STUK-B 122 / AUGUST 2010

B

Radiation practices

Annual report 2009

Erkki Rantanen (ed.)

Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority
STUK

STUK-B 122 / AUGUST 2010

Radiation practices

Annual report 2009

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:
Riina Alén
Ritva Bly
Ritva Havukainen
Santtu Hellstén
Kari Jokela
Hannu Järvinen
Markus Kangasniemi
Eero Kettunen
Jarno Koikkalainen
Helinä Korpela
Markku Koskelainen
Antti Kosunen
Maaret Lehtinen
Mika Markkanen
Eero Oksanen
Markku Pirinen
Jaakko Tikkinen
Eija Venelampi
Reijo Visuri

ISBN 978-952-478-558-7 (print) Edita Prima Oy, Helsinki/Finland 2010
ISBN 978-952-478-559-4 (pdf)
ISSN 0781-1713

RANTANEN Erkki (ed.). Radiation practices. Annual report 2009. STUK-B 122. Helsinki 2009. 35 pp. + apps. 12 pp.

Key words: use of radiation, radiation practices, safety licence, licence-exempt practices, inspections of the use of radiation, radiation sources, radioactive materials, 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

1 742 safety licences for the use of radiation were current at the end of 2009. 1 820 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.

The Radiation and Nuclear Safety Authority (STUK) conducted 414 inspections of licensed practices in 2009. 392 repair orders and recommendations were issued.

A total of nearly 11 600 workers were subject to individual monitoring in 2009. Just under 160 000 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. 108 workplaces including a total of 219 work areas were subject to radon monitoring during 2009. 3655 cockpit and cabin crew members were monitored for exposure to cosmic radiation.

STUK took part in three major ionizing radiation research projects. An IAEA research project tested IAEA/WHO diagnostic dosimetry guidelines. The accuracy and reliability of internal and external radiotherapy dosimetric methods in modern radiotherapy technology was studied as part of a European metrology research programme.

In metrological activities the calibration procedure for radiotherapy accelerator electron beam dosemeters was modified by changing from meter calibration in hospitals to laboratory calibration. Some irradiation appliances were also replaced. Calibration services continued as in previous years.

Regulatory control of the use of non-ionizing radiation in 2009 focused particularly on mobile phones, sunbeds and lasers. Fifteen mobile phone types were tested in market surveillance of wireless communication devices. 19 sunbed facilities were inspected and ten laser display inspections were performed.

There were 30 abnormal incidents involving the use of radiation in 2009. 22 of these incidents concerned the use of radiation in industry, research and education, seven involved medical uses of radiation 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
Non-ionizing Radiation Surveillance Unit (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.

The personal doses of all workers engaged in radiation work remained within the prescribed limits during the year under review. There was practically no exposure to man-made radiation outside of places where radiation is used.

The total radiation dose sustained by workers from the use of radiation and nuclear energy was smaller than in many earlier years. A particularly favourable, clear fall occurred in the total radiation dose sustained in the use of radiation in all operating sectors from a level that had previously remained fairly constant. There is no evident individual reason for this fall, and STUK will continue to monitor progress and the permanence of this change.

There was slightly more exposure to natural radiation at work than in previous years, and this increase particularly affected flight crews, who are the occupational group suffering the greatest exposure. The total number of workers belonging to flight crews was slightly smaller than in the preceding year and the number of hours spent in flight also fell. On the other hand, there was some increase in the total dose. One possible reason for this may be that airlines were flying at higher altitudes than in previous years in order to reduce fuel costs. The aggregate radiation dose of flight crew members was about twice that of persons engaged in radiation work proper.

The largest source of exposure to man-made radiation is the use of radiation in health services. The growing use of CT scanning using X-radiation for diagnostics involves a risk of increased patient doses. Statistics on the number of examinations in 2008 indicate a 23% increase in the number of CT scans since 2005. To ensure that the total increase in such exposure is kept firmly under control, STUK has consistently stressed the skills and supplementary training of health care staff in examinations causing major radiation exposure. The average radiation dose sustained by members of the public from X-ray examinations has risen in certain major industrialized countries by many times the corresponding figure for Finland in recent years.

STUK has been actively involved in international research work supporting regulatory control of the use of radiation. Some joint research projects have been pursued with fellow regulatory authorities in the Nordic countries and with partners in EU-funded initiatives. Other partners included international specialist institutes and their experts in IAEA projects. Thanks to research work done over the years, 698 copies of the PCXMC computer program designed at STUK for calculating patient doses in X-ray diagnostics have been supplied to partners in various countries.

In contrast to previous years, there was no increase in the use of ionizing radiation. During the operating year STUK endeavoured to make up a backlog of periodic inspections that had arisen due to a mismatch between inspection resources and increased work volumes. All of the planned inspections could not be performed when priority had to be given to commissioning a new comprehensive radiation supervision data system. Although all of the data registers on use of radiation had not yet been linked to the new data system during the year under review, a follow-up project is now transferring all of the required data into a single consistent system. To improve the effectiveness of inspections of radiation practices, a transition to risk-based regulatory control was prepared for implementation in 2010. This will prioritize the use of inspection resources to focus on the most risk-prone sites.

As part of a study of transportation of radioactive materials, STUK investigated the operations of transport businesses in Finland. Information gathered from the carriers studied, indicates that a large proportion of them carry excepted packages that have been discharged from special requirements governing the carriage of radioactive materials. The number of businesses carrying other kinds of package was smaller than expected. The study led to a decision on further measures concerning co-operation with other safety authorities, a revision of STUK guidelines, and more effective focusing of regulatory control on matters of goods transport.

As in previous years, major reorganizations have continued in the operations of responsible radiation practitioners. The regulatory control work of STUK has continued to pay particular attention to the effectiveness of the user´s organizations and to issues of responsibility and quality management in these cases. A case concerning came to light in early 2009 in which no safety licences had been arranged for new equipment commissioned during a reorganization of health services. STUK ordered the responsible party to rectify the matter immediately and provide a detailed account of the remedial measures that had been taken and of how any recurrence of the incident could be prevented.

STUK continued and expanded its work with stakeholders involved in the use of radiation by jointly developing guidelines and training to improve the quality of practices, and by arranging several very well-attended consulting and training events for various interest groups. One new initiative was the establishment of communication channels with the faculties of dental science that train students in using dental X-ray appliances and in attending to the condition of such equipment.

The DOS Laboratory of STUK acquired some new radiation sources for the purpose of maintaining the accuracy and reliability of radiation measurements. These small sources acquired from Russia via the debt conversion programme were installed in calibration instruments and taken into use. Competitive tendering was launched for acquisition of a large ^{60}Co source with a view to completing the purchase in the first half of 2010. The new apparatus will ensure the capacity of STUK to verify the accuracy of radiotherapy appliances and radiation dosemeters.

Substantial progress was made during the year under review in regulatory control of physical security arrangements. These arrangements seek to prevent unlawful acts and terrorism targeting nuclear facilities and radiation sources. This affects the work of all STUK departments in various ways. In June the Ministry of Employment and the Economy invited the IAEA to appoint a team of eight external experts to assess the effectiveness of physical security arrangements in Finland (IPPAS assessment). The two-week assignment of this team resulted in some good recommendations that led to a plan of action for improving physical protection. In line with this plan, STUK is preparing a Radiation Safety Guide on physical protection and is also focusing its own regulatory control work more effectively on this subject.

29 abnormal incidents in the use of ionizing radiation were reported during the year under review. STUK has encouraged practitioners to notify all important incidents and make the necessary adjustments to their work with a view to avoiding any further abnormal incidents. These incidents have been discussed with experts from responsible parties at the annual consulting and training events.

The Non-ionizing Radiation Surveillance Unit (the NIR Unit) serves as a regulatory authority for non-ionizing radiation and provides specialist assistance to the National Supervisory Authority for Welfare and Health (Valvira) 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 providing public information on the safety of electromagnetic fields and optical radiation.

The NIR Unit inspected 19 sunbed establishments. Some of these inspections were performed as part of a PROSAFE project to improve and harmonize regulatory control of sunbeds within the European Union. Although the shortcomings found were relatively minor, only four establishments passed the inspection on all counts. Particular attention was paid for the first time to the use of sunbeds by minors. One disturbing observation was that more girls under 18 years of age have begun visiting sunbed establishments. A decision was taken in negotiations with the Ministry of Social Affairs and Health that STUK would prepare a memorandum for the ministry by no later than 30 April 2010 recommending a ban on sunbed use by persons aged under 18 years.

STUK participated in work with optical radiation specialists from Sweden, Norway and Iceland to formulate a new position paper on sunbed use. This position paper, which was completed during the year under review, is strongly in favour of banning sunbed use by persons under 18 years of age.

The NIR Unit launched regulatory control of laser pointers and lasers for cosmetic use in association with the Finnish Customs and the Consumer Agency. An agreement had been concluded with the Customs in the previous year that battery-operated lasers for consumer use would be detained at the Customs if they exceeded a radiation limit of 1 mW and had not been appropriately inspected. The Customs requested an opinion on importation from STUK in 46 cases. Nearly all of the laser appliances intended for importing were detained at the Customs. The highest laser power was as much as 200 mW, i.e. forty times the 5 mW lower limiting power of a class 3B laser device that is hazardous to the eyes. Four complaints were made to the police concerning laser harassment. A significant policy measure was introduced for cosmetic lasers forbidding the use of class 4 lasers (minimum power 500 mW) without medical supervision.

STUK published a book on UV and laser radiation. This book is the last in a seven-volume STUK series on radiation and nuclear safety.

The emphasis in regulatory control of electromagnetic fields was on market control of mobile phones. Radiation tests were conducted on 15 types of GSM and UMTS phone. The largest SAR value measured was 0.823 W/kg, which did not exceed the maximum value prescribed in the Decree (294/2002) of the Ministry of Social Affairs and Health.

The work of the NIR Unit concerning electromagnetic fields focused on research and public information. A calibrator for calibrating body current meters operating at 10–50 MHz was completed as part of the EURAMET EMRP project. The WIRECOM project on mobile phone radiation developed functional apparatus for exposing test subjects and specified the SAR value for radiation absorbed by the test subjects. The Unit assisted in drafting a recommendation for the directors of the Nordic radiation safety authorities concerning fixed radio transmitters. This recommendation was completed during the year under review.

The standing orders and organization of the NIR Unit were reformed during the operating year, with the radio laboratory becoming an independent operating unit managed by a supervisor. It is worthwhile occasionally conducting a critical review of established ways of working in times of change.

1 General

The expression *use of radiation* refers to the use and manufacture of, and trade in radiation equipment and radioactive materials, 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 Non-ionizing Radiation Surveillance Unit (the NIR Unit) 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.

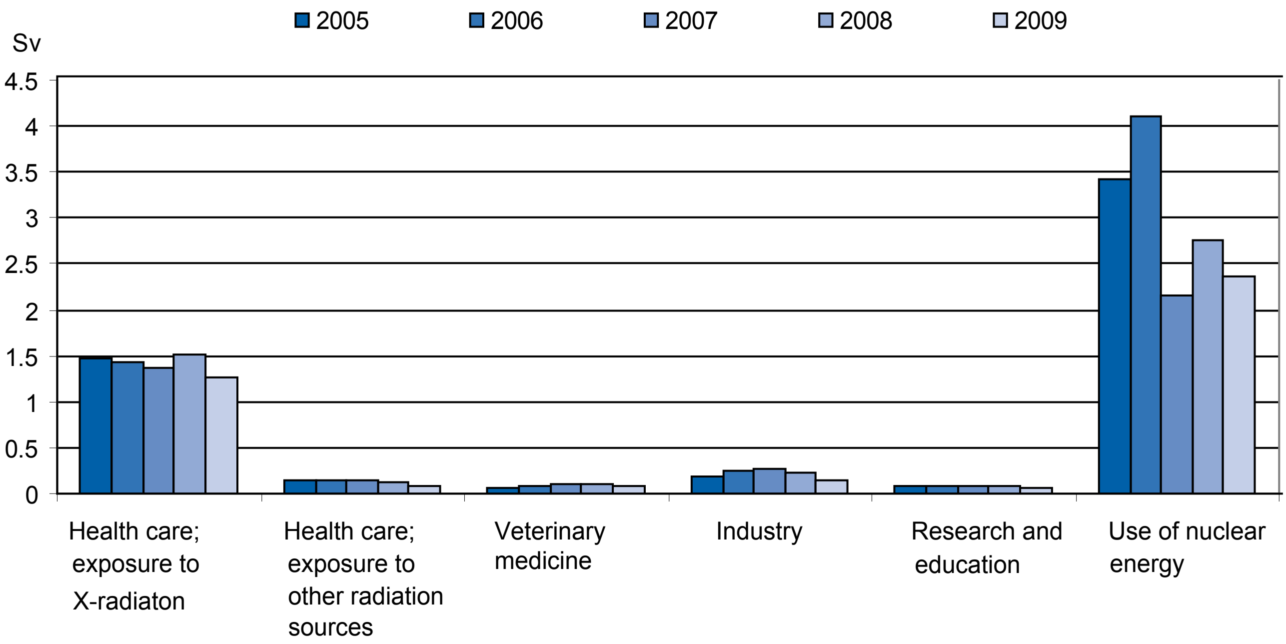

Figure 1. Combined doses ($H_p(10)$) of workers subject to individual monitoring by occupational category, 2005–2009. $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the use of X-rays in health care and veterinary practices, in which 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. Besides the workers specified in the graph, a small number of people subject to individual monitoring also work in the following sectors: manufacturing, installation/servicing/technical test operation, trade/import/export and services pertaining to radioactive materials (see Tables 11 and 12).

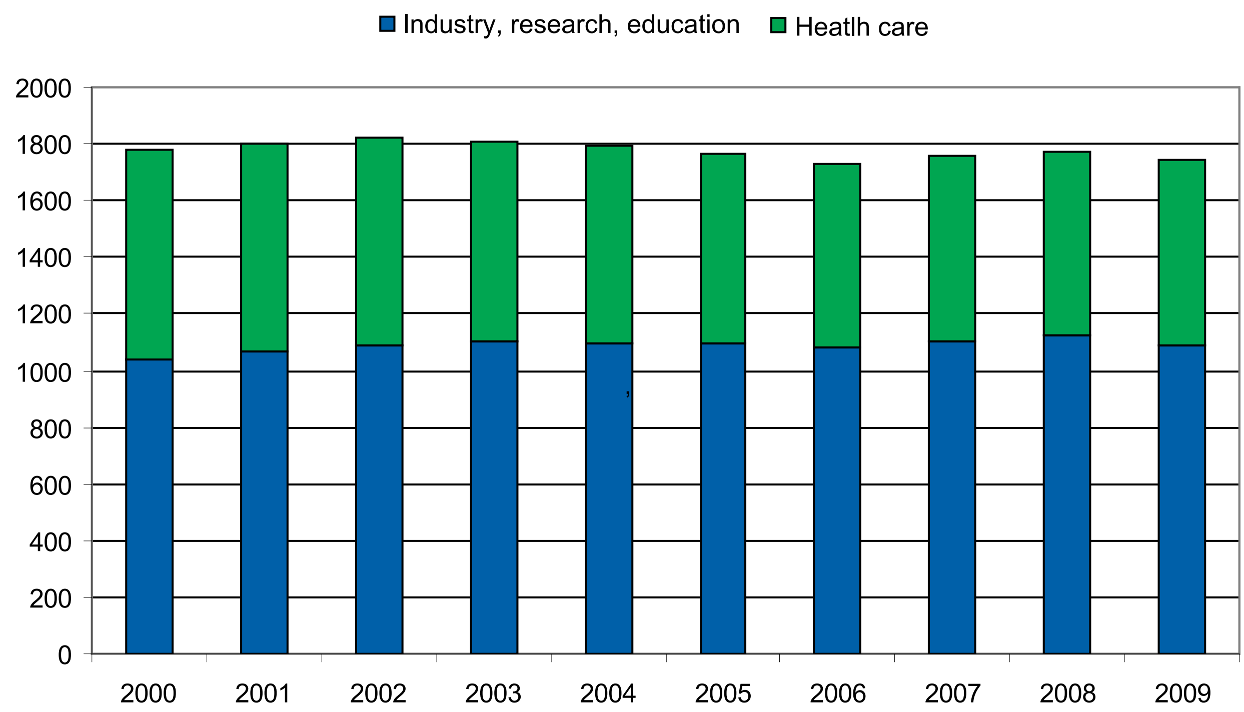

Figure 2. Current safety licences, 2000–2009.

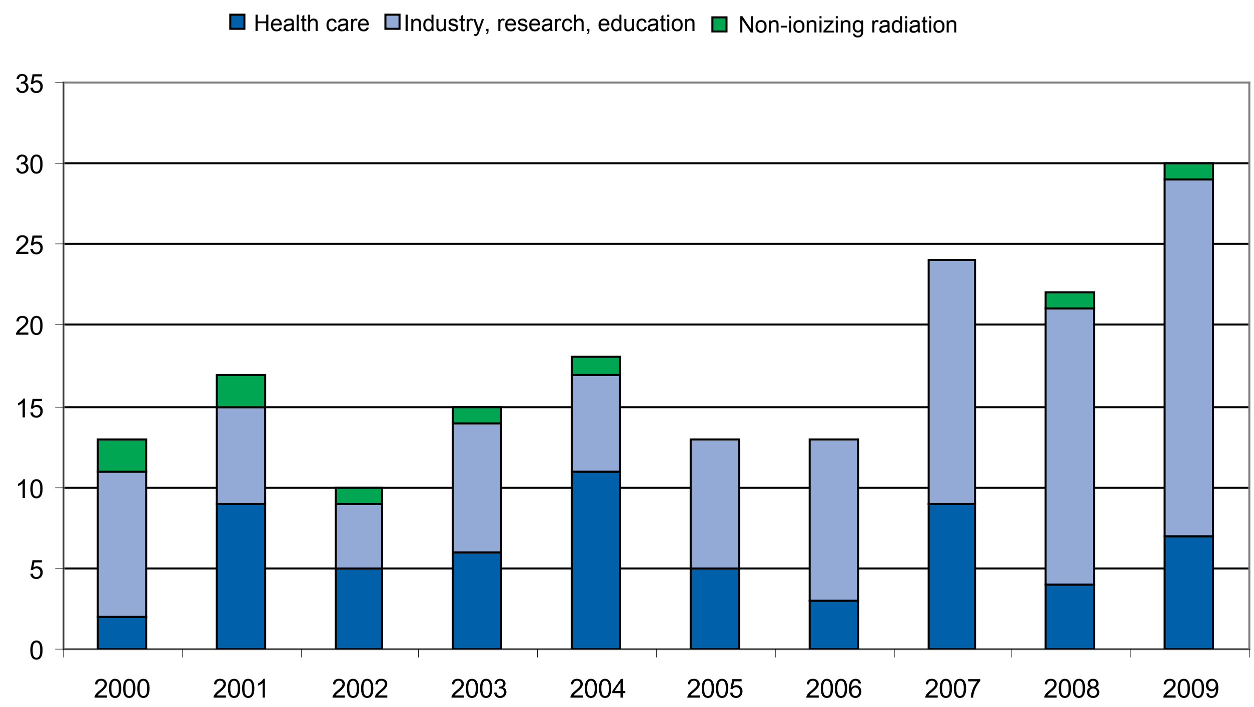

Figure 3. Abnormal incidents, 2000–2009.

2 Regulatory control of the use of ionizing radiation

New registration practices for safety licences, radiation appliances and sources, and inspections were introduced at STO in 2009. The details and classifications set out in this report may therefore differ slightly from corresponding tables in reports for earlier years.

2.1 Use of radiation in health care

Safety licences

At the end of 2009 there were 651 current safety licences for the use of radiation in health care (see also Figure 2), of which 219 concerned veterinary practices. 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 details of radiation appliances and sources, and of radionuclide laboratories used in health care and veterinary practices at the end of 2009.

Nuclear medicine

STUK conducted an inspection of the first nuclear medicine unit to be opened in a private hospital in Finland. The operations of the unit involve the use of sealed and unsealed sources and X-ray appliances. Imaging is performed using both SPET (single photon emission) and PET (positron emission) type CT scanners. Before this, a new nuclear medicine unit, the Turku PET centre, began operating in 1999. There were 16 SPET and five PET CT scanners operating in Finland at the end of 2009. One of the PET CT scanners has been installed in a lorry that tours various hospitals.

STUK has stipulated reference levels for patient radiation exposure from conventional X-ray examinations of adults, CT scans, paediatric X-ray examinations and cardiac radiology, and for the activities of radiopharmaceutical products administered to patients in the most common isotope examinations. In 2009 STUK updated the reference levels for isotope examinations based on patient research data from 2006 (decision no. 16/3020/2009 issued on 10 December 2009). Ten examination reference levels were modified, twelve were abolished, three remained unchanged and three new examination reference levels were issued. These changes were mainly due to modifications in examination methodology and the introduction of new radiopharmaceutical products.

Radiotherapy

STUK conducted an inspection of Finland's first private radiotherapy centre. The new centre has two multi-energy linacs, afterloading equipment and a CT simulator. There were 14 radiotherapy centres in Finland at the end of 2009, one of them specializing in boron neutron capture therapy (BNCT). A total of 40 linacs were used for radiotherapy at the end of 2009. The corresponding figure was 25 linacs in 1999, and the number of these appliances has been growing steadily since this time. There is also a tendency to replace single-energy accelerators with multi-energy versions, which increases the need for hospital quality control and regulatory control, as well.

2.2 Use of radiation in industry, research and education

The use of radiation in industry, research and education also includes its use in services, installation and maintenance work and the sale and manufacture of radioactive materials.

Safety licences

There were 1 091 current safety licences for the use of radiation in industry, research and education at the end of 2009 (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

Table 4 in Appendix 1 shows details of radiation appliances and sources, and of radionuclide laboratories operating in industry, research and education at the end of 2009.

Table 5 in Appendix 1 shows details of radionuclides used in sealed sources.

2.3 Inspections of licensed radiation practices

250 inspections were made of the use of radiation in health care and veterinary practices. These inspections resulted in 98 repair orders or recommendations issued to the responsible parties.

164 inspections were made of the use of radiation in industry, research and education. These inspections resulted in 294 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 itemized by type of practice.

2.4 Inspections of notifiable dental X-ray practices

1820 responsible parties were engaged in dental X-ray practices. Patient radiation exposure due to dental X-ray imaging was measured in 953 appliances. The average dose was 1.7 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 8 imaging appliances.

34 inspections of notifiable dental X-ray practices were made. Repairs were ordered in 18 inspections and recommended in 8 inspections.

2.5 Import, manufacture and export of radioactive materials

Details of radionuclides imported to, manufactured in and exported from Finland in 2009 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 materials imported and exported by responsible parties within the European Union for their own use. The statistics also exclude radioactive materials supplied to other countries via Finland.

Table 8 of Appendix 1 excludes smoke detectors and fire alarm system ion detectors containing americium (^{241}Am). 203 428 devices of this kind were imported with a combined activity of about 6.8 GBq. 5601 smoke detectors with a combined activity of 0.2 GBq were exported from Finland.

2.6 Radiation doses of workers

Individual Monitoring

A total of nearly 11 600 workers engaged in radiation work were subject to individual monitoring in 2009. Including doses falling below the registration threshold, about 160 000 dose records were entered in the Dose Register maintained by STUK (this figure also includes the dose records of workers exposed to natural radiation, see chapter 3).

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

The total dose recorded was 1.7 Sv in the use of radiation and 2.4 Sv in the use of nuclear energy. The total recorded dose in the use of both radiation and nuclear energy was about 14 % lower than in the preceding year. Total doses in the use of nuclear energy vary considerably each year depending on the duration of annual nuclear power plant servicing and the duties performed in servicing work at these facilities. There is no evident individual reason for the changes that occurred in the use of radiation, and so STUK must continue to monitor progress and the permanence of this change.

The largest $H_p(10)$ in health services was 26 mSv recorded in the case of an interventional radiologist. This corresponds to an effective dose of 0.4–2.6 mSv. The largest $H_p(10)$ in veterinary practice was 12 mSv recorded in the case of a veterinarian performing X-ray examinations. This corresponds to an effective dose of 0.2–1.2 mSv. The largest effective dose in industry was 9 mSv sustained by a person engaged in materials testing, while the largest effective dose in research was 8 mSv sustained by a person using several radiation sources of various kinds.

The largest dose to the fingers was 340 mSv, recorded in the case of a laboratory assistant working in health services.

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 2009 of persons sustaining high levels of exposure or of numerically large worker groups. The measurement results (Hp(10) values) shown in the figures and tables are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the use of X-radiation in health care and veterinary 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 (Hp(10) value) by a factor between 10 and 60.

Change in the coding conventions of the Dose Register

At the beginning of 2009, the Dose Register adopted a new coding convention for operating sectors, job titles and radiation sources. The new coding convention was formulated in association with users of radiation in health services and industry, and persons responsible for radiation protection in nuclear power plants.

STUK has maintained the Dose Register for workers engaged in radiation work since 1963, recording the radiation doses of workers due to uses of radiation and natural radiation (cosmic radiation in aviation work and radon in workplaces). The Dose Register was converted to an electronic format in 1977. The exposure conditions and functions of a worker are recorded using a code signifying the operating sector, the radiation sources used, and the characteristic duties. The coding convention is useful for comparing doses sustained in various practices, user groups and duties.

Regulatory control of dosimetric services

One dosimetry service was inspected during 2009, resulting in one repair order and one repair recommendation.

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. Approval for arranging radiation safety officer interviews and training was granted to three training organizations in 2009. A total of 25 such approval decisions were current at the end of 2009. 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. There were 305 STUK-accredited responsible medical practitioners in Finland at the end of 2009, of whom 22 were accredited during 2009.

2.8 Radioactive waste

214 waste packages had been transported to the national storage facility for low-level radioactive waste maintained by STUK by the end of 2009. 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. Table 15 of Appendix 1 shows the activities or masses of the waste that was surrendered to STUK in 2009.

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 29 cases in 2009 in which abnormal incidents or situations occurred or were suspected in the use of ionizing radiation, of which 22 concerned the use of radiation in industry, research and education and 7 involved medical uses of radiation (see also item 4.4 for abnormal incidents in the use of non-ionizing radiation). Figure 3 (in item 1.1) shows abnormal incident numbers between 2000 and 2009.

The case histories set out below specify the abnormal incidents in the use of ionizing radiation that occurred in 2009 and the reasons for them, together with the measures taken on account of each incident.

Incident 1

Some gaseous ^{18}F escaped into the working areas and corridor of a laboratory during transportation from an accelerator to the laboratory for the purpose of synthesis. There were four workers in the laboratory at the time. Although the release of radioactive material into a ventilation duct was detected by a continuous discharge monitor, some of the ^{18}F is assumed to have entered the duct together with helium gas used for transportation. As the discharge nevertheless seemed larger than normal, two workers measured themselves using the laboratory's own whole body counting instrument and detected a degree of ^{18}F contamination. The work had begun at 09.50 and an order to discontinue was issued at 10.05 when the contamination was detected. The workers exchanged their contaminated clothing for disposable overalls and whole body counting was performed on all of the workers. The door leading from the corridor to the laboratory was closed to isolate the contamination, and an access prohibited sign was placed on the door. The radiation safety officer contacted STUK and was instructed to submit the personal dosemeters immediately for analysis.

The results of whole body counting suggested that none of the exposed workers sustained a dose from internal radiation exceeding 10 µSv. The $H_p(10)$ of three workers did not exceed the registration threshold (0.1 mSv) for the individual monitoring period in question, while one worker sustained a dose of 0.2 mSv, meaning that none of the workers sustained a significant dose either from external radiation.

A full review of the incident was arranged for all workers engaged in the same duties. The probable cause of the incident was considered to be an incomplete seal in the apparatus used for transporting the ^{18}F. The open door between the corridor and laboratory facilities facilitated dispersion of the contamination into these areas. Special attention will be paid to these matters in future. The laboratory has also acquired more contamination meters and the workers have been advised to use them when working, so that any contamination is detected immediately.

Incident 2

Some course work in a laboratory involved preparing ^{11}C acetate from gaseous $^{11}CO_2$ created in the laboratory accelerator. A fixed dose rate meter in the laboratory sounded an alarm when the $^{11}CO_2$ gas was moved into its reaction vessel using carrier gas. There were two supervisors and three students in the laboratory at the time. Everyone immediately vacated the laboratory apart from the responsible supervisor, who remained momentarily to shut off the valves of the synthesizer and close the doors of the synthesizer cabinet. The cause of the incident was inadequate carrier gas pressure, enabling some $^{11}CO_2$ gas to flow towards the gas cylinder and escape from the cylinder connections on heating and expanding. A check valve was installed in the carrier gas line following the incident. Everyone in the laboratory had a personal electronic dosemeter. The dosemeter of the person who remained longest in the laboratory displayed a reading of 0.8 mSv, and other dosemeters displayed a reading of zero. Whole body counting was performed on everyone in the laboratory. Only the responsible supervisor had sustained a minimal intake (2.5 kBq) of ^{11}C. The resulting internal dose is negligible.

Incident 3

A worker used a different radioactive isotope than intended (^{32}P instead of ^{33}P) in a laboratory indicator test, and suspected a higher than normal radiation dose. The skin dose caused by the work was estimated at 4.5 µSv, which does not differ from the dose normally caused by an indicator test.

Incident 4
A malfunction occurred in the control system of a vehicle scanner. The operator screen incorrectly retained indications of active irradiation, even though the operating power had been disconnected at the main switch and at the emergency stop button. The apparatus functioned normally again after reinstalling the operating software.

Incident 5
One person remained inside a lorry during the scanning period due to human error in operating a vehicle scanner. The incident was discovered on examining the scanned image. The radiation dose sustained by the person concerned was assessed as minimal. The responsible party reported the incident to STUK, and the operating instructions for scanning were improved. Following the incident the radiation safety officer stressed the importance of attentiveness and supervision to staff.

Incident 6
A person aboard a freight train was exposed to radiation when the train carriages were scanned. A technical fault was found between the systems operating the movement of the train and the scanning process. The dose sustained by the exposed individual was estimated at a few microsieverts. Besides technical repairs, the operating guidelines were also clarified.

Incident 7
An outsider crossed the radiation beam during industrial radiography. The distance between the person and the radiation source at the time of exposure was about 4 metres and there was a steel tank in the intervening space. The person was exposed to radiation from an ^{192}Ir source of 1110 GBq for a few seconds as a result of the incident. The radiation dose caused by the incident was estimated to be smaller than 10 µSv. Following the incident, the importance of isolating and controlling access to the imaging area was stressed to the radiography team and other persons working in the area.

Incident 8
Three people working in maintenance duties on a power plant coal conveyor were briefly exposed to radiation when passing through the radiation beam of an appliance containing a radiation source (^{137}Cs, 110 MBq) that monitors blockages on the conveyor. The shutter of the appliance had not been appropriately closed for the duration of maintenance work. Owing to snowy and windy conditions, the workers also failed to see the sign stipulating the need to shut off the radiation source. The dose sustained by the persons exposed was estimated at 1–2 µSv.

Following the incident another radiation source warning sign was added in a more prominent place. A refresher course in the safe use of radiation sources was also arranged for power plant staff.

Incident 9
A worker in a pulp mill sustained a radiation dose of about 30 µSv during repair work. A pulp conveyor belt had broken and the worker accordingly went to dig out the pulp that had accumulated on the conveyor belt. However, the worker failed to shut off the pulp volume meter and its radiation source before beginning the work. The signs warning of a radiation source and the need to shut it off were buried under the extra volume of pulp. The work was discontinued after 12 minutes when somebody noticed that the radiation source shutter was open.

Corrective measures included improving the structure of obstacles barring access to the source and adding radiation hazard warning signs in a higher position so that they would not be obscured by pulp in the event of malfunctions. STUK also instructed the responsible party to arrange adequate guidelines for maintenance work and to ensure that the radiation source is shut off using a radiation meter if necessary.

Incident 10
While inspecting a power plant a STUK inspector observed the use of a radiation source in a manner contrary to instructions. The radiation sources of a weight scale had been left in the *shutter open* position for a period of servicing work and a detached radiation source, also with an open shutter, was found on the work platform of a fuel silo. The inspector ordered immediate corrective measures before work with the radiation sources could continue. An investigation of the incident revealed that nobody working at the weight scale had sustained an excessive radiation dose, and that

the dose sustained by a worker who had detached the radiation source from the fuel silo was very small.

One reason for failure to comply with instructions was evidently the fact that employees of several subcontractors worked in the facility during maintenance periods and there was no way to ensure safety under such circumstances. The power plant operating procedures were revised after this incident to ensure that qualified in-house staff from the facility would always verify the safe condition of radiation sources.

Incident 11

A potential danger of exposure was observed in the course of an inspection by STUK. The shutter of a radiation source (^{137}Cs, 3700 MBq) used for measuring the filling height of a raw material silo in a pulp mill had been left open, and servicing work was under way in the silo. There was also no warning sign near the manhole of the silo indicating that the radiation source should be shut off before entering the silo. Checking measurements revealed that the dose rate in the working area inside the silo was no higher than the dose rate from background radiation. The radiation beam was not directed at the working area. The inspector gave permission to continue working in the silo after the radiation source had been shut off and warning signs had been placed in the vicinity of the manhole.

Incident 12

Contrary to instructions, two workers made images of their own limbs in a food scanning appliance. They did not realize at the time that this is a “real” X-ray appliance that can involve a radiation hazard. The radiation dose sustained was estimated at a few tens of microsieverts. Following the incident the responsible party increased training and guidelines for use of the appliance, and introduced additional supervision and monitoring procedures to ensure that the instructions were understood and that training was adequate. The technical safety mechanism of the appliance was also modified to hamper any similar deliberate attempt at self-exposure more effectively.

Incident 13

A package of radioactive material was found at a transport business terminal with no documentation or details of the sender or consignee. The package contained four used ^{153}Gd sources with a total activity of 80 MBq. It was sent to STUK, which traced the sender and intended consignee. It turned out that the package had been sent nearly one year earlier, but that transportation had been interrupted due to the loss of address details. The intended consignee collected the package from STUK. The package in question bore a Radioactive White-I warning label and releases radiation quite weakly (less than 5 μSv/h on the surface), so the incident evidently caused no significant exposure to radiation. To avoid any recurrence, the sender was instructed to notify the consignee of any upcoming consignment and to ask the consignee to give a receipt for the consignment.

Incident 14

A radiation source removed from the production line was included in scrap metal at a paper mill. Radiation detectors at the metal recycling firm detected the radiation source when the batch of scrap metal was brought to its recycling centre. The radiation source was sent to the STUK waste storage unit. This was a ^{137}Cs source with an activity of 74 MBq. No radiation exposure was caused by the incident.

On investigating the origin of the source it was noticed that another, similar radiation source had also disappeared from the mill at the same time. Despite a thorough search, this source was not found at the mill or at the scrap metal recycling plant.

Incident 15

A transport company sent some decommissioned radiometric appliances to the wrong address. The appliances were supposed to be sent to the STUK waste storage unit, but only one pallet arrived instead of the three pallets despatched. The other two pallets had been sent to the appliance importer, to which another consignment was sent at the same time. A total of 22 appliances went to the wrong place, containing ^{137}Cs sources of activities ranging between 0.037 and 7.4 GBq. The shipping documents also failed to include the hazardous material warning labels that are required under transport regulations (Class 7, radioactive materials). After its whereabouts had been established, the consignment was forwarded to the correct destination at STUK. No extraordinary radiation exposure was caused by the incident.

Incident 16

A radiometric device containing a radiation source was found in the storage area of a scrap metal recycling business. The device had been sent to the business as part of another batch of metal back at the turn of the century. A representative of the business found the radiation source after recently acquiring a radiation meter and training in preparing to receive radiation sources. The device contained a ^{60}Co radiation source with an activity of 260 MBq.

It turned out that the radiation source came from a factory in the same district where some confusion had occurred at the time of decommissioning radiometric devices. A device containing a radiation source had been accidentally sent for scrapping when a corresponding empty device should have been sent. The device was sent from the scrap metal recycling business back to the factory, and was then forwarded to the STUK waste storage unit.

No radiation exposure was caused by the incident.

Incident 17

Some smoke detectors containing a radioactive substance (^{241}Am) wound up at a recycling centre for electrical and electronic waste. The presence of these irradiating detectors was revealed when they were taken from the recycling centre to a scrap metal crushing plant. The radiation control ports of the crushing plant detected the radioactive material in the consignment. Eleven smoke detectors were found in the consignment. They were kept at the recycling centre pending collection for storage by the Finnish radioactive materials recycling business Suomen Nukliditekniikka.

Although decommissioned household smoke detectors must be sent to recycling points for electrical and electronic waste, the detectors that were found in this incident came from the fire alarm systems of large buildings, and their disposal must be separately arranged with the importer.

Incident 18

An extraordinary radiation dose was sustained by some workers due to the improper use and storage near the workplace of a device containing a radiation source that is used for measuring soil density and moisture content. The dose was estimated at no more than 0.3–0.4 µSv. The incorrect use of the device was due to inadequate training and operating instructions. The safety instructions provided were also not entirely understood or followed. The responsible party arranged further training, established a register of training and rights of access to the device, and began keeping a precise log of its use. Guidelines and supervision of safe use of the device were also improved.

Incidents 19, 20 and 21

Three incidents arose at a steel mill in which a radiation source containing americium (^{241}Am) was sent for melting down with recycled metal. No radioactive material escaped the confines of the plant, nor was any radiation hazard caused to workers. The melting down of the source did not contaminate the metal batch, as most of the americium was captured in the slag from the process and a minimal quantity was released in exhaust gas dust. The contaminated slag and dust were stored within the plant area.

Specialists from the STUK Regional Laboratory in Northern Finland made radionuclide assays of the slag, exhaust gas dust, aerial dust and metal from the foundry. The workers used respiratory filters until measurements had verified that there was no radioactive material in the ambient air of the plant.

Incident 22

An amateur collector had a radioactive metal container. This old container had been presumed empty and was kept as a historical relic. Measurements taken by STUK indicated the presence of a ^{226}Ra source in the container. The dose rate on the surface of the sealed container was about 50 µSv/h. STUK consigned the container and radiation source to its storage facility for low-level radioactive waste. The source had not leaked out of its storage container and had caused no significant radiation dose to the collector.

Incident 23

On administering a radiopharmaceutical (^{99m}Tc-MAA, 150 MBq) to a patient via a vein in the forearm the medicine went into the surrounding tissue. The patient was then given a second injection for the purpose of the examination. The patient sustained an excessive effective dose of about 2 mSv due to the failure of the first injection.

Incident 24

The wrong radiopharmaceutical was mistakenly administered to a patient, who received 22 MBq of ^{123}I sodium iodide solution instead of ^{123}I DatScan. The estimated excessive effective dose administered to the patient was about 0.2 mSv. Thyroid accumulation of the medicine is assumed to be zero when estimating the dose, as the patient had received a regimen of potassium perchlorate before the injection. Potassium perchlorate prevents binding of iodine in the thyroid gland.

Incident 25

The metal fastening collar keeping a rubber stopper in place on an ampoule of a radiopharmaceutical (^{18}F-FDG of activity 12 GBq) was not seated properly and came off when the central metal part was removed. Part of the rubber stopper also became detached. There was no spillage of radioactive material to the surroundings, however. The ampoule was closed with a new metal collar using pliers to ensure that the radiopharmaceutical could be used. Two workers sustained some extraordinary dose particularly to the fingers. The radiopharmaceutical manufacturer was notified of the incident and a report of an incident jeopardizing safety was also submitted in accordance with hospital district procedures. The incident was also discussed at the unit self-assessment session. Greater attention will be paid to fastening stoppers in future.

Incidents 26 and 27

A hospital SPECT/CT scanner broke down several times while an examination was in progress. These breakdowns occurred despite repairs performed by the appliance manufacturer servicing unit whenever faults arose. The excessive dose sustained by the patients was between 1.5 and 7.5 mSv, depending on the examination. The appliance defect was also reported to Valvira (the National Supervisory Authority for Welfare and Health) and discussed at hospital department meetings.

Incident 28

Some radiation stayed on when using a C-arm appliance in hospital surgery. The radiation was switched off at the appliance power switch. The appliance was restarted and the examination continued, whereupon the radiation again stayed on. The appliance was turned off at the power switch and unplugged from the mains. It was removed from the operating theatre and the examination was continued using another appliance brought into the theatre. The defective appliance was sent to the supplier for examination.

Incident 29

An anaesthetist working at the foot of a radiotherapy table administered additional oxygen to an anaesthetized child, and owing to a misunderstanding then failed to vacate the treatment room during the therapy. The patient received electron beam therapy of 9 MeV (1.8 Gy) to the eye. The anaesthetist was wearing a lead apron and avoided soft scattered radiation to the eyes. Measurement taken in a reconstruction suggest that the estimated dose to the anaesthetist was less than 30 µSv.

2.10 International evaluation of operations

The International Atomic Energy Agency (IAEA) assessed the physical protection of radiation sources in Finland as part of an evaluation of security arrangements at nuclear facilities commissioned by the Ministry of Employment and the Economy. The assessment by the International Physical Protection Advisory Service (IPPAS) covered legislation and other regulations governing physical protection, and the associated work of public authorities and practical implementation of security arrangements.

The assessment team found several good practices in Finland, and also formulated many recommendations and proposals based on its observations for further improving the physical protection of radiation sources. These recommendations formed the basis for new work in planning, implementing and assessing physical protection in the use of radiation, which will be followed by a review of any needs to enhance security arrangements.

3 Regulatory control of practices causing exposure to natural radiation

3.1 Radon at workplaces

During 2009 STUK received 250 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. 111 inspection reports were sent to enterprises on the basis of radon measurements. The monitoring reports required reductions in radon concentrations or an investigation of radon concentration during working hours in 79 work areas, and a measurement at another time of year in order to determine an annual average in 22 work areas. Radon concentrations were successfully reduced in 26 work areas during the year. STUK discontinued regulatory control in 38 work areas on the basis of further investigations (measurement during working hours or determination of annual averages). Regulatory control was terminated at a total of 71 work areas for other reasons (e.g. short working periods or discontinued use of premises). 219 work areas at 108 workplaces were subject to regulatory control by STUK during the year.

Statutory radon inspections were conducted in seven subterranean mining facilities. The average radon concentration exceeded the action level at one of these. After corrective measures the measured radon concentration was below the action level.

Twelve underground quarries were inspected. Two of these facilities were ordered to limit radon exposure.

Radon exposure of workers was monitored by regular radon measurements and monitoring of working hours at four conventional workplaces and one excavation site where the radon concentration exceeded the action level. A total of 30 workers were subject to radon exposure monitoring during 2009.

Radiation Safety Guide ST 1.9 took effect in 2008, stipulating requirements for radon concentration measuring methods at workplaces. After these stipulations entered into force STUK sent an enquiry on compliance with the new requirements to 55 organizations at which STUK had previously approved the measurement methodology. 27 organizations reported that their operations had been discontinued or their measuring equipment had been decommissioned. Eight practitioners responded that their operations were continuing. However, the requirements of Guide ST 1.9 were not satisfied at two of these establishments. 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 continued in 2009. A total of 48 decisions were taken during the year to record the expiry of a decision approving radon measuring equipment, and two such decisions were revoked.

A list of organizations with measuring methodologies that have been approved in accordance with the new requirements of Guide ST 1.9 appears on the STUK website. These organizations have given permission for publication of their names on the approval list. It is a condition of such approval that the measuring instrument is properly calibrated.

3.2 Other natural radiation from the ground

STUK monitors radiation exposure caused by radioactive materials that occur naturally in water intended for human consumption, construction materials and other materials. Thirteen inspection reports on the radioactivity of construction materials were prepared during 2009. These reports imposed restrictions on the use of materials where necessary. Five statements were also prepared concerning uranium prospecting, a mining project, and the positioning of metal items containing naturally occurring radioactive materials.

3.3 Cosmic radiation

Implementation of radiation exposure monitoring at four airlines was inspected in 2009. A total of 12 repair orders were issued in the inspection reports.

The doses sustained by employees of six airlines were entered in the STUK Dose Register in 2009. In no case did the annual dose sustained by an employee exceed the limiting value of 6 mSv stipulated in Guide ST 12.4. The largest individual doses of cosmic radiation were 5.2 mSv sustained by a pilot and 5.6 mSv sustained by a cabin crew member. The average annual dose sustained by pilots in 2009 was 2.2 mSv and the average annual dose of cabin crew members was 2.5 mSv. The total number of workers belonging to flight crews was slightly smaller than in the preceding year and the number of hours spent in flight also fell. On the other hand, there was some increase in the total dose. One possible reason for this may be that airlines were flying at higher altitudes than in previous years in order to reduce fuel costs. The average doses over the period 2005–2009 are shown in Figure 4. The number of workers subject to individual monitoring of radiation exposure and their combined doses are shown in Table 16 of Appendix 1.

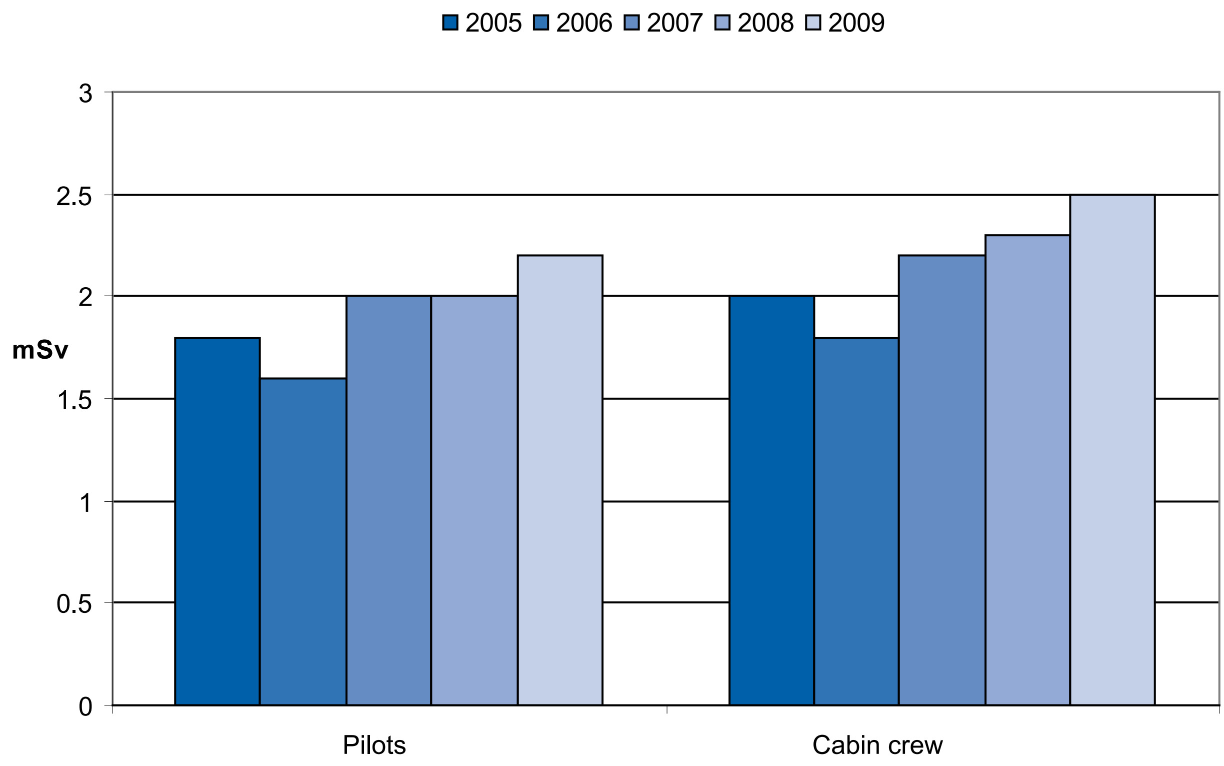

Figure 4. Average doses of air crews, 2005–2009.

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.
- Non-compliant laser pointers that are hazardous to the eye have been increasingly used for harassment. During the year under review STUK began regulatory control of laser appliances primarily intended for consumer use in accordance with an agreement concluded with the Ministry of Social Affairs and Health and the Finnish Customs. A policy decision on the use of lasers for cosmetic purposes was also issued on the basis of an enquiry on tattooing lasers submitted to STUK. The use of high power laser equipment at public performances has increased due to advances in laser technology (semiconductor lasers) and falling prices.
- Annual inspections have been made of a few public broadcasting stations and radar stations.

The work of the NIR Unit in regulatory control of the use of non-ionizing radiation between 2000 and 2009 is shown in Table 17 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

A total of 19 inspections were conducted at sunbed establishments (see Table 18 in Appendix 1). These opportunities were also used for training health inspectors. Four establishments passed the inspection on all counts. Use of one sunbed appliance was prohibited, because the timer failed to comply with requirements in only permitting a standard exposure time of 30 minutes. About 10% of appliances exceeded the maximum value of 0.3 W/m^2 prescribed in the Decree of the Ministry of Social Affairs and Health on the Limitation of Public Exposure to Non-ionizing Radiation (294/2002). About one in four of the operating instructions provided for sunbed users did not refer to the regulation limiting annual use of sunbed appliances (about 20 tanning sessions) and the recommended age limit of 18 years prescribed in the said Decree. The inspections also noted that sunbed use by girls under 18 years of age has increased in spite of the said recommendation. This is partly because of an increase in unsupervised self-service sunbed establishments.

Some of the sunbed inspections formed part of a sunbed market control development project implemented under the European Union PROSAFE programme (2008–2009).

Other regulatory control

An agreement was concluded with the Ministry of Social Affairs and Health, whereby STUK arranges regulatory control of laser appliances that are primarily intended for consumer use, for cosmetic use, and for lighting effects at public performances. In association with the Ministry and STUK, the Finnish Customs drafted instructions on regulatory control of laser pointer imports. STUK prepared a draft Radiation Safety Guide on safety of consumer lasers, began regulatory control of laser pointers and cosmetic lasers, and continued regulatory control of high power lasers for use at public performances.

Four cases of harassment caused by laser pointers were investigated by the police. STUK issued safety assessments to the police concerning the pointers used for harassment. The Finnish Customs requested advice from STUK in 46 cases involving import of lasers, and particularly laser pointers. Import permits were refused to nearly all laser pointers, either due to a lack of type inspection certificate or to failure of the appliance to comply with requirements. The highest power laser pointers detained by the Finnish Customs had a power rating of 200 mW, whereas the maximum power of lasers permitted for consumer use is only 1 mW. In response to an order issued by STUK, an importer withdrew a torch from the market that included a class 3B laser pointer with a power of 6.8 mW. This torch was the subject of a notification to the European Commission concerning a consumer product hazardous to the eyes. A children's archery set including a laser pointer that was investigated by the Consumer Agency in the course of regulatory control of toys was tested and found to be too powerful (power of 4.3 mW, class 3R). The Consumer Agency prohibited sales of this toy. Fifteen requests to remove advertisements from the huuto.net online sales forum were sent because of excessively powerful laser pointers.

In response to an enquiry, STUK announced that the use of class 4 lasers for tattoo removal was permitted only under medical supervision. This policy decision also applies to other cosmetic uses of class 4 lasers, such as epilation.

Ten inspections were made of laser show performances. One performance was cancelled, because the performer was not given permission to direct radiation beams at the sky. An investigation was conducted into three unlicensed laser displays that were reported.

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 100 mobile phones to date (see Table 19 of Appendix 1). A total of 15 GSM and UMTS type mobile phones were tested in 2009. The highest measured SAR value of 0.823 W/kg did not exceed the maximum of 2 W/kg prescribed in the Decree of the Ministry of Social Affairs and Health (294/2002).

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 laser radiation in 2009.

Incident 1

The police notified STUK that a teenage boy had been directing a laser pointer at passing motor vehicles from the roadside. In at least one case the laser beam passed through the vehicle windscreen and into the eye of the driver, who was severely dazzled and experienced pain in the eye. A measurement taken by the Finnish Institute of Occupational Health indicated that the device was a class 3B laser with a power of 31.5 mW. This power was therefore about six times greater than the 5 mW lower limit for class 3B, in excess of which the danger of laser radiation to the retina begins increasing rapidly. The police confiscated the device. The case led STUK to issue a bulletin warning of the danger of using laser pointers as toys.

Figure 3 (in item 1.1) shows abnormal incident numbers between 2000 and 2009.

5 Regulation work

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

The following ST Guide was published in 2009:

- ST 1.6 Operational Radiation Safety.

6 Research

The aim of research work conducted by STUK is to provide information on the occurrence of radiation, on its detrimental effects and how to combat them, and on the safe and optimal use of radiation sources and methods of using radiation. Research supports regulatory activities pertaining to radiation and maintains the preparedness to respond to radiological and nuclear emergencies. Research into uses of radiation seeks to improve knowledge and expertise in this field and to ensure reliable radiation measurements.

6.1 Ionizing radiation

Most research into ionizing radiation concerns medical uses of radiation and focuses on the radiation safety of patients. There is a growing need for research owing to rapid progress in examination and treatment methodologies. Research and development work was done in the following projects.

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). STUK was particularly involved in this project in testing work on dose-area-product meters, in testing calibration and measurement methods for the meters used in CT dosimetry, and in mammography dosimetry. This project continued in 2009. A final draft of the testing project report on dosimetric guidelines for X-ray diagnostics was approved. An IAEA report is currently being prepared on the research project.

European Metrology Research Programme (EMRP)

Two jointly-funded European research projects associated with metrology began in 2008: JRP6-Brachytherapy and JRP7-External Beam Cancer Therapy. These projects will end in 2011. The projects are developing primary measuring devices and measuring methods for clinical radiotherapy measurements. The aim of the entire project (JRP6) for internal radiotherapy is to ensure accurate and reliable dosimetry in dose distribution measurements of brachytherapy sources. With respect to external radiotherapy (JRP7) the aim is to ensure accurate and reliable dosimetry in modern therapy techniques for small and shaped radiation fields. From the point of view of STUK, the internal radiotherapy project seeks to investigate the properties of dosemeters used in measurement and the external radiotherapy project seeks to create a system for measurements of prostate cancer radiotherapy. The first test version of a water-filled measurement phantom was constructed at STUK in 2009. A wide range of detectors and anatomical structures corresponding to organs can be installed in this measurement phantom. A film reader device based on self-developing film was also designed and constructed. The properties of a wide range of dosemeters were studied both in the laboratory and in field measurements at radiotherapy clinics. The findings of this work were published in project reports.

Other projects

The following research projects concerning the use of ionizing radiation will continue in 2010:

- Energy loss of protons and heavy ions in water in the pertinent energy range for

dosimetry of radiotherapy and cosmic radiation. Measurements of the stopping power of water were made at the accelerator laboratory of the University of Jyväskylä. The project will continue with processing of findings.
- Modelling of a radiotherapy accelerator by BEAMnrc calculation coding. The modelling has been completed and the research project continues with processing of results. The findings will be applied in regulatory control of radiotherapy to verify dose distributions produced in dose planning.
- Determination of the radiation dose sustained by the public from X-ray diagnostics in health services. Calculation of the radiation dose to the public has been completed for plain X-ray examinations, partly through academic thesis work. The study will continue for other types of X-ray examination.
- Investigation of radiation doses sustained by patients from paediatric CT scans and dose reference levels. This study was launched in association with university hospitals in Finland and with Estonia and Lithuania.

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.

Determining the radiation dose sustained by the public from plain X-ray examinations.

This radiographer academic thesis work sought to formulate an estimate of public radiation exposure from plain X-ray examinations. The assessment employed a method of calculating public radiation exposure in accordance with guidelines issued by the European Commission.

Patient exposure monitoring and radiation qualities in two-dimensional digital X-ray imaging

The aim of this doctoral thesis work was to study dose-area-product meters used in measuring patient doses in X-ray diagnostics and mammography dosimetry.

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.

An EMRP-NIR-project launched in 2008 (JRP T4.J07 Traceable measurement of field strength and SAR for the physical agents directive) continued the work of developing a SAR-TEM chamber for calibrating SAR-measurement probes at frequencies of less than 400 MHz. The SAR-TEM chamber was tuned to operate at frequencies of 450 and 380 MHz by adjusting the thickness of a tissue-equivalent liquid layer. The LC circuits were connected to the input of the SAR-TEM chamber at frequencies of 300 MHz, 150 MHz and 30 MHz, providing a narrow band fitting for these frequencies when liquids mimicking the electrical properties of the head made by the UK project partner NPL (National Physical Laboratory) were used in the chamber. The STUK SAR measurement probe and the NPL measurement probe were calibrated at these frequencies. The NPL measurement probe will also be sent to Japan for calibration. After NPL has compared the calibration results a joint uncertainty report will be prepared, which will also consider the uncertainty in measurements of temperature and specific heat capacity.

The EMRP-NIR project also constructed a calibrator operating at a frequency of 10–50 MHz for the instruments that are used for measuring induced RF currents in limbs. The properties of the calibrator were measured and it was found in tests to work as planned. Measurements of currents in limbs and calibrations of measuring instruments will be compared with the NPL in 2010.

A mobile phone radiation research project (WIRECOM) financed by the Finnish Funding Agency for Technology and Innovation – TEKES was launched at the beginning of 2009 as a collaboration between the Finnish Institute of Occupational Health, the University of Turku and STUK. The exposure equipment required in physiological tests conducted by the University of Turku and the Finnish Institute of Occupational Health was designed and assembled at STUK and the testing institutes were trained in its operation. The exposure of test subjects was determined with optimal precision by SAR measurements and computer modelling before the exposures began. Dosimetric studies were made for the STUK epidemiological project by estimating factors affecting the exposure of mobile phone users.

The final report of the MF Safety project was completed on the basis of comments received on a draft report. Participation by STUK in this project came to an end in February 2009. The project was financed by TEKES and the role of STUK was to calculate the currents induced in a person working in an electrical distribution cabinet. A calculation program commissioned in the MF Safety project was used when preparing new ICNIRP (International Commission on Non-Ionizing Radiation Protection) guideline values for low-frequency electric fields. The reasonableness of the definition of an electric field induced in the body was verified by calculating the detailed distribution of an induced electric field in various parts of the body using a homogeneous field and a field generated by a transcranial magnetic stimulator as a magnetic field source.

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 Unit.

A draft was prepared for a scientific article on work by ICNIRP to formulate new guideline values for low-frequency electric and magnetic fields, and work on this draft will continue in the early months of 2010.

7 International co-operation

Representatives of STO and the NIR Unit 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).

Participation in meetings of international working groups

During 2009 representatives of STUK took part in meetings of the following international organizations and working groups:

- Working groups of the International Atomic Energy Agency (IAEA) preparing guidelines
- Ionizing radiation liaison person meeting of the European Association of National Metrology Institutes (EURAMET)
- Annual meeting and working groups of the European Radiation Dosimetry Group (EURADOS)
- Heads of European Radiation Control Authorities (HERCA) working groups
- European Alara Network (EAN) working group
- X-ray diagnostics working group of the Nordic radiation use regulatory authorities
- Dosimetry working group of the Nordic radiation use regulatory authorities
- Meeting of the Bioelectromagnetic Society (BEMS)
- Main Commission meetings of the International Commission on Non-Ionizing Radiation Protection (ICNIRP)
- TC61/MT16 sunbed working group of the IEC
- MT-62209 mobile phone working group
- Nordic UV and ozone working group (NOG)
- Nordic laser and light pulse device working group.

Participation in other international conferences

Representatives of STO and the NIR Unit 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

STUK arranged a training event for ionizing radiation calibration laboratories on its premises under the auspices of the Nordic dosimetry working group. This event consisted of lectures and laboratory practicals.

Two joint Nordic position papers on non-ionizing radiation were drafted on the initiative of the directors of Nordic radiation safety authorities (Chefsmöte):

- It was noted that there is no scientific evidence to support the alleged health drawbacks of weak RF background radiation from fixed radio transmitters (bases stations, public broadcasting stations). The technical appendix to the position paper, dealing with sources of RF radiation in the general habitat, was based on the STUK report *Väestön altistuminen radiotaajuisille kentille Suomessa* ("Public exposure to RF fields in Finland", report no. STUK-TR 5). STUK representatives were also assigned to the work of the expert task force that prepared the draft position paper.
- The directors of Nordic radiation safety authorities found that sunbed use by persons under 18 years of age should be prohibited because of the risk of skin cancer. In a

recommendation on age limits for sunbed use the radiation safety authorities of Finland, Sweden, Iceland and Norway thus recommended new legislative provisions that would prohibit the use of sunbeds by persons under 18 years of age and their sale and leasing to such persons. Denmark was unwilling to support this position.

8 Co-operation in Finland

Representatives of STO and the NIR Unit 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, SESKO and the Clinical auditing expert group appointed by the Ministry of Social Affairs and Health).

Finnish conferences arranged by STUK

STUK arranged the following conferences in 2009:

- Conference for radiation safety officer training organizations, 20 May 2009, Helsinki.
- Conference of radiotherapy physicists, 11–12 June 2009, Vuonislahti, attended by 23 participants.
- Conference for specialists in medical X-ray technology, 27–28 August 2009, Tervakoski, attended by a total of 60 participants.
- Radiation Safety Conference, 5–6 November 2009, Tampere, in association with the Radiological Society of Finland.
- Conference on radiation safety and quality in nuclear medicine, 19–20 November 2009, Helsinki, attended by a total of 70 participants.

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 Safety of domestic electrical appliances
- SESKO SK 106 Exposure to electromagnetic fields
- National RAPEX (Rapid alert system for non-food consumer products) network (European Union notification system for consumer products causing serious danger).

Participation in other Finnish conferences

Representatives of STO and NIR 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

Specialists from STUK gave a course of lectures at Aalto University School of Science and Technology on the biological effects and measurement of electromagnetic fields and optical radiation.

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 seventh part of the series, covering ultraviolet and laser radiation, was published in spring 2009.

A review on radio waves in the environment was translated into both Swedish and English, and published on the STUK website in these languages.

Public information on current affairs

During the year the NIR Unit 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.

A reform of the STUK website also incorporated some improvements in the pages dealing with non-ionizing radiation.

The Finnish Meteorological Institute, the Cancer Society of Finland and STUK arranged a joint information session on UV radiation in April. The topics covered at this session included how outdoor workers should protect themselves from sunlight, how UV radiation affects cancer statistics in specific occupations, and whether the incidence of skin cancer has continued to increase. This session has been arranged every spring since 2003.

Press releases were prepared on the following subjects:

- It is wise to limit mobile phone use by children
- Studies of the health impacts of mobile phones are continuing in Finland
- International co-operation assists in market surveillance of mobile phones
- A laser pointer is not a toy
- Radiation doses of workers unchanged
- It is wise to protect yourself from sunlight when working outdoors
- Solar UV radiation provides enough vitamin D from spring to autumn
- Laser tattoo removal can pose health risks
- Is this X-ray really necessary? Careful assessment of justification reduces the radiation dose to the public
- Sunbed use should be prohibited for persons under 18 years of age
- Joint Nordic position paper: No need to reduce electromagnetic fields from base stations and wireless networks.

10 Metrology

10.1 General

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 Unit for non-ionizing radiation. Metrology of ionizing radiation activity quantities is the responsibility of the Department of Research and Environmental Surveillance (TKO) at STUK.

External assessment of metrological activities

In 2009 STUK participated in a development study of national metrological standard and reference laboratory operations launched by the Ministry of Finance. A special investigator appointed by the Ministry of Social Affairs and Health examined metrological activities at STUK. The findings of the study are not yet available.

10.2 Ionizing radiation

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

The DOS Laboratory has replaced the radiation sources required for radiation protection calibrations. Six gamma radiation sources were ordered and four of these were taken into use in 2009. New beta radiation sources were also commissioned. A call for tenders was prepared for a new ^{60}Co source for use in radiotherapy calibrations. The bids will be processed in 2010.

The ionization chamber calibration procedure used for measuring electron radiation fields of radiotherapy accelerators was revised. The chambers will be calibrated at regular intervals in a ^{60}Co gamma ray beam and the conversion to electron radiation will be determined in accordance with the dosimetric guidelines of the IAEA/WHO. The chambers were previously calibrated in the electron beams of radiotherapy accelerators.

Meter and measurement comparisons

In 2009 the DOS Laboratory took part in the annual TLD comparison measurement of the absorbed dose of ^{60}Co gamma radiation (radiotherapy level accuracy) between calibration laboratories belonging to the laboratory network maintained by the IAEA/WHO. It was also involved in a TLD air kerma comparison with ^{137}Cs radiation (protection level accuracy) arranged by the IAEA/WHO. The deviation of the STUK result from the IAEA reference value was -1.4% in the ^{60}Co comparison and -2.8% in the ^{137}Cs comparison. These results were well within the IAEA acceptable range.

Figure 5 shows the deviations in the measurement results of STUK from the reference value in IAEA/WHO measurement comparisons over the period from 1999 to 2009.

External assessments

The metrological activities of the DOS Laboratory for dose quantities were subject to an external quality assessment by the Centre for Metrology and Accreditation. The quality of operations satisfies the requirements set for metrological activities.

The quality of the national metrological activities of Finland was presented for assessment to EURAMET by the Centre for Metrology and Accreditation. The metrological activities of the DOS Laboratory for dose quantities were also considered as part of Finnish metrological activities, and secured the approval of the EURAMET quality working group in February 2009.

10.3 Non-ionizing radiation

Meter and measurement comparisons

In 2008–2009 STUK participated in SAR comparison measurements of mobile phones arranged by the Swiss company Schmid & Partner Engineering AG (SPEAG). A total of 18 laboratories from various countries (9 from Europe, 4 from the Americas and 5 from Asia) took part in the comparison. The comparison was arranged by circulating two telephone handsets operating at UMTS frequency (1950 MHz). The results from STUK did not differ significantly from the average, which also confirmed the reliability of SAR tests of UMTS phones using the new simulator.

Some reference measurements of sunbed UV radiation were taken at the places of use of such appliances together with VWA (Voedsel en Waren Autoriteit – the Netherlands Food and Consumer Product Safety Authority), the Dutch co-ordinator of the EU PROSAFE programme sunbed project. Measurements taken in Finland indicated a discrepancy of less than 10 per cent in measurements made by STUK and VWA under laboratory conditions, but as much as 30% in similar measurements made at places of use. The main reason for the discrepancies at places of use was the temperature dependence of attenuation in the bandpass filter of the Ocean Optics spectroradiometer used by STUK. The problem was corrected by removing the filter.

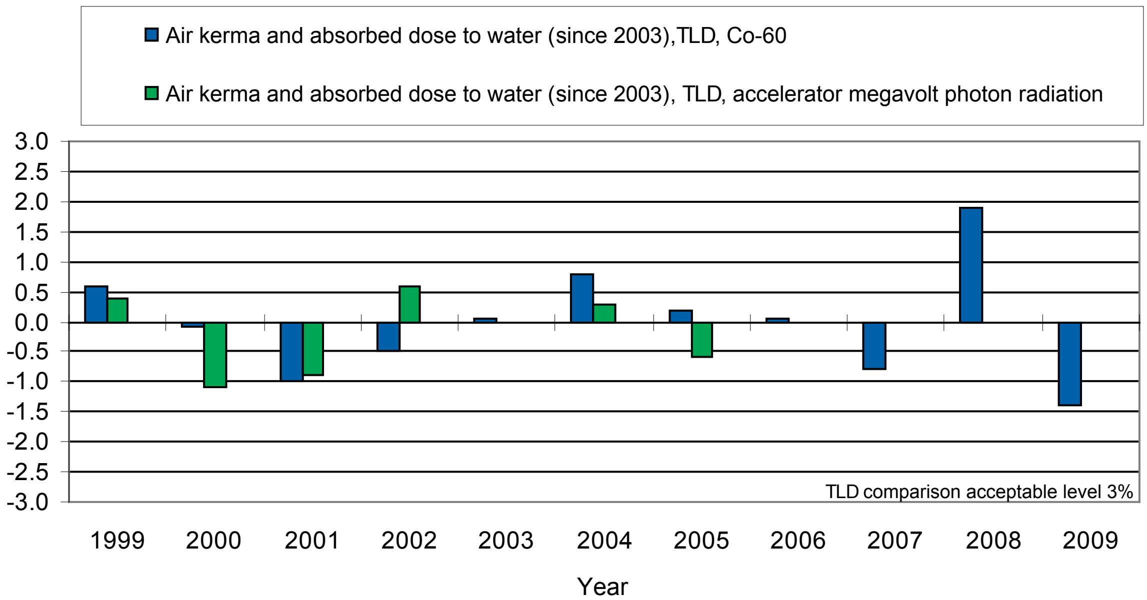

Figure 5. Deviations (%) in measurement results of STUK from the reference value in IAEA/WHO measurement comparisons, 1999–2009.

11 Services

11.1 Ionizing radiation

Calibration, testing and irradiation

The DOS Laboratory performed radiation meter calibrations and testing on request. 128 radiation meter calibration, inspection and testing certificates and 27 irradiation certificates were issued. About one fifth of the calibrations and one third of the irradiations were performed for in-house measuring instruments and samples at STUK.

Other services

78 copies were sold of the PCXMC computer application designed for calculating patient doses in X-ray diagnostics. Eight tests and reports were prepared on compliance of X-ray equipment with standards.

STUK arranged the following events as training services in 2009:

- Training conference on radiation safety and quality in X-ray diagnostics, 25–27 March 2009. Attended by 168 participants.
- Seventh industrial radiation safety conference, 7–8 October 2009, Hämeenlinna. Attended by 130 participants.

STUK implemented the European Commission Twinning project "Strengthening of administrative structures for radiation protection and safe use of ionizing radiation in diagnostics and therapy" in Bulgaria, 20 May 2008–19 May 2009. Nearly all of the STO inspectors supervising the use of radiation in health services and the specialists in medical uses of radiation at the STUK DOS Laboratory took part in this project, which achieved all of its assigned objectives for improving safety in the use of radiation in Bulgaria. The first publication of findings from the project was completed during 2009 (see Appendix 2, International publications, Korpela et al.).

11.2 Non-ionizing radiation

Calibration, testing and irradiation

The NIR Unit performed a total of 31 radiation meter calibrations and tests and 12 safety assessments and radiation measurements. The service work of the NIR Unit between 2000 and 2009 is shown in Table 17 of Appendix 1.

APPENDIX 1

TABLES

Table 1. Radiation practices in the use of radiation in health care and veterinary medicine at the end of 2009.

Use of radiation	Number of practices
Conventional dental X-ray practices	1 820
Use of X-ray appliances (excluding veterinary practices)	395
Use of X-ray appliances (veterinary practices)	219
Use of unsealed sources	40
Use of sealed sources	26
Radiotherapy	14

Table 2. Radiation sources and appliances and radionuclide laboratories in the use of radiation in health care and veterinary practices at the end of 2009.

Appliances/sources/laboratories	Number
X-ray diagnostic appliances (generators)*)	**1532**
• conventional X-ray appliances	765
• fluoroscopy appliances	402
• mammography appliances	171
• CT appliances	76
• Bone mineral density measurement appliances	76
• Dental X-ray appliances (licensed)	65
• other X-ray appliances	4
Dental X-ray appliances	**5440**
• conventional dental X-ray appliances	4766
• panoramic X-ray appliances	674
Radiotherapy appliances	**110**
• accelerators	40
• afterloading appliances	6
• manual afterloading appliances	5
• X-ray therapy appliances	1
• X-ray imaging appliances	19
• radiotherapy simulators	19
• sealed sources (check sources)	19
• BNCT therapy unit	1
Sealed sources	**191**
• attenuation correction units	16
• calibration and testing equipment	164
• gamma irradiators	6
• other sealed sources in health care	5
X-ray appliances in veterinary practices	**273**
Radionuclide laboratories	**58**
• B-type laboratories	23
• C-type laboratories	35
*) 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 in the use of radiation in industry, research and education at the end of 2009.

Use of radiation	Number of practices
Use of sealed sources	615
Use of X-ray appliances	418
Import and export of radioactive materials or trade in them	128
Installation, test operations and servicing	125
Use of unsealed sources	134
Use of particle accelerators	18

Table 4. Radiation sources and appliances and radionuclide laboratories in the use of radiation in industry, research and education at the end of 2009.

Appliances/sources/laboratories	Number
Appliances containing radioactive materials	**6403**
• level switches	2234
• continuous level gauges	1141
• density gauges	1007
• basis weight meters	640
• weight scales	584
• appliances or sources used for calibration, testing or education	177
• moisture and density gauges	125
• fluorescense analyzers	90
• radiography appliances	21
• other sources	384
X-ray appliances and accelerators	**1345**
• X-ray screening appliances	491
• radiography appliances	368
• diffraction and fluorescence analyzers	323
• basis weight meters	46
• particle accelerators	20
• other X-ray appliances	97
Radionuclide laboratories	**159**
• A-type laboratories	4
• B-type laboratories	27
• C-type laboratories	125
• activities outside laboratories (tracer element tests in industrial plants)	3

Table 5. Radionuclides most commonly used in sealed sources in industry, research and education at the end of 2009.

Radionuclide	Number of sources
Other than high-activity sealed sources	
Cs-137	4475
Co-60	1527
Kr-85	414
Am-241 (gamma sources)	384
Pm-147	185
Am-241 (AmBe neutron sources)	136
Fe-55	126
Ra-226	74
Ni-63	65
Sr-90	62
High-activity sealed sources	
Cs-137	60
Co-60	27
Ir-192	11
Am-241 (gamma sources)	8
Sr-90	5
Am-241 (AmBe neutron sources)	5

Table 6. Inspections of licensed practices in 2009 (itemized by type of inspection).

Type of inspection	Number of inspections	
	Industry, research and education	Health care and veterinary practices
Initial inspection	0	139
Periodic inspection	158	111
Repeat inspection	0	0
Other inspection or measurement	6	0
Total	**164**	**250**

Table 7. Inspections of licensed practices in 2009 (itemized by type of practice).

Type of practice	Number of inspections
Use of radiation in health care and veterinary practices*)	
• X-ray diagnostics	188
• radiotherapy	42
• dental X-ray diagnostics	35
• veterinary X-ray diagnostics	26
• nuclear medicine	9
• other uses of radiation	0
Use of radiation in industry, research and education*)	
• industry	137
• research and/or education	19
• trade in radioactive materials	5
• installation and/or servicing	6
• other uses of radiation	3
Total	**470**

*) The total number of these inspections is larger than in Table 6, because in some cases one inspection concerned two types of practice.

Table 8. Imports and exports of sealed sources in 2009.

Radionuclide	Import		Export	
	Activity (GBq)	Number	Activity (GBq)	Number
Ir-192	51 722	14	6076	15
H-3	1480	500	15	5
Kr-85	956	69	-*)	-
Fe-55	100	21	3	2
Gd-153	36	18	0	68
Am-241 (gamma sources)	23	89	-	-
Sr-90	8	12	0	5
Am-241 (AmBe neutron sources)	6	4	-	-
Co-57	4	21	0	6
Pm-147	4	20	1	7
Ni-63	2	5	2	3
Cd-109	2	2	2	2
Cs-137	1	9	0	1
Ge-68	1	5	-	-
Co-60	1	1	0	1
others total **)	1	36	15	5
Total	**54 347**	**826**	**6114**	**120**

*) The symbol ”-” indicates no export.
**) Import, nuclides: Ba-133, Cf-252, Eu-152, Po-210, Ra-226, Sr-89, Tc-99m.

Table 9. Imports and exports of unsealed sources in 2009.

Radionuclide	Activity (GBq)	
	Import	Export
Mo-99	42 456	7290
I-131	6230	2086
Tc-99m	2542	-*)
I-123	1126	50
P-32	226	60
Tl-201	123	-
I-125	113	3
Sm-153	82	-
In-111	46	-
Sn-117m	28	-
S-35	18	-
H-3	17	2
Y-90	15	-
Cr-51	5	-
C-14	4	0
F-18	-	102
others total **)	6	1956
Total	**53 037**	**11 549**

*) The symbol ”-” indicates no import/export.
**) Import, nuclides: Ba-133, Ca-45, Co-60, Cs-137, Fe-55, Ga-67, Ge-68, I-124, I-128, Lu-177, Na-22, Nb-94m, P-33, Pb-210, Re-186, Se-75.
Export, nuclides: Eu-152, Ge-68, Lu-177.

Table 10. Manufacturing of radioactive materials (unsealed sources) in 2009.

Radionuclide	Activity (GBq)
F-18	62 343
C-11	10 892
Br-82	2591
others total*)	5
Total	**75 831**

*) Nuclides, such as: Au-198, Co-60, Cu-64, Ho-166, Na-24, Pt-191.

Table 11. Number of workers subject to individual monitoring in 2005–2009.

Year	Number of workers in various sectors in the use of radiation and nuclear energy								
	Health care		Veterinary practices	Industry	Research and education	Manufacturing of radiaoactive materials	Others*)	Use of nuclear enebrgy**)	Total***)
	Exposed to X-radiation	Exposed to other radiation sources							
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
2009	4440	992	458	1232	810	15	49	3704	11 571

*) Sectors included: installation/servicing/technical test runs, trade/import/export and services.

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

***) The figures 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 2005–2009.

Year	Total dose (Sv) in various sectors in the use of radiation and nuclear energy								
	Health care		Veterinary practices*)	Industry	Research and education	Manufacturing of radiaoactive materials	Others**)	Use of nuclear energy***)	Total
	Exposed to X-radiation*)	Exposed to other radiation sources							
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
2009	1.27	0.09	0.08	0.15	0.06	0.01	0	2.37	4.04

*) $H_p(10)$ 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 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 Hp(10) value by a factor between 10 and 60.

**) Sectors included: installation/servicing/technical test runs, trade/import/export and services.

***) 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 2009.

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 and interventional cardiologists**)	190	0.54	3.5	2.8	24.5
Radiologists**)	459	0.25	2.3	0.5	14.9
Interventional radiologists**)	31	0.23	8.3	7.3	25.8
Consultant physicians **) ***)	296	0.08	2.1	0.3	25.3
Radiographers**)	2355	0.09	0.6	0.0	4.4
Nurses**)	1134	0.06	0.5	0.1	3.3
Veterinary surgeons**)	195	0.03	1.6	0.2	8.7
Veterinary nurses and assistants**)	265	0.04	1.3	0.2	12.4
Industrial tracer testing technicians	25	0.04	2.4	1.8	7.9
Industrial material inspection technicians****)	455	0.09	0.7	0.2	9.3
Researchers	657	0.04	1.0	0.1	6.7
Nuclear power plant workers					
• mechanical duties and machine maintenance	706	0.61	1.4	0.9	9.5
• cleaning	249	0.28	1.7	1.1	9.9
• material inspections	165	0.16	1.3	1.0	7.3
• insulation work	62	0.16	3.5	2.7	7.3
• radiation protection	82	0.11	1.6	1.3	8.4
• building and real estate work	314	0.12	1.0	0.4	7.0
• electrical and automation work	662	0.20	0.7	0.3	6.1

*) 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.

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

***) Including surgeons, urologists, orthopedists, neuroradiologists ja gastroenterologists.

****) Exposure arising elsewhere than in nuclear power plants.

Table 14. The principal low-level radiaoctive waste in the national storage facility (December 2009).

Radionuclide	Activity (GBq) or mass
H-3	13 415
Cs-137	2467
Kr-85	1780
Am-241	1667
Pu-238	1571
Sr-90	241
Ra-226	232
Co-60	138
Cm-244	97
U-238	1270 kg

Table 15. Low-level radioactive waste received by STUK in 2009.

Radionuclide	Activity (GBq) or mass
Kr-85	273
Cs-137	130
Pm-147	52
Am-241 (gamma sources)	28
Co-60	11.6
H-3	8.9
Am-241 (AmBe neutron sources)	3.5
Fe-55	1.9
Ni-63	1.5
Ra-226	0.83
Sr-90	0.20
C-14	0.14
Co-57	0.04
U-238	181 kg

Table 16. Number of air crew members subject to individual monitoring of radiation exposure and total dose of crew members (sum of effective doses) in 2005–2009.

Year	Number of workers		Total dose (Sv)	
	Pilots	Cabin crew	Pilots	Cabin crew
2005	739	1861	1.31	3.80
2006	1072	2412	1.73	4.35
2007	1125	2583	2.30	5.61
2008	1206	2562	2.45	5.93
2009	1195	2460	2.68	6.07

Table 17. Work of the NIR unit in 2000–2009.

Year	Regulatory inspections	Decisions	Statements	Calibrations and tests	Safety assessments and radiation measurements	Total
2000	17	0	7	31	1	56
2001	23	2	16	27	9	77
2002	36	1	4	31	13	85
2003	49	0	3	23	11	86
2004	55	3	1	30	12	101
2005	66	1	1	25	31	124
2006	48	1	7	17	7	80
2007	64	3	3	33	17	120
2008	67	5	6	46	24	148
2009	108	2	9	31	12	162

Table 18. Inspections of sunbed facilities in 2000–2009.

Year	Number of inspections
2000	14
2001	17
2002	36
2003	31
2004	30
2005	36
2006	25
2007	31
2008	26
2009	19

Table 19. Mobile phone SAR-tests in 2003–2009.

Year	Number of tests
2003	12
2004	18
2005	15
2006	15
2007	15
2008	10
2009	15

APPENDIX 2 Publications in 2009

The following publications completed in 2009 were authored by one or more employees of STO or the NIR unit:

International publications

Faulkner K, Järvinen H, Butler P, McLean ID, Pentecost M, Rickard M, Abdullah B. A clinical audit programme for diagnostic radiology: the approach adopted by the International Atomic Energy Agency. In: Optimisation in X-ray and Molecular Imaging. Programme and abstracts. Third Malmö Conference on Medical Imaging, Malmö, Sweden 25–27 June 2009.

Hakanen A, Siiskonen T, Turunen J. Simulated and measured spectral characteristics of ^{137}Cs reference radiation beams. Radiation Protection Dosimetry 2009; 133 (2): 81–88. DOI: 10.1093/rpd/ncp021.

Järvinen H. Double Dosimetry with Recommedations. In: Comissariat à L'Énergie Atomique (CEA). Radiation protection dosimetry in medicine. Report of the working group no 9 of the European radiation dosimetry group (Eurados). CEA-R-6220. Gif-Sur-Yvette Cedex: CEA; 2009.
(Although not specificly mentioned, Hannu Järvinen was the author of the chapter Double Dosimetry with Recommendations).

Kiljunen T, Tietäväinen A, Parviainen T, Viitala A, Kortesniemi M. Organ doses and effective doses in pediatric radiography: Patient-dose survey in Finland. Acta Radiologica 2009; 50 (1): 114–124. DOI: 10.1080/02841850802570561.

Korpela H, Bly R, Vassileva J, Ingilizova K, Stoyanova T, Kostadinova I, Slavchev A. Recently revised DRLs in nuclear medicine in Bulgaria and in Finland. In: Optimisation in X-ray and Molecular Imaging. Programme and abstracts. Third Malmö Conference on Medical Imaging, Malmö, Sweden 25–27 June 2009.

Kännälä S, Toivo T, Alanko T, Jokela K. Occupational exposure measurements of static and pulsed gradient magnetic fields in the vicinity of MRI scanners. Physics in Medicine and Biology 2009; 54: 2243–2257.

Lipping T, Rorarius M, Jäntti V, Annala K, Mennander A, Ferenets R, Toivonen T, Toivo T, Värri A, Korpinen L. Using the nonlinear control of anaesthesia-induced hypersensitivity of EEG at burst suppression level to test the effects of radiofrequency radiation on brain function. Nonlinear Biomedical Physics 2009; 3:5.

Manninen, P, Koskela T, Ylianttila L, Kärhä P, and Ikonen E, Estimation of the optical receiving plane positions of solar spectroradiometers with spherical diffusers on the basis of spatial responsivity data, Optics Letters 2009; 34 (20): 3241–3243.

Puranen L, Toivo T, Toivonen T, Pitkäaho R, Turunen A, Sihvonen A-P, Jokela K, Heikkinen P, Kumlin T, Juutilainen J. Space Efficient System for Whole-Body Exposure of Unrestrained Rats to 900 MHz Electromagnetic Fields. Bioelectromagnetics 2009; 30: 120–128.

Pöllänen R, Karhunen T, Siiskonen T, Toivonen H, Pelikan A. Deconvolution of alpha spectra from hot particles. In: Oughton, D., Kashparov, V. (eds). Radioactive Particles in the Environment. NATO Science for Peace and Security Series C: Environmental Security. Springer 2009, 209–220.

Siiskonen T, Huikari J, Haavisto T, Bergman J, Heselius S-J, Lill J-O, Lönnroth T, Peräjärvi K. Excitation functions of proton-induced reactions in ^{nat}Cu in the energy range 7–17 MeV. Applied Radiation and Isotopes 2009; 67: 2037–2039.

Siiskonen T, Huikari J, Haavisto T, Bergman J, Heselius S-J, Lill J-O, Lönnroth T, Peräjärvi K, Vartti V-P. Excitation functions for proton-induced reactions on natural hafnium: Production of ^{177}Lu for medical use. Nuclear Instruments and Methods in Physics Research B. Doi: 10.1016/j.nimb.2009.08.016

Toivonen T, Toivo T, Puranen L, Jokela K. Specific absorption rate and electric field measurements in the near field of six mobile phone base station antennas. Bioelectromagnetics 2009; 30:307–312.

Toni MP, Aubineau-Lanièce I, Bovi M, Bordy J-M, Cardoso J, Chauvenet B, Gabris F, Grindborg J-E, Guerra AS, Kosunen A, Oliveira C, Pimpinella M, Sander T, Selbach H-J, Sochor V, Solc J, de Pooter J, van Dijk E. Traceability to absorbed-dose-to-water primary standards in dosimetry of brachytherapy sources used for radiotherapy. XIX IMEKO World Congress, Fundamental and applied metrology, September 6–11, 2009, Lisbon, Portugal.

Toroi P, Nieminen MT, Tenkanen-Rautakoski P, Varjonen M. Determining air kerma from pixel values in digital mammography. Physics in Medicine and Biology 2009; 54: 3865-3879. DOI: 10.1088/0031-9155/54/12/017.

Toroi P, Kosunen A. The energy dependence of the response of a patient dose calibrator. Physics in Medicine and Biology 2009; 54: N151-N156. DOI: 10.1088/0031-9155/54/9/N02.

Research publications in STUK publication series

Mustonen R, Sjöblom K-L, Bly R, Havukainen R, Ikäheimonen TK, Kosunen A, Markkanen M, Paile W. Säteilysuojelun perussuositukset 2007. Suomenkielinen lyhennelmä julkaisusta ICRP-103 (Basic recommendations in radiation protection. An abridged Finnish language edition of the ICRP publication 103). STUK-A235. Helsinki: STUK; 2009.

Toroi P. Patient exposure monitoring and radiation qualities in two-dimensional digital x-ray imaging. Academic dissertation. STUK-A239. Helsinki: STUK; 2009.

Regulatory control reports

Havukainen R, Bly R, Markkanen M. Säteilyturvallisuudesta vastaavan johtajan koulutus Suomessa vuonna 2008 (Training of radiation safety officers in Finland in 2008). STUK-B 109. Helsinki: STUK; 2009.

Rantanen E (toim.). Säteilyn käyttö ja muu säteilylle altistava toiminta. Vuosiraportti 2008 (Use of radiation and other activities involving exposure to radiation. Annual report 2008). STUK-B 102. Helsinki: STUK; 2009.

Rantanen E (ed.). Radiation Practices. Annual Report 2008. STUK-B 107. Helsinki: STUK; 2009.

Regulatory guides

Finnish language

Säteilyturvallisuus työpaikalla. Ohje ST 1.6 (Operational radiation safety. Guide ST 1.6). STUK (10 Dec. 2009).

Swedish language

Användning av kontroll- och analysröntgenapparater. Direktiv ST 5.2 (The use of control and analytical x-ray apparatus. Guide ST 5.2). STUK (26 Sep. 2008).

Handel med strålkällor. Direktiv ST 5.4 (Trade in radiation sources. Guide ST 5.4). STUK (19 Dec. 2008).

English language (translations)

Trade in Radiation Sources. Guide ST 5.4. STUK (19 Dec. 2008).

The Dose Register and Data Reporting. Guide ST 7.4. STUK (9 Sep. 2008).

Other publications

Bly R. Optimoituja tutkimuksia ammattitaidolla (Professionalism in optimizing examinations). Radiografia 2009; 1: 15.

Bly R. ICRP 103 kokoaa säteilyn käytön suositukset ja ohjeet (ICRP 103 provides a compendium of recommendations and guidelines in the use of radiation). Radiografia 2009; 3: 10–11.

Bly R. Säteilyn käytön poikkeavat tapahtumat – mitä STUKille pitää ilmoittaa. Kirjassa: Luennot. XXXIII Sädeturvapäivät Tampere-talossa, Tampere 5.–6.11.2009 (Abnormal events in the use of radiation - notifications to STUK. In the book:

Lectures. XXXIII Radiation Safety Conference at Tampere Hall, Tampere 5–6 November 2009). Tampere: Lege Artis Oy; 2009. p. 10–11.

Lehtinen M. Työntekijöiden säteilyaltistuksen seuranta (Monitoring of radiation exposure for workers). ATS Ydintekniikka 2009; 3 (vol 38): 6–9.

Merimaa K. Säteilyn lääketieteellisen käytön vaikutukset, UNSCEAR:n raportti. Kirjassa: Luennot. XXXIII Sädeturvapäivät Tampere-talossa, Tampere 5.-6.11.2009 (Effects of the medical use of radiation, UNSCEAR report. In the book: Lectures. XXXIII Radiation Safety Conference at Tampere Hall, Tampere 5–6 November 2009. Tampere: Lege Artis Oy; 2009. p. 82–86.

Niemelä Jarkko. Hammas-TT:n laadunvalvonta ja vastuullinen käyttö. Kirjassa: Luennot. XXXIII Sädeturvapäivät Tampere-talossa, Tampere 5.-6.11.2009 (Quality control and responsible use of dental CT. In the book: Lectures. XXXIII Radiation Safety Conference at Tampere Hall, Tampere 5–6 November 2009. Tampere: Lege Artis Oy; 2009. s. 90–94.

Tenkanen-Rautakoski Petra. Uutta STUKin ohjeista, päätöksistä ja selvityksistä. Kirjassa: Luennot. XXXIII Sädeturvapäivät Tampere-talossa, Tampere 5.–6.11.2009 (Whats´s new in STUK instructions, decisions and studies. In the book: Lectures. XXXIII Radiation Safety Conference at Tampere Hall, Tampere 5–6 November 2009). Tampere: Lege Artis Oy; 2009. p. 77–81.

Alara magazine

Venelampi E. Työpaikkojen radon on mitattava korkean radonpitoisuuden alueilla (Radon at workplaces must be measured in areas of high radon concentrations). Alara 2009; 4: 18–19.

Academic thesis works

Mäkinen A. Natiiviröntgentutkimuksista väestölle aiheutuvan säteilyannoksen määrittäminen. Röntgenhoitajan opinnäytetyö. Metropolia Ammattikorkeakoulu (Determination of the radiation dose sustained by the public from plain X-ray examinations. Academic thesis work for a radiographer. Helsinki Metropolia University of Applied Sciences), 2009.

Toroi P. See Publications in STUK series.

Bulletins and brochures

Säteilytoiminta ja turvallisuus. (STO:n yleisesite) (Radiation practices and safety. (Brochure of the Department of Radiation Practices Regulation (STO)). Helsinki; STUK: 2009.

APPENDIX 3

ST Guides published by STUK. Situation as of 31 December 2009.

General Guides

ST 1.1 Safety Fundamentals in Radiation Practices, 23 May 2005
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 Safety, 10 December 2009
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 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 Doses, 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