zwijndrecht in the Netherlands, which focused on planning sunbed establishment inspections under the project. Some inspections in Finland in 2009 will be performed under the ambit of this project, and will also involve an inspector from the Dutch Food and Consumer Product Safety Authority (VWA), which is the organization co-ordinating the project.

Other regulatory control

Nine public performance laser installations were inspected during the year, with adjustments to the direction of laser radiation ordered in some cases.

STUK issued a decision prohibiting online consumer sales of 30 mW class 3B green laser pointers. These devices emit about thirty times the ocular radiation safety limit, damaging the retina if the beam shines in the eye. Laser vendors were required to advise the purchaser of this hazard to the eye. Sales of 1–5 mW laser pointers were also discontinued until the vendor has demonstrated that these devices do not exceed the 1 mW power limit prescribed in a Decree of the Council of State (291/2008).

Guidance was provided to customs authorities in intercepting imports of non-compliant 150 mW laser pointers.

The power of a laser pointer used for harassment at school was measured at STUK, and found to be less than 3 mW. Shining such a laser beam directly into the eye could cause retinal damage.

4.3 Electromagnetic fields

Market surveillance of wireless communication devices

Market surveillance of mobile phones began in 2003, and was extended to UMTS phones in 2007. Radiation tests have been conducted on a total of 85 mobile phones to date (see Table 20 of Appendix 1). Tests were conducted in 2008 on 10 mobile phone models, six of which were UMTS phones. Five baby monitors were also tested. None of the tested devices 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 values were 1.2 W/kg for mobile phones and 0.4 W/kg for baby monitors.

Other regulatory control

STUK issued a statement to the City of Helsinki on the projected location of a playground at a distance of about 10 metres from 110 kV power lines in Julius Park in the Kulosaari district of the city. This statement held that magnetic fields constitute no obstacle to the projected location, as the power lines are at an unusually high elevation (magnetic flux density of less than 0.4 µT within the playground area). It also noted, however, that exposure to electric and magnetic fields was a factor that ought to be taken up at the early stages of the planning process, as magnetic fields have been a matter of concern to parents. STUK also issued statements on power lines planned for Sokli in eastern Lapland, and a planning amendment concerning power lines at Joddböle in Inkoo, southwest Finland. In neither case were the electric and magnetic fields produced by power lines considered to pose any problems for local residents.

Two reports were prepared for the Ministry of Social Affairs and Health on the impact of mobile phones on heart pacemakers operation and on general mobile phone safety. The Ministry requested these reports in order to respond to a query from the Ministry of Transport and Communications. In accordance with the STUK reports, the Ministry of Social Affairs and Health found that no significant changes were envisaged in the radiation limits governing mobile communications, and that heart pacemaker users had no cause for concern over mobile phones operating at a distance of at least 20 cm from the pacemaker.

4.4 Abnormal incidents

The abnormal incident reporting required under section 17 of the Radiation Decree (1512/1991) also applies to incidents arising in the use of non-ionizing radiation (see item 2.9 above). STUK was advised of one abnormal incident involving the operation of a sunbed in 2008.

Incident 1

Two sunbed customers sustained skin burns (including blistering) from UV lamps in the upper section of a self-service sunbed appliance. The type of UV lamp that caused these injuries was subsequently tested at STUK. Based on measurements taken, the UV-dose rate of the appliance was estimated at four times the maximum permitted value of 0.3 W/m^2. The sunbed user had sustained an erythema-weighted UV-dose to the skin of no less than 1.4 kJ/m^2. This is about one third of the maximum annual dose recommended by STUK (5 kJ/m^2) and about seven times the threshold value for reddening of sensitive skin (0.2 kJ/m^2). The skin burns were due not only to excessively powerful lamps, but also to the fact that the exposure timer of the appliance could not be set for short exposure periods, but only for a standard period of 20 minutes.

Although the proprietor of the self-service sunbed establishment had already voluntarily installed new UV lamps of lower power, even these exceeded the radiation limits prescribed in the Decree of the Ministry of Social Affairs and Health (294/2002). STUK ordered the proprietor to install regulation-compliant lamps and to repair the appliance exposure timer.

Figure 3 (in item 1.1) shows abnormal incident numbers between 1999 and 2008.

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 Radiation Safety Guides were published in 2008:

- ST 1.9 Radiation Practices and Radiation Measurements
- ST 5.2 The Use of Control and Analytical X-Ray Apparatus
- ST 5.4 Trade in Radiation Sources
- ST 6.1 Radiation Safety when Using Unsealed Sources
- ST 7.4 Dose Register and Reporting of Data.

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

5.2 Other regulation work

An amendment was made in 2008 to section 52 a of the Radiation Act, implementing Council Directive 2006/117/Euratom on the supervision and control of shipments of radioactive waste and spent fuel. This amendment prescribes that no decommissioned radiation source manufactured elsewhere than in Finland may be imported to Finland as radioactive waste. Shipments of radioactive waste must be arranged in the manner prescribed in the Directive. The amendment authorizes STUK to issue a version of the standard document referred to in Article 17 of the Directive in its collected regulations. This standard document will be issued in an ST Guide to be prepared during 2009.

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:

Determination of radiation doses in paediatric X-ray examinations

As paediatric patients are subject to higher radiation risks than adults, they enjoy special radiation protection status. The aim of the project was to set patient dose reference levels for the most common paediatric X-ray examinations and to determine organ doses and effective doses in paediatric imaging. A study of good practice methodology was also conducted by comparing imaging values and patient doses. The project findings have been published in three scientific articles and used in a doctoral thesis prepared at STUK (see the item Academic thesis work). STUK has issued a decision setting reference levels for paediatric X-ray examinations based on the project findings. The decision is available on the STUK website. The project data were also used when preparing two STUK bulletins on paediatric X-ray imaging.

Examination-specific radiation doses of staff in interventional radiology

The aim of the study was:

- 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) sustained by interventional radiologist/cardiologist.

Measurements were taken at four hospitals for the cardiology studies. The other project participants were the University of Kuopio, Savonia University of Applied Sciences, Doseco Oy and Rados Technology Oy. Staff radiation exposure was determined by examination-specific dosimetry for examination types selected in advance. The dosimetric methods proved serviceable and verified data were obtained on their practical effectiveness. A summary of project findings was published at the 2008 Radiation Safety Conference and on the STUK website. The results will also be covered in a forthcoming more detailed STUK-A report.

IAEA code of dosimetry practice in X-ray diagnostics

An IAEA research project to test a code of diagnostic dosimetry practice began in 2006 (Coordinated Research Project 2006–2007: Testing of the Implementation of the Code of Practice on Dosimetry in X-ray Diagnostic Radiology). This project continued in 2008. STUK was particularly involved in this project in testing work on dose-area-product (DAP) meters, in testing calibration and measurement methods for the meters used in CT dosimetry, and in mammography dosimetry. The evaluation and testing were performed both for the calibration methods used in the DOS Laboratory of STO and for the clinical dosimetry methods used in hospitals. The methods of measurement used at STUK and elsewhere in Finland were compared to the methods outlined in IAEA dosimetric instructions. On the basis of this comparison a decision was taken to revise the STUK measuring methods in mammography, and certain calibration methods were updated. A summary of international findings will be published in the IAEA TECDOC report in 2009. An internal STO report of the findings has been prepared for dosimetry in mammography. Two scientific articles have been prepared on calibration methods for DAP meters.

One polytechnic graduation thesis has also been prepared on the use of kVp meters.

Comparison and development of mammography dosimetry

The aim of this project was to assess and improve the reliability of mammography dosimetry. The project tested and assessed the properties of types of meters used in mammography within the energy range of such use, and investigated the calibration requirements of these meters and the radiation qualities used in calibration. The findings will serve as a basis for gradually revising dosimetry practices when mammography appliances are inspected. A shift will be made in measurements in particular towards using ionization chambers designed for mammography and the dose to glandular tissue will also be reported in addition to the values of measured quantities. The DOS Laboratory radiation qualities in the field of mammography will be revised over the coming years by replacing Al-filtered radiation qualities with Mo and Rh filtering.

European Metrology Research Programme (EMPR)

Two jointly-funded European research projects associated with metrology began in 2008: JRP6-Brachytherapy and JRP7-External Beam Cancer Therapy. These projects are part of the Health field of the European Metrology Research Programme (EMPR), and are both concerned with dosimetry in radiotherapy. The aim of the projects is to improve metrology and dosimetry for current techniques in brachytherapy and external radiotherapy. The role of STUK in the project is:

- development of dosimetry and dose distribution verification methods for ^{191}Ir and ^{125}I brachytherapy sources using radiochromic and scintillation detectors, and for ^{125}I eye applicators using solid state detectors
- development of dosimetry and dose distribution verification methods for intensity modulated radiotherapy (IMRT) of prostate cancer.

These projects began by preparing a testing programme for detectors and a preliminary plan for the required measurement phantoms.

Calibration of radiotherapy plane-parallel ionization chambers in a ^{60}Co gamma ray beam

An investigation began at the start of 2008 into the accuracy and reliability of calibrating plane-parallel ionization chambers used in the electron radiation beams of radiotherapy linear accelerators in a ^{60}Co gamma ray beam. The project studies the prospects for changing the calibration of plane-parallel ionization chambers from the electron radiation beams of linear accelerators in radiotherapy clinics to the ^{60}Co gamma ray beam in the DOS Laboratory of STO. The project will involve revising the calibration phantom at the DOS Laboratory and testing and reception measurements of the laser range finder used in positioning the chambers, and a calibration comparison of plane-parallel ionization chambers used in radiotherapy clinics in Finland in a ^{60}Co gamma ray beam and in the electron beams of linear accelerators. The DOS Laboratory calibration phantom was revised during 2008 to make it suitable for using a laser range finder. The laser range finder was tested in test calibrations of STUK's own cylinder and plane-parallel ionization chambers in a ^{60}Co gamma ray beam. The standard deviation of the test calibration results was less than 0.2%. This project will continue in 2009 with a calibration comparison of radiotherapy clinic plane-parallel ionization chambers in the ^{60}Co gamma ray beam of the DOS Laboratory and in the electron beams of clinic linear accelerators.

Energy loss of protons and heavy ions in water

This project measures the stopping power of water for beams of protons and heavy ions within the energy range of interest in dosimetry of radiotherapy and cosmic radiation (about 1–30 MeV/nucleon). The measurements of stopping power will be made in the accelerator laboratory of the University of Jyväskylä. The findings have potential uses in dosimetry of radiotherapy and cosmic radiation. The stopping power of water is a fundamental factor in many other dosimetric applications, such as assessing the radiation dose caused by neutron radiation. During 2008 a prototype water target was designed and constructed, and the first test measurement series was obtained using a proton beam. The test measurements were used to ensure that it was possible to construct a thin-layer liquid target and that the thickness of the target could be determined with sufficient accuracy. The final target will be constructed and proton measurements will be taken during 2009 on the basis of experiences gained in the test measurements. This timetable may be affected by work to enlarge the University of Jyväskylä accelerator laboratory.

Stakeholder involvement processes in radioactive scrap metal

The study will be conducted in association with the University of Manchester. It will focus on processing of activated and contaminated scrap metal that has been exempted from official regulatory control. The aim is to assess the serviceability of methods used elsewhere supporting stakeholder involvement in scrap metal processing. This assessment will be based on both a literature review and by testing methods in practice. A further aim is to improve the transparency of policymaking at STUK with respect to regulatory control of radioactive scrap metal, and to prepare a long-term action plan for regulatory control.

Academic thesis work

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

Patient doses in CT, dental cone beam CT and projection radiography in Finland, with emphasis on paediatric patients

The aim of this doctoral thesis investigation was to develop and compare various dosimetry systems for computed tomography scans (CT) and paediatric plain X-ray examinations, to promote the adoption of paediatric reference levels, and to produce new patient dose data for optimizing X-ray examinations.

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.

A jointly financed research project, "Traceable measurement of field strength and SAR for the physical agents directive" began in association with EURAMET (European Collaboration in Measurement Standards). Characterization of a previously developed TEM calibrator was improved by numerically simulating the calibrator at a frequency of 380 MHz. The measuring system calibration of specific heat capacity that is vital to SAR calibration was determined again, and the calibration was compared with tissue-equivalent liquids calibrated by the National Physical Laboratory in the UK (results available at a later date). The TEM calibrator was tested at a frequency of 380 MHz. Work began on an article for a scientific journal concerning the calibrator. A current transformer calibrator was designed measuring RF current in the limbs at a frequency of 10–50 MHz.

The contribution of STUK to the MF Safety research project partly funded by the Finnish Funding Agency for Technology and Innovation – TEKES was successfully completed. This project examines the risks posed by magnetic fields at electricity distribution centres. The function of STUK was to calculate the current density induced in an electrician working in the vicinity of electricity distribution cabinets and to compare this with the maximum exposure value prescribed in the EMF Directive (2004/40/EC). New commercial software (the SEMCADX ELF solver) was commissioned and tested for the purpose of this calculation. In the course of testing the manufacturer had to make improvements to the program at the request of STUK. The modifications enabled a three-phase current feed to the magnetic field source. The current densities were calculated in the Virtual Family male Duke, an anatomically realistic human model comprising heterogeneous tissues representing an adult male. The principal finding of the project was that STUK now possesses dosimetric calculation capacity in the low frequency range.

Other research activities

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

Occupational health and safety measurements of the low frequency and static magnetic fields of a 1 T open MRI scanner and a 3 T closed MRI scanner were performed on the premises of Philips Medical

Systems Oy. These measurements used a three dimensional magnetic field sensor developed at STUK, which enables simultaneous measurements of the equivalent dB/dt caused by movement of the body and the dB/dt of gradient fields. An article was prepared on the measurements and associated exposure estimates, and was submitted to the journal *Physics in medicine and biology*.

7 International co-operation

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

STUK leads formulation of European clinical auditing guidelines

A European recommendation on the content and practice of clinical auditing was completed in a project financed by the European Union and led by STUK. This recommendation was submitted to the European Commission on 1 December 2008 and approved at the beginning of 2009. The draft recommendation was considered at an international conference organized by STUK in Tampere between 8 and 10 September 2008, at which critical comments were canvassed for the purpose of finalizing the draft while presenting the implementation of clinical auditing in the Member States and experiences of auditing in practice. Some 130 specialists from 29 countries attended the conference.

Participation in meetings of international working groups

During 2008 representatives of STUK took part in meetings of the following international organizations and working groups:

- Nordic sealed source working group (NORGUSS)
- meeting of the IEC sunbed working group TC61/MT16
- International Commission on Non-Ionizing Radiation Protection (ICNIRP) TG-ELF working group
- European Radiation Dosimetry Group (EURADOS)
- EURAMET working group on ionizing radiation.

Participation in other international conferences

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

Other international co-operation

A representative of the NIR Laboratory took part in a Nordic co-operation conference in Stockholm on dermal treatments administered using lasers and light pulse instruments. Another representative participated in Nordic co-operation conferences on the measurement of radio frequency background radiation fields held in Borås, southern Sweden, in March, and in Stockholm in September. Some comparative base station measurements were taken in Borås and the results were analyzed at the conference in Stockholm (see item 10.2).

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 the following conferences in 2008:

- The International Commission on Radiological Protection (ICRP) published its new basic recommendations (ICRP 103) in 2008. STUK issued a Finnish language report on the recommendations (STUK-A235) and arranged a training event on them for users of radiation in health services and industry, and for other parties with an interest in the matter. This event will be repeated in 2009.
- A planning meeting on radiation safety training included in vocational training for Radiation Safety Officers and radiation users was arranged in association with external specialists. A survey was conducted in October on radiation safety training arranged by training organizations for Radiation Safety Officers. This survey investigated implementation of the requirements in Guide ST 1.8 and the consistency of training arranged by various training organizations. The findings will be reported in 2009.
- A conference was arranged for the first time with representatives of airlines and aviation authorities. The purpose of this event was to improve collaboration by meeting one another and discussing matters of topical concern. The conference will be repeated as a roughly biennial event from now on.
- The 6th conference on radiation safety in industry was arranged between 8 and 10 April 2008 aboard the m/s Mariella cruise ferry. The event attracted 147 users of radiation in industry and research, and traders in radioactive materials.
- A seminar on quality control of health service X-ray equipment was arranged at the President Hotel in Helsinki between 10 and 11 April 2008. This event discussed and collected audience comments concerning draft guidelines on the seminar topic. The seminar was attended by 212 specialists in X-ray diagnostics.
- A combined event comprising an introductory course in radiotherapy dosimetry and the 25th conference of radiotherapy physicists was arranged at STUK between 12 and 13 May 2008.
- A conference of X-ray physicists was arranged at Kehvonsalo Manor in Siilinjärvi, eastern Finland, between 28 and 29 August 2008. This conference considered such topics as quality control of CT scanning equipment.

Participation in meetings of Finnish working groups

Representatives of STUK took part in the following meetings of Finnish organizations and working groups:

- SESKO SK 61
- SESKO SK 106.

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

The Ministry of Social Affairs and Health has reappointed the specialist group on clinical auditing for a term of office running from 1 January 2007 to 31 December 2009. STUK is providing the secretary to the group.

The main policy lines governing regulatory control of lasers sold to consumers were agreed at a conference arranged by the occupational health and safety department of the Ministry of Social Affairs and Health with representatives from this Ministry and from STUK, the Finnish Consumer Agency, the Safety Technology Authority (TUKES) and the Finnish Institute of Occupational Health. STUK serves as the regulatory authority for consumer sales of lasers other than toys, which are supervised by the Finnish Consumer Agency. The occupational health and safety authorities continue to serve as the regulatory authority for laser equipment used at work. The Finnish Institute of Occupational Health continues type inspections of battery-operated laser devices that are not governed by the Low Voltage Directive (2006/95/EC). The type approval procedure was abolished for these battery-operated devices in June 2008 when a new Decree of the Council of State (291/2008) took effect.

9 Information activities

Books, bulletins, reviews

STUK publishes the Radiation and Nuclear Safety book series comprising a total of seven books (in Finnish). The following parts of the series were published between 2002 and 2006:

- Part 1: Radiation and its detection
- Part 2: Radiation in the environment
- Part 3: Use of radiation
- Part 4: Health impacts of radiation
- Part 5: Nuclear safety
- Part 6: Electromagnetic fields

The text for the seventh part of this series, covering ultraviolet and laser radiation, was completed in 2008 and sent for make up.

Two guides were published in the bulletins series of STUK (in Finnish):

- 1/2008 Criteria for paediatric X-ray examinations
- 2/2008 Quality control guide for health service X-ray appliances.

These guides were prepared by STUK in association with external specialists.

Public information on current affairs

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

During the year the NIR Laboratory received several questions from members of the public, radiation users, the media, and other parties interested in non-ionizing radiation. Several interviews were given to the media. Queries came from members of the public through the website every day and telephone calls were received on a very wide range of radiation concerns.

Press releases were prepared on the following subjects (in Finnish):

- The smallest possible radiation dose for small patients
- Research completed on the human impacts of mobile phone radiation
- The spring sun is shining again – enjoy it in moderation
- Third generation mobile phones emit no more radiation than earlier models
- Alara magazine: We are exposed to cosmic radiation generated millions of years ago
- Extensive study finds no indications that mobile phone use affects the risk of meningeal tumours
- Radioactive iodine discharge in Belgium
- Medical users of radiation meet in Tampere: Seeking optimal examination and therapy practices
- New international recommendations on radiation protection
- Radioactive americium source melted down in Tornio
- Lift buttons containing radioactive cobalt may also turn up in Finland
- No radioactive lift buttons found in Finland
- Baby monitor radiation clearly within safety limits.

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 EURAMET organization.

Metrological activities are the responsibility of the Radiation Metrology Laboratory (the DOS Laboratory) at STO for ionizing radiation and the NIR Laboratory for non-ionizing radiation. Metrology of ionizing radiation activity quantities is the responsibility of the Department of Research and Environmental Surveillance (TKO) at STUK.

10.1 Ionizing radiation

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

The DOS Laboratory prepared the replacement of the radiation sources (^{60}Co and ^{137}Cs sources) in its Revolver irradiation appliance. The new sources will be installed in the appliance during 2009.

The DOS Laboratory was subject to an internal audit of its security arrangements in which the security arrangements for the laboratory's radiation sources were found to be excellent. A planned audit of the laboratory's metrological standard equipment was deferred to 2009.

The laboratory operating system guidelines were supplemented and substantially updated.

Meter and measurement comparisons

The DOS Laboratory took part in EURAMET calibration comparisons arranged between 2005 and 2006, the results of which were obtained during 2008:

- EURAMET 545, comparison of air kerma with X-radiation
- EURAMET 738, comparison of dose equivalent with X-radiation
- EURAMET 739, comparison of absorbed dose to tissue with beta radiation (^{90}Sr/^{90}Y)
- EURAMET 813, comparison of absorbed dose to water with ^{60}Co gamma radiation.

In comparison 545 the maximum deviation of the results of the DOS Laboratory from the reference value was 2.8%, which exceeded the estimated measurement uncertainty of 2.46% (coverage factor 2). This difference was considered to be due to instability of the X-ray equipment during the measurement, and did not lead to any modification of the calibration procedure. The result of the DOS Laboratory in comparison 739 was excellent, deviating from the reference value by only -0.8%. The provisional results from comparisons 738 and 813 indicated that the laboratory results were well within the estimated uncertainties.

In 2008 the DOS Laboratory took part in the annual TLD comparison measurement of the 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 1.9%. This result was well within the acceptable range of ± 3.5%. A separate ionization chamber calibration check was also performed between the IAEA dosimetry laboratory and the DOS Laboratory, which verified that the deviation was due to TLD inaccuracy.

Figure 8 shows the deviations in the measurement results of STUK from the reference value in IAEA/WHO measurement comparisons over the period from 1998 to 2008.

As quality assurance of activity quantities, STUK also took part in several inter-laboratory comparison measurements. The results from a total of seven radioactivity comparison analyses were reported during 2008, many of which involved determinations for several radionuclides. Three of the comparisons were international, one was national, and three were internal to STUK. The results of comparison measurements were generally either good or very good.

10.2 Non-ionizing radiation

Meter and measurement comparisons

The EURAMET 819 calibration comparison involved calibrating a small electric field sensor in laboratories specialized for field strength measurements in ten countries. Each laboratory used its own calibration equipment to determine, at intervals of 0.25 GHz through the frequency range of 1–2.5 GHz, the electric field strenght for which the reading of the sensor was 20 V/m. The comparison calibrations began at the end of 2007 and continued for about a year. STUK performed the calibrations and prepared a measurement report in March-April 2008 describing the calibration method and apparatus, and presenting the calibration results and uncertainty estimate. A pilot laboratory in the Czech Republic will prepare the final report of the calibration comparison, which will probably be completed in the first half of 2009.

Some comparative base station measurements between the Nordic countries were taken in Borås and the results were analyzed at a conference in Stockholm (see chapter 7). The results obtained by various measurers varied by no more than ±7 dB, which was very much the expected outcome. The participants were free to consider whether the measurement comparison should be repeated under more precise guidelines.

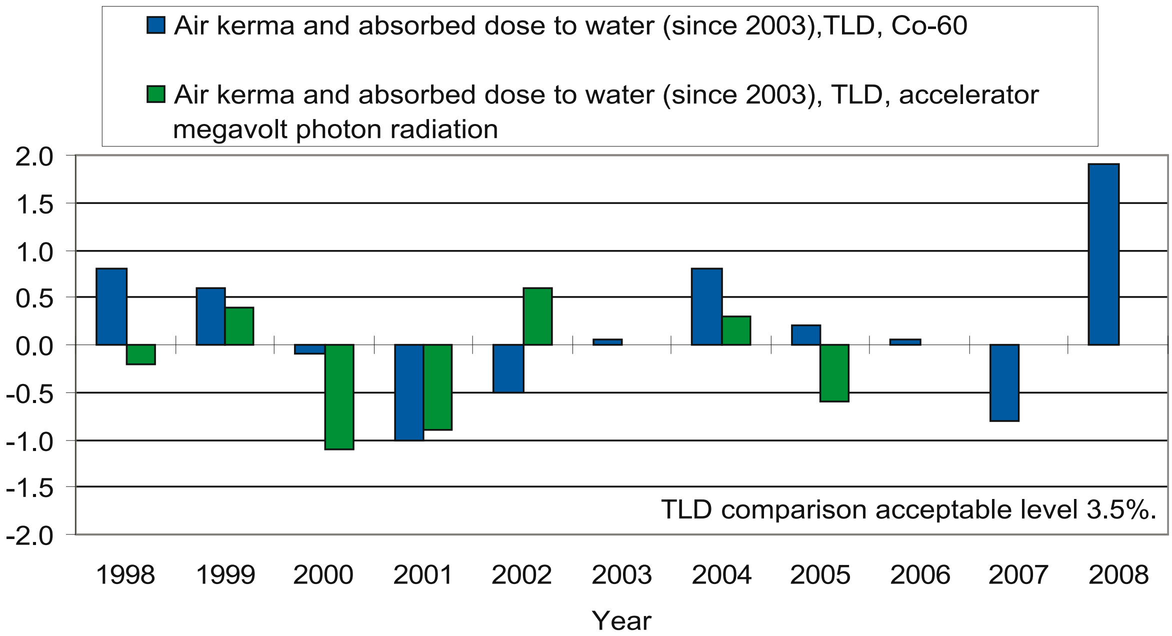

Figure 8. Deviations (%) in measurement results of STUK from the reference value in IAEA/WHO measurement comparisons, 1998–2008.

11 Services

11.1 Ionizing radiation

Calibration, testing and irradiation

The DOS Laboratory performed radiation meter calibrations and testing on request. 110 radiation meter calibration, inspection and testing certificates and 26 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

83 copies of the PCXMC measurement program developed at STUK were sold for dose computation 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 46 radiation meter calibrations and tests and 24 safety assessments and radiation measurements. The service work of the NIR Laboratory between 2000 and 2008 is shown in Table 18 of Appendix 1.

APPENDIX 1

TABLES

Table 1. Radiation practices referred to in safety licences for the use of radiation in health care at the end of 2008.

Use of radiation	Number of practices
X-ray examination	387
Dental X-ray examination*)	16
Veterinary X-ray examination	210
Use of unsealed sources	42
Use of sealed sources	26
Radiotherapy	14
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 2. Radiation sources and appliances used in health care and in veterinary X-ray practices, and radionuclide laboratories at the end of 2008.

Appliances/laboratories	Number
X-ray diagnostic appliances (generators) *)	**1529**
X-ray tubes	**1610**
• image-intensifier television chain	316
• mammography (not screening)	105
• screening mammography	91
• computer tomography	95
• angiography (not DSA)	31
• digital subtraction angiography (DSA)	66
• bone mineral density measurement	83
• dental X-ray imaging	51
Dental X-ray appliances	**5422**
• conventional dental X-ray appliances	4752
• panoramic X-ray appliances	670
Radiotherapy appliances	**98**
• accelerators	40
• afterloading appliances	11
• X-ray therapy appliances or radiographic appliances	17
• radiotherapy simulators	9
• BNCT therapy unit	1
• other appliances	20
Appliances containing radioactive substances	**174**
• attenuation correction units	16
• flood sources	36
• calibration sources	22
• gamma irradiators	6
• other appliances	94
Veterinary X-ray appliances	**259**
Radionuclide laboratories	**61**
• B-type laboratories	21
• C-type laboratories	39
• 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 3. Radiation practices referred to in safety licences for the use of radiation in industry, research and education and in trade of radioactive substances at the end of 2008.

Use of radiation	Number of practices
Use of sealed sources (excluding gamma radiography)	628
Use of X-radiation (excluding radiography)	287
Import, export and trade	129
Installation, test operation and servicing	119
Use of unsealed sources	117
X-ray radiography	86
Gamma radiography	7
Use of particle accelerators	7
Production of radioactive substances	5
Other uses of radiation	26

Table 4. Radiation appliances and sources used in industry, research, and education, and radionuclide laboratories at the end of 2008.

Appliances/laboratories	Number
Appliances containing radioactive substances	**6319**
• level switches	2284
• continuous level gauges	1174
• density gauges	1017
• weight scales	582
• basis weight meters	524
• moisture and density gauges	123
• fluorescense analyzers	103
• thickness gauges	69
• radiography appliances	20
• other appliances	423
X-ray appliances and accelerators	**1266**
• X-ray screening appliances	432
• radiography appliances	379
• diffraction and fluorescence analyzers	274
• thickness gauges	49
• ash meters	17
• particle accelerators	18
• other analytical appliances	97
Radionuclide laboratories	**154**
• A-type laboratories	2
• B-type laboratories	24
• C-type laboratories	115
• other laboratories	13

Table 5. Radionuclides most commonly used in sealed sources in industry, research and education, and number and activities of sources at the end of 2008.

Radionuclide	**Number of radiation sources**	**Total activity*) (GBq)**
Other than high-activity sealed sources		
Cs-137	4023	9052
Co-60	1388	1139
Kr-85	393	5087
Am-241 (gamma sources)	349	1704
Pm-147	150	4578
Am-241 (AmBe neutron sources)	119	486
Fe-55	110	317
Cd-109	52	21
Sr-90	51	28
Ni-63	51	20
High-activity sealed sources		
Cs-137	54	229 496
Co-60	17	98 111
Ir-192	13	50 717
Am-241 (gamma sources)	9	1036
Sr-90	5	167
Am-241 (AmBe neutron sources)	4	591

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

Table 6. Inspections of the use of radiation in 2008.

Type of inspection	**Number of inspections**		
	Industry, research, education, trade, installation, maintenance	**Health care**	
		Licensed practices	**Notifiable licence-exempt dental X-ray practices**
Initial inspection	15	145	0
Periodic inspections	134	120	10
Repeat inspections	1	6	0
Other inspections or measurements	0	3	8
Total	**150**	**274**	**18**

Table 7. Inspections of licensed practices in health care in 2008.

Type of practice	**Number of inspections**
• X-ray diagnostics	177
• dental X-ray diagnostics	3
• veterinary X-ray diagnostics	47
• nuclear medicine	11
• radiotherapy	36
• other uses of radiation	0
Total	**274**

Table 8. Imports and exports of sealed sources in 2008.

Radionuclide	Imports		Exports	
	Activity (GBq)	Number	Activity (GBq)	Number
Ir-192	60 680	14	4208	11
Se-75	2960	1	-*)	-
Kr-85	1341	96	848	57
Cs-137	364	187	143	71
Fe-55	123	36	105	25
Sr-90	115	11	3	6
Pm-147	87	68	79	30
I-125	76	**)	-	-
Gd-153	48	13	2	34
Am-241	9	40	4	620
Co-60	6	19	-	-
Ni-63	5	10	2	4
Cd-109	5	9	4	8
Co-57	5	32	-	-
Am-241***)	3	2	-	-
Ge-68	1	10	2	8
others total ****)	2	16	-	24
Total	**65 830**	**564**	**5400**	**898**

*) The symbol "-" indicates no import/export.

**) The exact number of small I-125 sources is not known.

***) AmBe neutron sources.

****) Import, nuclides: Ba-133, Ba-133m, Cf-252, Eu-152, Ge-68, Mn-54, Na-22, Po-210.
Export, nuclides: Ba-133, Eu-152.

Table 9. Imports and exports of unsealed sources in 2008.

Radionuclide	Activity (GBq)	
	Import	Export
Mo-99	37 022	37 021
I-131	5278	1113
Tc-99m	3710	25
I-123	662	47
Sm-153	236	-*)
P-32	173	66
Tl-201	105	-
Y-90	61	-
In-111	48	-
I-125	45	4
H-3	31	22
S-35	21	-
C-14	9	-
Cr-51	6	-
Sn-117m	4	4
others total **)	3	1122
Total	**47 414**	**39 424**

*) The symbol "-" indicates no import/export.

**) Imports, nuclides: Ba-133, Bi-207, Ca-45, Co-57, Co-60, Cs-137, Eu-152, Ga-67, Ge-68, Na-22, P-33, Rb-86, Re-186, Se-75, Sn-113, Th-229, Zn-65.
Exports, nuclides: F-18.

Table10. Manufacturing of radioactive substances (unsealed soursed) in 2008.

Radionuclide	**Activity (GBq)**
F-18	40 722
O-15	16 900
C-11	12 524
Br-82	2914
I-123	1940
others total*)	145
Total	**75 145**

*) Nuclides, such as: Cr-51, Cu-64, Ho-166, La-140.

Table 11. Number of workers subject to individual monitoring in 2004–2008.

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**					
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
2007	4767	961	368	1275	927	3257	11 441
2008	4872	984	392	1293	884	3444	11 550

*) 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 figures in other columns of the same row, as some health care staff are exposed both to X-radiation and other forms of radiation, and there are workers in industry who also work in the use of nuclear energy.

Table 12. Total doses (sums of $H_p(10)$ values) of workers subject to individual monitoring in 2004–2008.

Year	**Total dose (Sv) 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**					
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
2007	1.37	0.15	0.11	0.26	0.08	2.16	4.13
2008	1.51	0.12	0.11	0.22	0.09	2.76	4.69

*) $H_p(10)$ 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 13. Data ($H_p(10)$ values) on certain occupational groups in 2008.

Group	Number of workers	Total dose (Sv)	Average dose (mSv)		Largest dose (mSv)
			Workers*) whose dose exceeds recording level	All workers subject to individual monitoring	
Cardiologists**)	189	0.58	3.9	3.1	25.8
Radiologists**)	523	0.29	2.4	0.6	24.1
Interventional radiologists**)	23	0.21	10.2	9.3	25.3
Surgeons**)	274	0.06	1.9	0.2	14.7
Radiographers**)	2555	0.12	0.6	0.0	5.8
Industrial tracer testing technicians	25	0.07	3.0	2.8	14.8
Industrial radiographers	448	0.11	0.6	0.2	4.7
Researchs	670	0.08	1.9	0.1	8.3
Nuclear power plant workers					
• mechanical duties	692	0.79	1.7	1.1	12.4
• cleaning	235	0.34	2.2	1.4	9.5
• material testing	197	0.26	1.7	1.3	9.5
• insulation work	58	0.21	4.5	3.7	13.5
• radiation protection	78	0.20	3.1	2.5	12.8
• operating staff	268	0.12	0.9	0.4	3.8

*) 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.

**) Hp(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 in 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 14. The principal low-level radioactive waste in the national storage facility (December 2008).

Radionuclide	Activity (GBq) or mass
H-3	14 182
Cs-137	2392
Am-241	1641
Kr-85	1602
Pu-238	1583
Sr-90	247
Ra-226	231
Co-60	146
Cm-244	101
U-238	1089 kg

Table 15. Low-level radioactive waste received by STUK in 2008.

Radionuclide	Activity (GBq)
Kr-85	153
Cs-137	119
Am-241 *)	21
H-3	9.8
Fe-55	3.8
Co-60	3.0
Pm-147	1.9
C-14	1.5
Am-Be **)	1.4
Sr-90	1.3
Pu-Am	0.2
Co-57	0.02
Ra-226	0.06
Cd-109	0.002

*) Gamma sources
**) Neutron sources

Table 16. Organizations having instruments approved for determining worker exposure to radon.

Organization	Instrument	Calibration valid until	Notes
Gammadata Mätteknik AB/ Gammadata Finland Oy	Alpha track detector	8 Aug. 2009	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 Tampere Polytechnic Turku Polytechnic Kuopio University City of Espoo Fortum Power and Heat	Pylon AB-5 AlphaGuard Pylon AB-5 Pylon AB-5 Pylon AB-5 AlphaGuard	9 Sep. 2010 9 Sep. 2010 2 Apr. 2010 4 Jul. 2010 9 Dec. 2010 9 Jun. 2009	Continuously monitoring instruments that can record variations in radon concentration over time. These instruments are suitable for measuring radon concentration during working hours.

Table 17. Number of air crew members subject to individual monitoring of radiation exposure and total dose of crew members (sum of effective doses) in 2004–2008.

Year	Number of workers		Total dose (Sv)	
	Pilots	Cabin crew	Pilots	Cabin crew
2004	739	1801	1.19	3.45
2005	739	1861	1.31	3.80
2006	1 072	2412	1.73	4.35
2007	1 125	2583	2.30	5.61
2008	1 206	2562	2.45	5.93

Table 18. Work of the NIR Laboratory in 2000–2008.

Year	Regulatory control inspections	Decisions	Statement	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
2007	64	3	3	33	17	120
2008	67	5	6	46	24	148

Table 19. Inspections of sunbed facilities in 2000–2008.

Year	Number of inspections
2000	14
2001	17
2002	36
2003	31
2004	30
2005	36
2006	25
2007	31
2008	26

Table 20. Mobile phone SAR tests in 2003–2008.

Year	Mobile of tests
2003	12
2004	18
2005	15
2006	15
2007	15
2008	10

APPENDIX 2 PUBLICATIONS IN 2008

The following publications completed in 2008 were authored by one or more employees of STO or the NIR Laboratory:

Internatonal publications

Aarnio PA, Ala-Heikkilä JJ, Isolankila A, Kuusi A, Moring M, Nikkinen M, Siiskonen T, Toivonen H, Ungar K, Zhang W. LINSSI: Database for gamma-ray spectrometry. Journal of Radioanalytical and Nuclear Chemistry 2008; 276 (3): 631–637.

O'Connor U, Dowling A, Larkin A, Sheahan N, Gray L, Gallagher A, O'Reilly G, Kosunen A, Zdesar U, Malone JF. Development of training syllabi for radiation protection and quality assurance of dual-energy x-ray absorptiometry (DXA) systems. Radiation Protection Dosimetry 2008; doi:10.1093/rpd/ncn088.

Hülsen G, Gröbner J, Bais A, Blumthaler M, Disterhoff P, Johnsen B, Lantz KO, Meleti C, Schreder J, Vilaplana Guerrero JM, Ylianttila L. Intercomparison of erythemal broadband radiometers calibrated by seven UV calibration facilities in Europe and the USA. Atmos. Chem. Phys. 2008; 8: 4865–4875.

Ilvonen S, Toivonen T, Toivo T, Uusitupa T, Laakso I. Numerical specific absorption rate analysis and measurement of a small indoor base station antenna. Microwave and Optical Technology Letters 2008; 50: 2516–2521.

Järvinen H, Buls N, Clerinx P, Jansen J, Miljanic S, Nikodemová D, Ranogajec-Komor M, d'Errico F. Overview of double dosimetry procedures for the determination of the effective dose to the interventional radiology staff. Radiation Protection Dosimetry 2008; 129 (1-3): 333–339.

Kapanen M, Sipilä P, Bly R, Järvinen H, Tenhunen M. Accuracy of central axis dose calculations for photon external radiotherapy beams in Finland: The quality of local beam data and the use of averaged data. Radiotherapy and Oncology 2008; 86: 264–271.

Kojo K, Lahtinen T, Oikarinen A, Oivanen T, Aartama M, Pastila R. Reliability and validity of bioimpedance measurement device in the assessment of UVR damage to the skin. Arch. Dermatol. Res. 2008; 300: 253–261.

Keyriläinen J, Fernández M, Karjalainen-Lindsberg M-L, Virkkunen P, Leidenius M, von Smitten K, Sipilä P, Fiedler S, Suhonen S, Suortti P, Bravin A. Toward high-contrast breast CT at low radiation dose. Radiology 2008; 249: 321–327.

Kännälä S, Puranen L, Sihvonen A-P, Jokela K. Measured and computed induced body currents in front of an experimental RF dielectric heater. Health Physics 2008; 94: 161–169.

Malisan MR, Padovani R, Faulkner K, Malone JF, Vano E, Jankowski J, Kosunen A. Proposal for patient database on cardiac interventional exposures for epidemiological studies. Radiation Protection Dosimetry 2008; doi:10.1093/rpd/ncn036.

Meinander O, Kontu A, Lakkala K, Heikkilä A, Ylianttila L, Toikka M. Diurnal variations in the UV albedo of arctic snow. Atmos. Chem. Phys. 2008; 8: 6551–6563.

Niittymäki H, Hakanen A, Rautio S, Järvinen H. Portable TL dosemeter – ESD phantom combination for chest and lumbar spine radiography. Radiation Protection Dosimetry 2008; 130: 224–227; doi:10.1093/rpd/ncm492.

Pöllänen R, Siiskonen T. Direct high-resolution alpha spectrometry from nuclear fuel particles in an outdoor air sample. Radiation Protection Dosimetry 2008; 124: 454–463.

Siiskonen T, Pöllänen R, Karhunen T. A versatile simulation code for alpha spectrometry: developmet of the graphical user interface and applications. Esarda Bulletin 2008; 40: 26–30.

Siiskonen T, Tapiovaara M, Kosunen A, Lehtinen M, Vartiainen E. Occupational radiation doses in interventional radiology: simulations. Radiation Protection Dosimetry 2008; 129: 36–38.

Smans K, Tapiovaara M, Cannie M, Struelens L, Vanhavere F, Smet M, Bosmans H. Calculation of organ doses in x-ray examinations of premature babies. Med. Phys. 2008; 35 (2): 556–568.

Smans K, Vaño E, Sanchez R, Schultz FW, Zoetelief J, Kiljunen T, Maccia C, Järvinen H, Bly R, Kosunen A, Faulkner K, Bosmans H. Results of a european survey on patient doses in paediatric radiology. Radiation Protection Dosimetry 2008; doi:10.1093/rpd/ncn031.

Tapiovaara MJ. Review of relationships between physical measurements and user evaluation of image quality. Radiation Protection Dosimetry 2008; 129 (1-3): 244–248; doi:10.1093/rpd/ncn009.

Toivonen T, Toivo T. Pitkäaho R. Puranen L, Silfverhuth M, Mennander A, Hannula M, Hyttinen J, Jokela K. Setup and dosimetry for exposing anaesthetised pigs *in vivo* to 900 MHz GSM mobile phone fields. Biolectromagnetics 2008; 29: 363–370.

Toivonen T, Toivo T, Puranen L, Jokela K. Setup and dosimetry for exposure of human skin invivo to RF-EMF at 900 MHz. Bioelectromagnetics 2008; 29: 207–212.

Toroi P, Komppa T, Kosunen A. A tandem calibration method for kerma-area product meters. Phys. Med. Biol. 2008; 53: 4941–4958.

Toroi P, Komppa T, Kosunen A, Tapiovaara M. Effects of radiation quality on the calibration of kerma-area product meters in x-ray beams. Phys. Med. Biol. 2008; 53: 5207–5221.

Vähävihu K, Ylianttila L, Salmelin R, Lamberg-Allardt C, Viljakainen H, Tuohimaa P, Reunala T, Snellman E. Heliotherapy improves vitamin D balance and atopic dermatitis. British Journal of Dermatology 2008; 158: 1323–1328.

Proceedings publications

Bly R, Järvinen H, Almen A, Einarsson G, Friberg EG, Leitz W, Olerud H, Waltenburg H, Widmark A. Current activities of the Nordic Working Group on X-ray diagnostics [abstract]. In: Nordic Society for Radiation Protection – NSFS. Proceedings of the NSFS XV conference in Ålesund Norway, 26–30 of May 2008. Strålevern Rapport 2008: 13. Østerås: Norwegian Radiation Protection Authority; 2008. p. 29–30.

Godske Friberg E, Almen A, Einarsson G, Järvinen H, Leitz W, Waltenburg H, Bly R. Dose from pediatric CT examinations and level of optimization of the scan protocols in the Nordic countries. In: Nordic Society for Radiation Protection – NSFS. Proceedings of the NSFS XV conference in Ålesund Norway, 26–30 of May 2008. Strålevern Rapport 2008:13. Østerås: Norwegian Radiation Protection Authority; 2008. p. 41–50.

Korpela H, Niemelä J. Survey on quality control measurements for nuclear medicine imaging equipment in Finland in 2006. In: Proceedings. IRPA 12 – Strengthening Radiation Protection Worldwide. The 12th International Congress of the International Radiation Protection Association. 2008 Oct 19–24; Buenos Aires, Argentina. Buenos Aires: Sociedad Argentina de Radioprotección; 2008. [CD-ROM, TS III.3.3: 675 (9 pp.)]

Lehtinen M, Ansaranta T, Havukainen R. Trends and dose distributions for occupational radiation exposure in Finland. In: Proceedings. IRPA 12 – Strengthening Radiation Protection Worldwide. The 12th International Congress of the International Radiation Protection Association. 2008 Oct 19–24; Buenos Aires, Argentina. Buenos Aires: Sociedad Argentina de Radioprotección; 2008. [CD-ROM, TS II.2.3: 655 (10 pp.)]

Nieminen K. Extended abstract: A practical method for determination of patient doses in computed tomography. Tenth National Conference on Biomedical Physics and Engineering 16–18 October 2008, Sofia, Bulgaria.

Pöllänen R, Siiskonen T. Direct high-resolution alpha spectrometry for identifying transuranium elements in outdoor air. In: Proceedings of the International Conference on Monitoring, Assessments and Uncertainties for Nuclear and Radiological Emergency Response. 2005 Nov 21–25, Rio de Janeiro, Brazil. [CD-ROM]

Tenkanen-Rautakoski P, Järvinen H, Bly R. Estimation of the collective effective dose to the population from medical x-ray examinations in Finland. In: Proceedings. IRPA 12 – Strengthening Radiation Protection Worldwide. The 12th International Congress of the International Radiation Protection Association. 2008 Oct 19–24; Buenos Aires, Argentina. Buenos Aires: Sociedad Argentina de Radioprotección; 2008. [CD-ROM, TS III.3.1: 690 (6 pp.)]

Research publications

Kiljunen T. Patient doses in CT, dental cone beam CT and projection radiography in Finland, with emphasis on paediatric patients. Academic dissertation. STUK-A232. Helsinki: Radiation and Nuclear Safety Authority; 2008.

Siiskonen T. Syöpäriski säteilyhaittana: riskilaskentaohjelmisto (Cancer risk as a radiation hazard: risk assessment software). STUK-TR 6. Helsinki: Radiation and Nuclear Safety Authority; 2008.

Tapiovaara M, Siiskonen T. PCXMC 2.0, User's Guide. STUK-TR 7. Helsinki: Radiation and Nuclear Safety Authority; 2008.

Tapiovaara M, Siiskonen T. PCXMC, A Monte Carlo program for calculating patient doses in medical x-ray examinations (2nd ed.). STUK-A231. Helsinki: Radiation and Nuclear Safety Authority; 2008.

Tapiovaara T, Tapiovaara M, Siiskonen T, Hakanen A. Säteilyturvakeskuksen Dosimetrialaboratorion röntgensäteilyn vakiolaatujen spektrit (Standard X-ray quality spectra of the STUK Radiation Metrology Laboratory). STUK-TR 2. Helsinki: Radiation and Nuclear Safety Authority; 2008.

Tapiovaara M, Tapiovaara T. Spektripaja (2.0) -ohjelman käyttöohje ja validointi (Operating instructions and validation for the Spektripaja (2.0) program). STUK-TR 3. Helsinki: Radiation and Nuclear Safety Authority; 2008.

Toroi P, Komppa T, Kosunen A. Annoksen ja pinta-alan tulon mittaaminen (Measuring dose-area product). STUK-TR 4. Helsinki: Radiation and Nuclear Safety Authority; 2008.

Regulatory reports

Rantanen E (toim.). Säteilyn käyttö ja muu säteilylle altistava toiminta (Use of radiation and other activities involving exposure to radiation). Vuosiraportti 2007 (Annual report 2007). STUK-B 90. Helsinki: Radiation and Nuclear Safety Authority; 2008.

Korpela H. Radioaktiivisten lääkevalmisteiden käyttö Suomessa vuonna 2006 (Use of radiopharmaceuticals in Finland in 2006). STUK-B 93. Helsinki: Radiation and Nuclear Safety Authority; 2008.

Rantanen E (ed.). Radiation Practices. Annual Report 2007. STUK-B 95. Helsinki: Radiation and Nuclear Safety Authority; 2008.

Regulatory guides

Finnish language

Säteilytoiminta ja säteilymittaukset (Radiation practices and radiation measurements). Ohje ST 1.9 (Guide ST 1.9). Radiation and Nuclear Safety Authority (17 March 2008).

Tarkastus- ja analyysiröntgenlaitteiden käyttö (The use of control and analytical X-ray apparatus). Ohje ST 5.2 (Guide ST 5.2). Radiation and Nuclear Safety Authority (26 Sep 2008).

Säteilylähteiden kauppa (Trade in radiation sources). Ohje ST 5.4 (Guide ST 5.4). Radiation and Nuclear Safety Authority (19 Dec 2008).

Säteilyturvallisuus avolähteiden käytössä (Radiation safety when using unsealed sources). Ohje ST 6.1 (Guide ST 6.1). Radiation and Nuclear Safety Authority (17 March 2008).

Annosrekisteri ja tietojen ilmoittaminen (Dose register and reporting of data). Ohje ST 7.4 (Guide ST 7.4). Radiation and Nuclear Safety Authority (9 Sep 2008).

Swedish language

Strålningsverksamhet och strålningsmätningar (Radiation practices and radiation measurements). Direktiv ST 1.9 (Guide St 1.9). Radiation and Nuclear Safety Authority (17 March 2008).

Strålsäkerheten hos apparater med slutna källor (Radiation safety of sealed sources and devices containing them). Direktiv ST 5.1 (Guide ST 5.1). Radiation and Nuclear Safety Authority (7 Nov 2007).

Användning av kontroll- och analysröntgenapparater (The use of control and analytical X-ray apparatus). Direktiv ST 5.2 (Guide ST 5.2). Radiation and Nuclear Safety Authority (26 Sep 2008).

Strålsäkerhet vid användning av öppna källor (Radiation safety when using unsealed sources). Direktiv ST 6.1 (Guide ST 6.1). Radiation and Nuclear Safety Authority (17 March 2008).

Dosregister och anmälan av uppgifter (Dose register and reporting of data). Direktiv ST 7.4 (Guide ST 7.4). Radiation and Nuclear Safety Authority (9 Sep 2008).

Strålsäkerheten vid storeffektlasrar som används i underhållning (Radiation safety of high-power display lasers). Direktiv ST 9.4 (Guide ST 9.4). Radiation and Nuclear Safety Authority (28 Feb 2007).

English language (translations)

Radiation Practices and Radiation Measurements. Guide ST 1.9. Radiation and Nuclear Safety Authority (17 March 2008).

X-ray Examinations in Health Care. Guide ST 3.3. Radiation and Nuclear Safety Authority (20 March 2006).

The Use of Control and Analytical X-ray Apparatus. Guide ST 5.2. Radiation and Nuclear Safety Authority (26 Sep 2008).

Radiation Safety when Using Unsealed Sources. Guide ST 6.1. Radiation and Nuclear Safety Authority (17 March 2008).

Dose Register and Reporting of Data. Guide ST 7.4. Radiation and Nuclear Safety Authority (9 Sep 2008).

Other publications

Bly R. Säteilysuojelun perussuositukset 2007 (Basic radiation protection recommendations 2007). In the book: Luennot. XXXII Sädeturvapäivät Tampere-talossa. Tampere 23.–24.10.2008 (Lectures XXXII Radiation Safety Conference at Tampere Hall, Tampere 25–26 October 2008). Tampere: Lege Artis Oy; 2008. s. 72–76.

Nieminen K. Uutta STUK:n ohjeista, päätöksistä ja oppaista 2008 (What´s new in STUK instructions, decisions and guides, 2008). In the book: Luennot. XXXII Sädeturvapäivät Tampere-talossa. Tampere 23.–24.10.2008 (Lectures XXXII Radiation Safety Conference at Tampere Hall, Tampere 25–26 October 2008). Tampere: Lege Artis Oy; 2008. s. 77–82.

Parviainen T. Henkilökunnan annokset (Staff doses). In the book: Luennot. XXXII Sädeturvapäivät Tampere-talossa. Tampere 23.–24.10.2008 (Lectures XXXII Radiation Safety Conference at Tampere Hall, Tampere 25–26 October 2008). Tampere: Lege Artis Oy; 2008. s. 37–41.

Pirinen M. Säteilysuojelun perusasiat: oikeutus, optimointi, vastuut, pätevyydet ja täydennyskoulutus (Fundamentals of radiation protection: justification, optimization, responsibilities, qualifications and supplementary training). In the book: Luennot. XXXII Sädeturvapäivät Tampere-talossa. Tampere 23.–24.10.2008 (Lectures XXXII Radiation Safety Conference at Tampere Hall, Tampere 25–26 October 2008). Tampere: Lege Artis Oy; 2008. s. 93–95.

Toroi P. Suodatuksen vaikutus röntgentutkimuksissa (Effect of filtrarion in X-ray examinations). In the book: Luennot. XXXII Sädeturvapäivät Tampere-talossa. Tampere 23.–24.10.2008 (Lectures XXXII Radiation Safety Conference at Tampere Hall,

Tampere 25–26 October 2008). Tampere: Lege Artis Oy; 2008. s. 83–86.

Alara magazine

Järvinen H. Kliinisellä auditoinnilla parempiin tutkimus- ja hoitokäytäntöihin (Clinical auditing: Better examination and therapy practices). Alara 2008; 3: 8.

Venelampi E. Radioaktiivisella merkkiaineella parannetaan teollisuusprosessia (Improving industrial processes with radioactive tracers). Alara 2008; 1: 21.

Academic thesis work

See Research publications: Kiljunen T.

Bulletins and prochures

Lasten röntgentutkimuskriteerit (Criteria for paediatric X-ray examinations). STUK tiedottaa 1/2008 (STUK bulletin 1/2008). Helsinki; Radiation and Nuclear Safety Authority: 2008.

Terveydenhuollon röntgenlaitteiden laadun-valvontaopas (Quality control guide for health service X-ray appliances). STUK tiedottaa 2/2008 (STUK bulletin 2/2008). Helsinki; Radiation and Nuclear Safety Authority: 2008.

APPENDIX 3

ST GUIDES PUBLISHED BY STUK. SITUATION AS OF 31 DECEMBER 2008.

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
ST 1.9 Radiation Practices and Radiation Measurements, 17 March 2008

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 Devices Containing Them, 7 November 2007
ST 5.2 The Use of Control and Analytical X-ray apparatus, 26 September 2008
ST 5.3 Use of Ionising Radiation in the Teaching of Physics and Chemistry, 4 May 2007
ST 5.4 Trade in Radiation Sources, 19 December 2008
ST 5.6 Radiation Safety in Industrial Radiography, 17 February 1999
ST 5.8 Installation, Repair and Servicing of Radiation Appliances, 4 October 2007

Unsealed Sources and Radioactive Wastes

ST 6.1 Radiation safety when using unsealed sources, 17 March 2008
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, 2 August 2007
ST 7.2 Application of Maximum Values for Radiation Exposure and Principles for the Calculation of Radiation Dose, 9 August 2007
ST 7.3 Calculation of the Dose Caused by Internal Radiation, 23 September 2007
ST 7.4 The Dose Register and Data Reporting, 9 September 2008.
ST 7.5 Medical Surveillance of Occupationally Exposed Workers, 4 May 2007

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, 28 February 2007 (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