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Radiation practices

Annual report 2011

Erkki Rantanen (ed.)

Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

STUK

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Abstract

1791 safety licences for the use of radiation were current at the end of 2011. 1702 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 575 inspections of licensed practices in 2011. 633 repair orders and recommendations were issued in the course of inspections.

A total of nearly 11 700 workers were subject to individual monitoring in 2011 and about 143 000 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. 166 workplaces including a total of 288 work areas were subject to radon monitoring during 2011. Just over 3600 cockpit and cabin crew members were monitored for exposure to cosmic radiation.

STUK was involved in four ionizing radiation research projects, and also took part in an international expert group evaluation of STUK research activities.

New alpha and beta sources were procured for metrological activities and a ^{60}Co irradiation device procured in 2010 was installed and taken into use. Calibration and testing services continued as in previous years.

Regulatory control of the use of non-ionizing radiation in 2011 focused particularly on mobile phones, sunbeds and lasers. Orders were issued to 5 responsible parties to discontinue the use of tattoo removal lasers. 7 sunbed facilities were inspected and 10 on-site laser display inspections were performed. Five mobile phone types were tested in market surveillance of wireless communication devices. Non-ionizing radiation research activities were also subjected to the evaluation of STUK research activities conducted by an international expert group.

There were 46 abnormal incidents involving the use of radiation in 2011. 13 of these incidents concerned the use of radiation in industry, research and education, 29 involved medical uses of radiation, 1 arose in transportation of radiation sources and 3 concerned the use of non-ionizing radiation. None of these incidents had serious consequences.

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Management foreword

Eero Kettunen
Director
Department of Radiation Practices Regulation (STO)

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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.

A total of nearly 7900 workers involved in the use of ionising radiation were subject to individual monitoring in 2011. This figure excludes nuclear power plant workers. The sharpest increase in the number of people subject to individual monitoring in recent years has occurred in the field of veterinary science. In no case did the effective dose of a worker in 2011 exceed the annual dose limit or the five-year dose limit for workers.

Exposure to natural radiation at work continued to increase, and this increase particularly affected flight crews, who are the occupational group suffering the greatest exposure. The number of flight personnel subject to individual monitoring increased by 6 per cent and the total dose rose by nearly 10 per cent.

Work to update the individual dose monitoring registers continued during the year under review, engaging a substantial part of the working capacity of this regulatory control team. The individual dose register will be completed during 2012.

The increased number of urgent safety licence applications previously observed in the regulatory control operations of STUK has continued. In many cases the application was submitted to STUK only when it was time to take an appliance into use, and sometimes even after the appliance had already been taken into use. Focused and enhanced control measures have revealed an increasing number of unlicensed appliances found in the course of inspections and regulatory control surveys. This may indicate a deteriorating safety culture that should be tackled more effectively at places of use. STUK will continue to conduct various regulatory control surveys in addition to normal inspection work, and will highlight the aspect of safety culture at training events.

43 abnormal incidents in the use of ionizing radiation were reported during the year under review, exceeding the figure for the preceding year by more than 10. STUK has encouraged responsible parties to continue notifying all important incidents and to make the necessary adjustments to their work with a view to avoiding any further abnormal incidents. The falling notification threshold is one factor to bear in mind when considering the reason for the increase in notifications of abnormal incidents to STUK. Abnormal incidents are discussed at training days and conferences arranged by STUK, and notifying them is important for joint training purposes in the sector. STUK carefully monitors the nature of abnormal incidents and focuses its advisory and regulatory control measures in the manner required to ensure high safety standards.

Work has been done with industries using recycled metal to ensure the removal of radiation sources from the recycling process and a good level of preparedness for potentially hazardous situations. The recycled metal trade is an international business and it has become more likely that scrap metal consignments will contain undesirable radiation sources that are difficult to detect by measurement. During the year

under review STUK prepared a poster for use by metal recycling enterprises providing advice to facilitate detection of the most common radiation sources.

The need for radiotherapy and the number of treatment sessions have continued growing in Finland, and the number of radiotherapy appliances will increase in coming years. New therapy techniques enabling better dose precision are also being introduced. One challenge in new therapy techniques is verifying the precision of patient doses. STUK has conducted dose verification research work as part of the European EMRP project. The findings of this research have been applied in regulatory control work.

The largest source of exposure to man-made radiation involves the use of radiation in health care. Although increased use of CT scans is the largest factor in rising patient doses, this growth has been successfully managed in Finland. 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. A project co-ordinated by STUK and financed by the European Commission is assessing the population dose due to diagnostic X-ray and nuclear medicine examinations for the first time in Europe, and is due for completion in 2012.

The radiation safety authorities of the Nordic countries have prepared a joint opinion on CT scans stressing the need to avoid needlessly precise imaging and unnecessary multiple exposures. It was observed when preparing this opinion that the increase in radiation doses was significantly smaller in Finland than in the other Nordic countries.

One priority for regulatory control of the use of radiation in health care during the year under review was to improve supervision of dental X-ray imaging. STUK conducted a survey of X-ray equipment suppliers and sent an inventory query to all responsible parties running dental X-ray practices. Guidelines were revised during the year under review and a joint opinion was prepared under the co-ordination of STUK concerning radiation safety training and qualification requirements of health care professionals using new imaging methods. This opinion will be completed during 2012.

Regulatory control of practices causing exposure to natural radiation is an important part of the work of STUK and renewed interest in mining operations in Finland will ensure even greater emphasis on this area in future. Expertise in this field was further enhanced during the year under review. A revision of the natural radiation monitoring register was prepared as part of a more extensive update of regulatory control registers.

New radiation sources were procured to maintain accuracy and reliability in radiation measurements. STUK now has an adequate number of radiation sources of varying size, enabling the authority to provide the radiation meter calibration and testing services that are required in Finland. A large ^{60}Co source obtained for radiotherapy clinic requirements in 2010 was taken into use at the beginning of 2011.

The Non-Ionizing Radiation Unit (the NIR Unit) serves as a regulatory authority for non-ionizing radiation and provides specialist assistance to other public authorities. Regulatory control of non-ionizing radiation has focused particularly on lasers, sunbed facilities and mobile phones. Key research areas in recent years have been mobile phone dosimetry studies and motion induction fields in a static magnetic field. Considerable effort has been applied in recent years to providing public information on the safety of electromagnetic fields and optical radiation.

Increased attention was paid in 2011 to regulatory control of tattoo removal lasers. Finnish legislation prohibits the use of powerful class 4 lasers on the skin or eyes by persons other than health care

professionals. Use of the non-compliant appliances disclosed through enhanced regulatory control measures was prohibited and these appliances were entirely withdrawn from the market in some cases.

Regulatory control of indicator lasers continued in association with the Finnish Customs Authority. This regulatory control has been effective. The relatively cheap appliances hazardous to the eyes that anyone could formerly order online no longer enter Finland through the Customs under the laser device designation. Laser devices with powers of up to 200 mW have been detained by the Customs. The incidence of such laser beams into the eyes at close range can destroy the *fovea centralis* area of the retina responsible for maximum acuity of vision.

Significantly more information concerning the carcinogenicity of sunbed use has become available in recent years and the International Organization for Research on Cancer (IARC) has accordingly assigned sunbeds to its highest cancer risk category. In 2011, the NIR Unit was actively involved in work to amend the Radiation Act (592/1991) under the direction of the Ministry of Social Affairs and Health (STM). This amendment will prohibit sunbed operators from exposing persons under 18 years of age to sunbed radiation, and will also require them to check the age of their customers and ensure that operating staff instruct customers in using sunbed appliances. The new legislation is expected to take effect on 1 July 2012.

Regulatory control of electromagnetic fields focused on mobile phones and fields generated by new technology. The highest measured mobile phone SAR value of 1.07 W/kg did not exceed the maximum value prescribed in the Decree of the Ministry of Social Affairs and Health (294/2002).

A review of power lines was completed. This provides information on low frequency magnetic field risks and clarifices in detail the recommendation of STUK with respect to building construction in the vicinity of power lines.

In 2011, the European Commission was engaged in work to prepare a new Directive on health and safety at work in relation to electric and magnetic fields. STUK assisted the STM occupational health department in drafting the Directive. STUK prepared a new proposal for amending annex 2 of the Directive to comply more closely with the latest guideline values of the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

In the field of research, STUK and the Finnish Institute of Occupational Health submitted a joint application for finance from the Finnish Work Environment Fund for a research project seeking to determine the exposure of workers to magnetic fields, and to prepare general safety guidelines for magnetic imaging work. The Fund granted finance to this research work for three years.

Two extensive research projects were also completed. In one of these projects, human test subjects were exposed to mobile phone radiation and the biological responses caused by this exposure were studied by various methods (including PET imaging, monitoring of temperature and blood flow measurements using near-infrared spectroscopy). The NIR Unit manufactured the apparatus used for test subject exposures and determined their precise exposure levels numerically. The function of STUK in the other completed research project was to develop a calibration method for SAR measurement probes at frequencies of less than 400 MHz and a calibration method for limb current measuring instruments at frequencies of between 10 and 50 MHz. The effectiveness of these methods was tested by comparison measurements.

The NIR Unit received several questions from members of the public, radiation users, the media, and other parties interested in non-ionizing radiation during the year.

The outlook and strategy of the NIR Unit were considered at various development meetings held during the year under review. Regulatory control of the radiation safety aspects of lasers and sunbeds imposes a major radiation safety challenge in the field of optical radiation, whereas the challenge with respect to electromagnetic fields is to produce and disseminate solid expertise when new technology is introduced that causes concern for many members of the public.

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, importing, exporting, storage, transportation, and the process of rendering radioactive waste harmless. The expression “radiation practices” refers to radiation use 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.

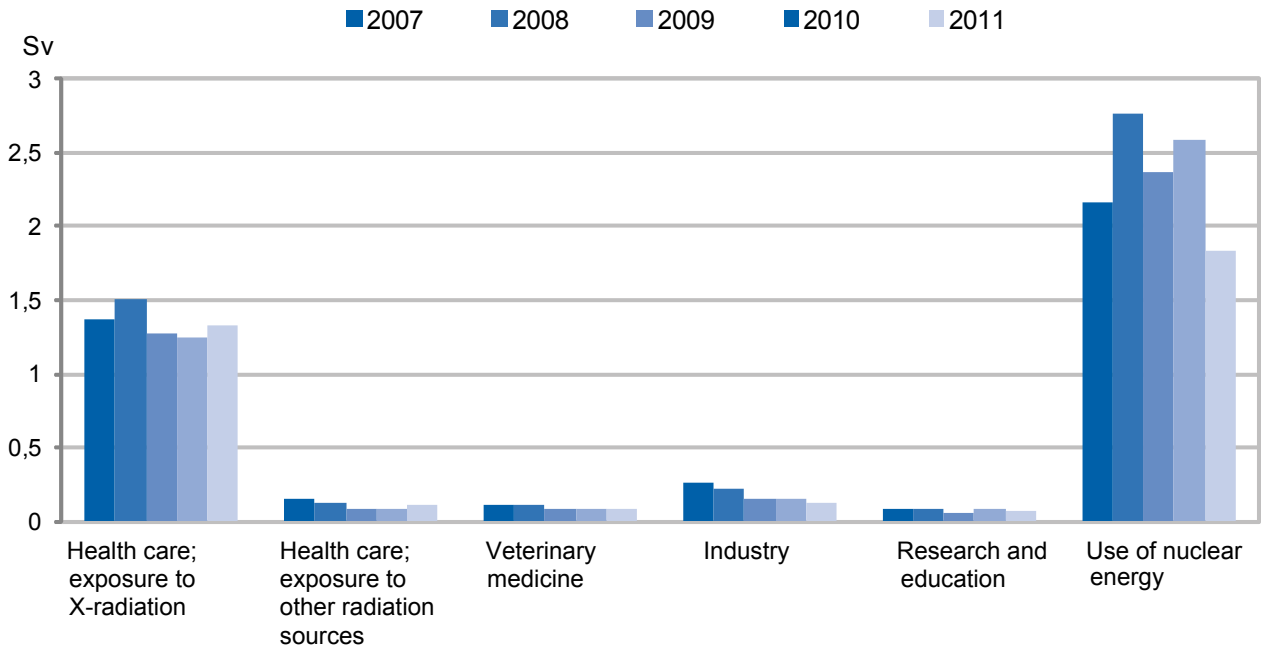

Figure 1. Combined doses ($H_p(10)$) of workers subject to individual monitoring by occupational category, 2007–2011. $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the use of X-rays in health care and veterinary practices, in which 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 of radioactive materials, installation/servicing/technical test operation, trade/import/export and services pertaining to the use of radiation and radioactive materials (see Tables 14 and 15 in Appendix 1).

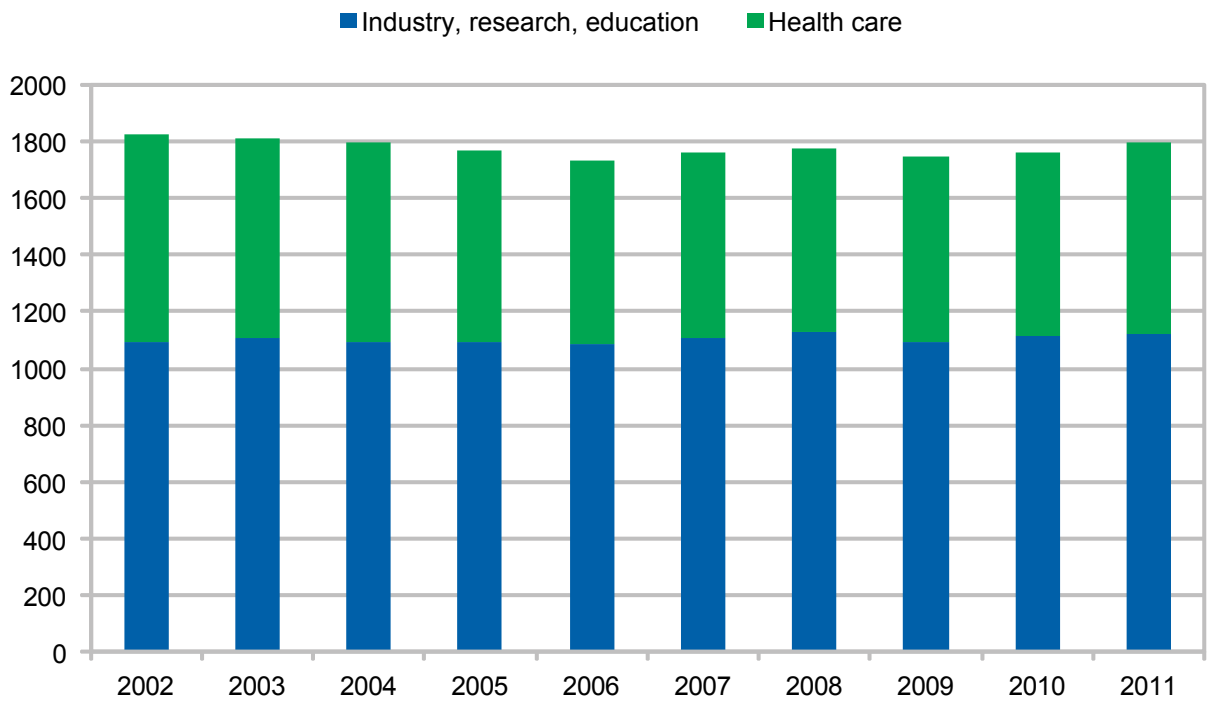

Figure 2. Current safety licences, 2002–2011.

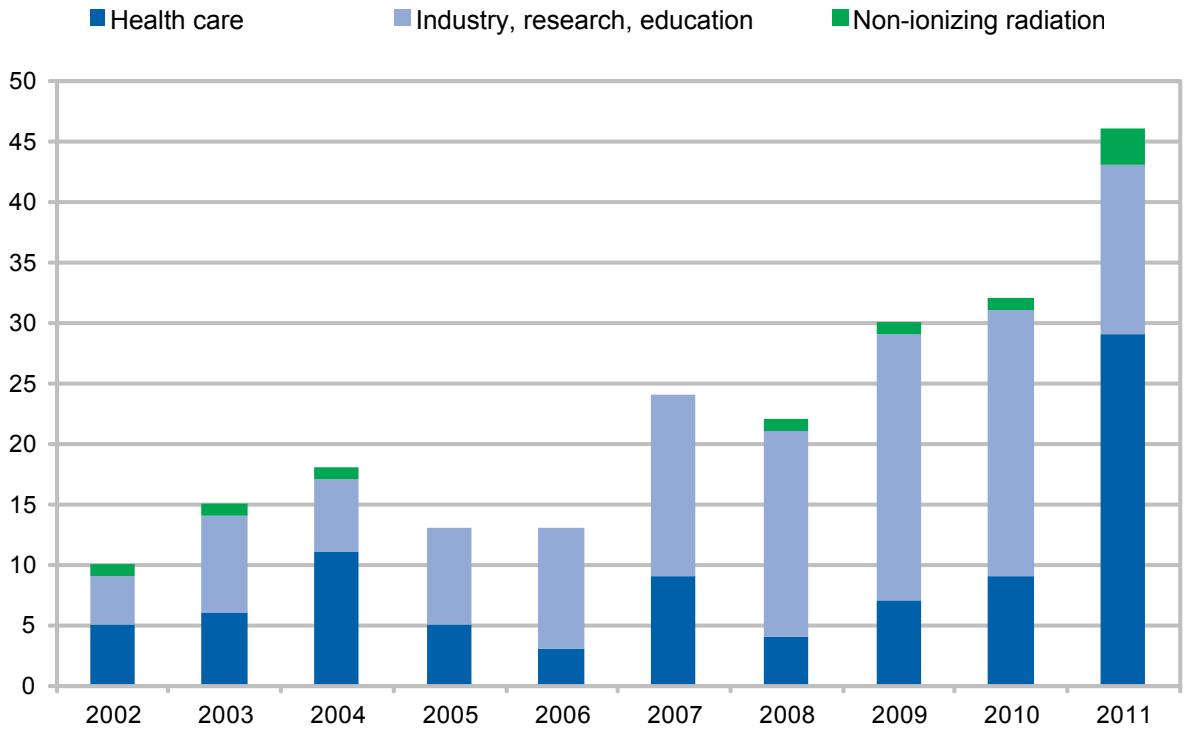

Figure 3. Abnormal incidents, 2002–2011.

2 Regulatory control of the use of ionizing radiation

2.1 Use of radiation in health care and veterinary practices

Safety licences

At the end of 2011 there were 673 current safety licences for the use of radiation in health care (see also Figure 2), of which 235 concerned veterinary practices. A total of 284 licensing decisions (new licences or amendments to previous licenses) were issued during the year. 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.

The average time taken to process safety licence applications for X-ray practices in health care was 15 days. More than 30% of all licence applications were processed as urgent applications, meaning that the application was submitted to STUK only when it was time to take an appliance into use, and sometimes even after the appliance had already been taken into use.

Radiation appliances, 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 2011.

X-ray practices

STUK introduced MGD (Mean Glandular Dose) as a new reference quantity for mammography and established an associated reference level. One reason for introducing this quantity was progress in mammography appliance technology, including new anode and filtration materials in mammography appliances and the ability to use them in combinations for adjusting properties of the radiation spectrum. The surface dose in mammography imaging may then be kept constant even as the average MGD caused by the examination varies and the radiation-related risk also changes accordingly. Setting of the reference level was based on phantom measurements made by STUK in on-site inspections and also on doses determined with patients. Corresponding reference levels used internationally were also taken into account. The MGD reference level for Finland was set at 1.5 mGy. Use of the previous quantity ESD (Entrance Surface Dose) and its reference level of 8 mGy may continue in addition to the new MGD quantity and its reference level during a transition period until the end of 2013.

STUK conducted its first survey of X-ray appliance suppliers in 2011, inviting them to report the health care X-ray appliances that they had installed or reinstalled in 2010. The survey revealed 1 mammography appliance and 1 mobile imaging appliance lacking the required safety licence. It also disclosed numerous dental X-ray appliances that had not been notified to the STUK register.

In addition to its survey of X-ray equipment suppliers, STUK also sent an inventory query to all practitioners of dental X-ray practices. The inventory resulted in the removal of 264 appliances and inclusion of 242 appliances in the STUK register of dental X-ray appliances. 103 responsible parties were also removed from the register.

STUK´s decision exempting the use of dental X-ray appliances from safety licence requirements in conventional dental X-ray practices was revised. A new guide on dental X-ray practices was also issued (Guide ST 3.1), together with two publications in “Advice from STUK” series. One of these concerns quality assurance and structural radiation shielding in dental X-ray practices, and the other concerns the use of cone beam CT scanners. The revised licensing exemption decision clarifies the distinction between forms of dental X-ray practices that require a safety licence and

those that are exempt. The revised Guide ST 3.1 in turn specifies in more detail the practical requirements governing dental X-ray practices. Cone beam CT scans are examinations requiring special indications and expertise, in which the radiation exposure sustained by the patient is greater than the exposure caused by conventional dental X-ray examinations.

STUK co-ordinated the preparation of an opinion on the radiation safety training of health care professionals performing cone beam CT scanning. Supplementary training of this kind is required under Guide ST 3.1 for individuals with insufficient radiation safety training in their basic training. An opinion has been prepared on the radiation safety training of nursing staff and this will be published during 2012. A draft opinion has also been formulated on the radiation safety training of dental practitioners, and this was considered at a conference of stakeholders in January 2012. It will also be published during 2012.

Some discussion arose concerning abnormal incidents that occurred in health care X-ray practices during 2011. The number of such incidents reported to STUK was significantly larger than in previous years. Where previously STUK had on average been advised of only one abnormal incident in X-ray practices every two years, a total of 16 incidents were reported in 2011 alone. This sudden increase in notifications was not due to any rise in the number of abnormal incidents, but rather resulted from the fact that STUK had not been advised of earlier cases. This highlighted the need to agree standard practices concerning the cases in which STUK must be notified of abnormal incidents. The matter was discussed at a conference for specialists in X-ray technology arranged by STUK in September (see Chapter 8) and the debate was continued in the final months of the year, with a view to clarifying the standard practice in early 2012.

Official guidelines are being prepared for veterinary X-ray practices. These guidelines will form an integrated module specifying the principal details that are relevant to radiation safety and safety licence procedures. A draft Guide ST 8.1 “Radiation safety in veterinary X-ray examinations” was circulated for comments at the end of 2011. The new guide was confirmed in early 2012.

Contributions to professional journals were also written on contemporary issues in regulatory control of dental and veterinary X-ray practices.

Nuclear medicine

In 2011 STUK conducted an investigation into the use of SPECT-CT and PET-CT appliances in Finland. This revealed a total of 26 appliances, comprising 21 SPECT-CT and 5 PET-CT devices. The number of devices found in 2011 was nearly three times the number found in 2006.

The investigation also requested details of radiation user training for using an appliance, quality control for appliances, estimated patient doses for the most common examinations and optimization of CT scanning programs. Responses were received for 20 appliances (16 SPECT-CT and 4 PET-CT). The survey findings for training, quality control and patient doses are shown in Tables 3, 4 and 5 of Appendix 1.

The survey indicates that although quality control measurements are taken regularly for SPECT-CT and PET-CT appliances at all hospitals, some of the tests recommended by STUK in the quality control guide for health care X-ray appliances (Advice from STUK 2/2008) and the quality control guide for nuclear medicine examination appliances (Advice from STUK 1/2010) are not performed. 12 hospitals failed to report the tests performed on CT scanners. The survey indicated that there was no general practice of optimizing CT scans, with only 11 hospitals reporting that they performed optimization.

These findings support the conclusion that that hospitals have yet to apply the quality control guides in practice. The regulatory control work of STUK has been enhanced for combination CT scanners. New guidelines prepared for paediatric CT scanning also include directions for optimizing SPECT-CT and PET-CT.

Radiotherapy

In 2011 STUK conducted an investigation into radiotherapy practices in Finland. For this purpose a questionnaire was sent to all hospitals administering external or internal radiotherapy. The survey did not include radionuclide therapy, as

this was covered by the data collected in a previous study in 2009.

The findings indicated that radiotherapy was administered to some 14 000 patients in Finland in 2010. This figure was 32% higher than a decade ago.

A new Guide ST 2.1 concerning safety in radiotherapy (in force as of 1 June 2011) imposes minimum staffing requirements. The survey indicated that whereas all hospitals meet these requirements with respect to radiographers and nearly all hospitals have the required hospital physicists, only half of all hospitals have a specialist in oncology working in radiotherapy. Some radiotherapy practices were ordered to rectify staff shortages on inspection. Although staffing has increased by 46% over the last decade, therapy technologies have become more complex, and special technologies are generally more time consuming.

In addition to their treatment duties, radiographers working in radiotherapy are also involved in creating beam modifiers at nearly all clinics. At least two radiographers will generally be involved in any therapy simulation. Radiographers are responsible for at least half of all dose plans at one in two clinics, but do no dose planning at all at one third of all clinics. Nurses and practical nurses also perform various duties at most radiotherapy clinics.

The number of radiotherapy accelerators has risen by 60% from 25 to 40 over the last decade (see Figure 4). The number of therapy beams has increased because multi-energy accelerators have supplanted single-energy accelerators (see Figure 5).

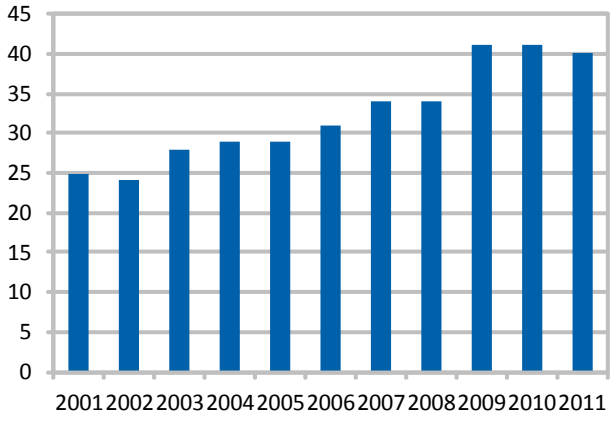

Figure 4. Radiotherapy accelerators in Finland, 2001–2011.

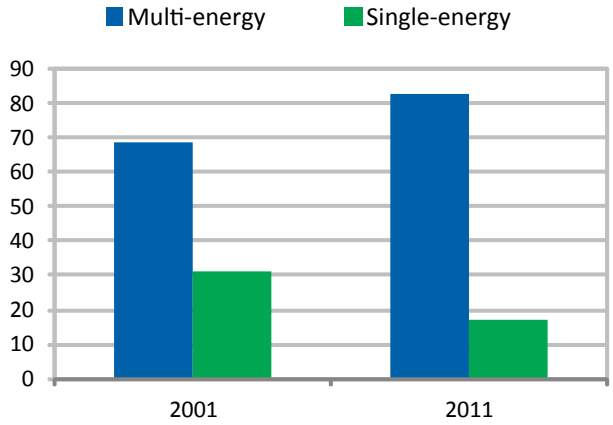

Figure 5. Proportions (%) of single-energy and multi-energy radiotherapy accelerators in 2001 and 2011.

Comparison measurements taken between STUK and hospitals indicated that radiotherapy dose precision is very high: the average discrepancy in measurements was 0.3% in photon beams and -0.5% in electron beams. No doses jeopardizing safety in treatment were detected on the basis of comparison measurements.

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 1118 current safety licences for the use of radiation in industry, research and education at the end of 2011 (see also Figure 2). The numerical distribution of radiation practices referred to in these licences is shown in Table 6 of Appendix 1.

STUK requested an annual notification from all known vendors of X-ray appliances (51 vendors) concerning appliances sold and their custodians. These notifications disclosed 9 responsible parties who had failed to apply for a licence on taking one or more X-ray appliances into use. It was also discovered that 20 licensees had acquired one or more new X-ray appliances without notifying this to STUK. STUK issued the required orders to rectify the observed shortcomings and supervised appropriate licensing of all of the foregoing appliances.

Radiation appliances, sources and laboratories

Table 7 in Appendix 1 shows details of radiation appliances and sources, and of radionuclide laboratories operating in industry, research and education at the end of 2011.

Table 8 in Appendix 1 shows details of radionuclides used in sealed sources.

High Activity Sealed Sources

There were 145 high activity sealed sources (HASS) in Finland at the end of 2011. Following an amendment to the Radiation Act that took effect at the beginning of 2006, a HASS waste management plan must be provided before a safety licence can be granted. STUK has separately investigated the waste management plans for older sources. It turns out that most old sources can be returned to the source manufacturer, even though the decommissioning costs can be very high in some cases. No return option has so far been found for 6 sources. Some of these sources can probably be consigned to the national storage facility for low-level radioactive waste if necessary, but this possibility has yet to be separately investigated for each source.

Sealed source inventory

In 2011 STUK prepared a sealed source inventory for all of the 79 licensees using no fewer than 20 sealed sources. The inventory served as the basis for making several dozen amendments and specifications to safety licences and the STUK register of radiation sources.

2.3 Inspections of licensed radiation practices

343 inspections were made of the use of radiation in health care and veterinary practices. These inspections resulted in 88 repair orders or recommendations issued to the responsible parties. A further 9 appliances were also found that did not have the safety licence required for their use.

232 inspections were made of the use of radiation in industry, research and education. These inspections resulted in 545 repair orders or recommendations.

Table 9 in Appendix 1 shows the number of inspections itemized by type of inspection. Table 10 in Appendix 1 shows the number of inspections itemized by type of practice.

2.4 Inspections of notifiable dental X-ray practices

1702 responsible parties were engaged in dental X-ray practices. Patient radiation exposure due to dental X-ray imaging was measured in 838 appliances. The average dose was 1.7 mGy. This dose corresponds to the dose administered at the surface of the cheek (Entrance Surface Dose, ESD) when imaging a tooth. The reference level of 5 mGy was exceeded in 14 imaging appliances.

73 notifiable dental X-ray appliances were inspected. 37 repair orders and 7 repair recommendations were given. Inspections disclosed 33 dental X-ray appliances that had not been duly notified to STUK for registration. Doses exceeding the reference level were measured in 18 panoramic tomography appliances.

2.5 Importing, manufacture and exporting of radioactive materials

Details of deliveries of radioactive materials to and from Finland and of manufacturing of such materials in Finland in 2011 are shown in Tables 11–13 of Appendix 1. The figures in the tables are based on data gathered from radiation safety licensees engaged in trading, importing, manufacturing and exporting. These tables exclude radioactive materials procured by responsible parties for their own use from elsewhere within the European Union, and consigned from the said use to other European Union countries. They also exclude radioactive materials supplied to other countries via Finland.

Table 11 of Appendix 1 excludes smoke detectors and fire alarm system ion detectors containing americium (^{241}Am). 193 000 of these were imported with a combined activity of approximately 5.6 GBq. Approximately 4700 smoke detectors with a combined activity of 0.14 GBq were exported from Finland. The data in the tables also exclude imported lamps and fuses containing radioactive materials. Some of these appliances contain small quantities of tritium (^{3}H), krypton (^{85}Kr) or thorium (^{232}Th).

2.6 Radiation doses of workers

A total of nearly 11 700 workers engaged in radiation work were subject to individual monitoring in 2011. Including doses falling below the recording level, about 143 000 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 in 2011 exceed the annual dose limit of 50 mSv or the five-year dose limit of 100 mSv. In no case did the dose to a worker's hands exceed the annual limit of 500 mSv.

The total recorded $H_p(10)$ values were 1.7 Sv sustained in the use of radiation and 1.8 Sv sustained in the use of nuclear energy. The total recorded doses were 5.5% higher in the use of radiation and nearly 30% smaller in the use of nuclear energy than the corresponding figures for the previous year. Total doses in the use of nuclear energy vary considerably each year depending on the duration of annual nuclear power plant servicing and the duties performed in servicing work at these facilities.

The largest $H_p(10)$ value in health care was 33 mSv recorded in the case of an interventional radiologist. This corresponds to an effective dose of 0.6–3.3 mSv. The largest effective dose in health care from a source other than X-radiation was 15.1 mSv recorded in the case of a nuclear physician. The largest $H_p(10)$ value in veterinary practice was 9.5 mSv recorded in the case of a veterinarian performing X-ray examinations. This corresponds to an effective dose of 0.2–1.0 mSv. The largest effective dose in industry was 7.2 mSv. The largest effective dose in research was 12.2 mSv sustained by a person using a wide range of radiation sources.

The largest dose to the fingers was 320 mSv, recorded in the case of a research worker using unsealed sources.

Table 14 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 15. Table 16 shows the doses in 2011 of persons sustaining high levels of exposure or of numerically large worker groups. The measurement results ($H_p(10)$ values) shown in the figures and tables are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the use of radiation in health care and veterinary X-ray practices, in which workers use personal protective shields, and in which the dose is measured by a dosemeter on the exposed side of the shield. The effective dose is then estimated by dividing the measurement result ($H_p(10)$ value) by a factor between 10 and 60.

2.7 Approval decisions and verification of competence

Training organizations providing radiation protection training for radiation safety officers

In Guide ST 1.8 STUK has stipulated the minimum qualifications of the radiation safety officers who are responsible for the safe use of radiation. Training organizations that arrange training and competence exams for radiation safety officers must apply to STUK for the right to arrange such exams. Approval for arranging radiation safety officer exams and training was granted to seven training organizations in 2011. A total of 21 such approval decisions were current at the end of 2011.

The number of competence areas provided by training organizations increased in 2011 to cover all of the competence areas of Guide ST 1.8 when STUK approved a training organization that arranges radiation safety officer training and exams for installation, repair and servicing of radiation appliances and sources in health care.

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 343 STUK-accredited responsible medical practitioners in Finland at the end of 2011, of whom 24 were accredited during the year under review.

2.8 Radioactive waste

STUK maintains a national storage facility for low-level radioactive waste. The activities or masses of the most significant waste held in the storage

*) www.stuk.fi/proinfo/koulutus/sateilysuojelu/fi_FI/koulutusorganisaatiot_1/ (in Finnish only)

facility are shown in Table 17 and the waste quantities consigned to the storage facility in 2011 are shown in Table 18 of Appendix 1.

2.9 Abnormal incidents

Under section 17 of the Radiation Decree (1512/1991), STUK must be notified of any abnormal incident 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 43 cases in 2011 in which abnormal incidents or situations occurred or were suspected in the use of ionizing radiation, of which 13 concerned the use of radiation in industry, research and education, 29 involved medical uses of radiation, and 1 arose in transportation of radiation sources (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 2002 and 2011.

The case histories set out below specify the abnormal incidents in the use of ionizing radiation that occurred in 2011 and the reasons for them, together with the measures taken on account of each incident.

Incident 1

A gamma radiography team working on a large construction site left a tank containing a gamma ray source (^{74}Se) unsupervised while preparing the next imaging location. A fire inspector conducting rounds noticed the unsupervised source and submitted a report. No extraordinary dose was sustained by any person due to the incident, as the device had not yet been set in condition for measurement.

Incident 2

Based on accompanying documentation, some metal items found in a box in a university library store were suspected to contain radium sources used for radiotherapy. The sources had been used between 1930 and 1969. The box also contained a radium bottle that, according to instructions, could be used for making "healthy water". The radium bottle probably dated from the early 20th century.

An inspector from STUK visited the site to ensure and verify the nature of the items in question by taking radiation measurements. The items suspected of being radiotherapy sources did not contain any radium (^{226}Ra) or other radioactive material, but were empty protective covers for radium sources. The radium bottle was also found not to contain any radium. The items were left in the custody of the university for use as museum artefacts.

Incident 3

On 4 occasions an ^{241}Am source delivered to a steel mill in a consignment of scrap metal was sent to the smeltery. No radioactive material escaped the confines of the mill, nor was any radiation hazard caused to workers. The melting down of the source did not contaminate the metal batches in question, as most of the americium was captured in the slag from the process and a minimal quantity was released in exhaust gas dust. Cases of this kind have also occurred in previous years. ^{241}Am sources end up in the smeltery because this isotope is difficult to detect in large consignments of metal due to the soft (60 keV) gamma radiation that it emits.

Incident 4

A fitter at an industrial plant was assigned to weld cracks in a flue gas cooling reactor. The shutter of a radiation source housing on the side of the reactor could not be locked in the closed position. The fitter decided to detach the radiation source from its mountings and carried it for a distance of 3 metres with the primary beam of the radiation source pointing away from the fitter's body. The equivalent dose to the fitter's upper body did not exceed 30 µSv. The responsible party has repeated the safety review for tank work permit procedures.

Incident 5

An installation company worker sustained an excessive dose to the hands during tank insulation work. The shutter of a radiation source in the tank level meter was in the open position during the work

and the fitter's hands were momentarily exposed to the radiation beam. Based on measurements taken by the radiation safety officer and the duration of exposure, the equivalent dose to the hands was estimated at not more than 5 µSv. The reasons for the incident were the fitter's disregard for warning signs and inadequate direction and supervision of the work.

Incident 6

Following a coffee break a radiographer initiated X-ray imaging in an elaborate imaging location. Another plant worker was sitting quietly on a coffee break in a recessed area of the location about 6 metres from the X-ray tube during this imaging. On returning from a coffee break a third worker observed the situation and alerted the radiographer that a worker was sitting in the imaging location. The X-ray imaging lasted for a total of 23 seconds at a voltage of 180 kV. The dose sustained by the worker was estimated at no more than approximately 5 µSv. The cause of the incident was considered to be inadequate supervision of radiography.

Incident 7

The sender of a radiation source had put two radiation source housings together and enclosed four radiation sources within them. The consignee was notified of two radiation sources. The activity of each of the unreported radiation sources (^{137}Cs) was 18.5 GBq. The radiation source consignee was estimated to have sustained an excessive dose of some 150 µSv in the course of dismantling the radiation source housings. The cause of the incident was an unauthorized transfer of radiation sources into temporary housings and failure to notify radiation sources. STUK called attention to the need to use an alarm dosemeter when unpacking radiation sources from their housings.

Incident 8

A responsible party selling radioactive materials reported that an extra radiation source (^{137}Cs, 18,5 MBq) had been found in its stock. Delivery of the source from the manufacturer to a customer had been cancelled for some reason and the source had been returned to the responsible party's store. The radiation source was sent to a recognized facility.

Incident 9

Two workers were engaged in pipe modification work at an industrial plant. Disengaging the old pipe involved first removing a density gauge containing a radiation source that was mounted on the pipe. The workers failed to ensure that the latch of the source housing was locked in the closed position when lifting the radiation source out. The source was nevertheless lifted onto the floor without exposing the workers to its primary beam. The reason for the risk of exposure was failure to comply with instructions given.

Incident 10

A metal cylinder with a radiation hazard warning sign was found in an old factory area. Based on photographs and the text of the warning sign, STUK determined that the item was an X-ray tube. STUK issued instructions to detach the warning sign from the cylinder, which could then be discarded as electrical and metal scrap.

Incident 11

A leak occurred in a transmission line when a radioactive solution was moved in a particle accelerator. The leak caused spillage of radioactive solution onto the hands of two workers. Despite using protective equipment, their hands were contaminated. It was estimated that the incident caused equivalent doses of approximately 15 mSv and 4 mSv to the hands of the workers.

Incident 12

A worker sustained an extraordinary radiation dose for a period of about one month when making test images using an X-ray appliance. The imaging was performed in a room with a lead shielding on only part of the wall due to a construction error. The worker did not have the use of a personal dosemeter, but the extraordinary dose was estimated at approximately 40 µSv on the basis of measurement and working time.

Testing with the X-ray appliance was suspended after the shortcoming was discovered. The X-ray room was not used until the required lead shielding had been installed on the wall. In an inspection conducted after the repairs had been made STUK also found that there were minor defects in the shieldings of other imaging rooms used on the site. This inspection resulted in orders to install

additional shielding and to take other measures to improve radiation safety (including individual monitoring for workers).

Incident 13

The user of airport X-ray equipment contravened instructions by intentionally using a fluoroscopy appliance for personal fluoroscopy. It was estimated that the person concerned sustained an effective radiation dose of approximately 3 µSv from this incident.

Incident 14

A radiation source remaining from the bankrupt's estate of a freight forwarding business was found while cleaning a customs warehouse. The source had been part of a device assembly bound for Russia. STUK was contacted by the enterprise assigned to clean the warehouse. The consignment had not originated in Finland, but was a transit shipment. While a request had been sent to the clients of the bankrupt's estate to collect their goods, no party had missed the consignment in question, and for some reason the consignee could not be determined from the consignment documentation. As the source could not be delivered to the consignee, STUK instructed the bankrupt's estate to send it to a recognized facility for disposal.

Incident 15

82 seeds of ^{125}I were implanted into the prostate gland of a hospital patient. Review images taken on the following day indicated that 2 of the seeds were not in the prescribed location. Bronchial and other X-ray images of the patient were taken to ensure that the seeds had not been carried in the bloodstream to capillaries. The equipment and premises were also checked, but the missing seeds were not found. The hospital waste and laundry bins had already been changed and could no longer be searched.

Incident 16

A health centre performed conventional thorax imaging on the wrong patient. The patient was collected for imaging from the ward and asked for a name at this time. The patient's date of birth was not checked. The effective dose sustained by the patient from the imaging was about 0.06 mSv. The images taken were archived for possible future requirements.

Incident 17

A urinary tract CT scan was performed at a hospital on a patient who was found to be pregnant on the day after the examination. The patient had taken a pregnancy test on the day preceding the scan and the result of this test had been negative. The estimated effective dose sustained by the foetus was approximately 9.8 mSv.

Incident 18

A thoracic CT scan was performed on the wrong patient at a hospital. There were two patients of the same sex and with the same surname in the ward from which the patient was collected for the scan. The ward office directed the orderly to the wrong person. The patient was not asked to give a name, but responded to the wrong name. Neither the orderly nor the technician who performed the scan verified the patient's personal identity number. The patient sustained an effective dose of about 4 mSv from the scan. The staff who performed the scan destroyed the images on noticing the error.

Incident 19

A CT scan was taken of the head of a hospital patient (a woman born in 1946) involving native and contrast medium series. After the native medium series the procedure continued by administering a contrast agent to the patient using a contrast agent syringe controlled from the control room, followed by a 3-minute wait before performing the scan. In accordance with normal practice, a technician entered the exposure room to monitor the contrast medium injection. Another technician in the control room inadvertently initiated the scan immediately after the contrast medium injection. The technician in the exposure room did not have time to vacate the room before the scan ended. The scan of the patient was repeated 3 minutes after injecting the contrast medium. It was estimated that the patient sustained an excessive effective dose of about 2 mSv and the technician (a category B worker) sustained an effective dose of not more than approximately 0.1 mSv. These doses were estimated in the place of radiation use on the basis

of the imaging parameters and the distribution of scattered radiation notified by the appliance manufacturer.

Incident 20

Arm fracture control imaging (AP and PA images) was performed on a patient (an 11 year-old boy) at a hospital. The initial appliance selection was an automatic imaging program for a small patient in the AP direction, resulting in normal exposure and image. The next selection was automatic imaging for a small patient in the PA direction. The exposure did not shut off in the normal way, but on noticing the sound of a prolonged exposure the operator released the imaging switch. The electrical charge subsequently displayed was 204.7 mAs (4.4 mAs in the AP direction). On reconstructing the situation it was observed that the program in question had a standard factory setting (500 mAs). It is difficult to estimate the extraordinary effective dose. The normal dose for an adult patient is about 0.01 mSv, suggesting an upper estimate of the extraordinary paediatric dose of 50 · 0.01 mSv = 0.5 mSv.

Incident 21

A fluoroscopic examination of a female patient was performed at a hospital. The patient claimed that she was not pregnant. About 3-4 months later it became necessary to perform an MRI scan of the same patient, at which point it was found that she had been pregnant at the time of the fluoroscopic examination. It was estimated in retrospect that the foetus had sustained a dose of about 5 mSv from the said examination.

Incident 22

In bone imaging, three hospital patients were mistakenly administered 600 MBq of ^{99m}Tc pertechnetate instead of ^{99m}Tc-HDP, resulting in an extraordinary dose of 7.8 mSv. New imaging times were agreed for the patients concerned and the extraordinary doses were entered in their medical records.

Incident 23

A ghost image from the preceding session repeatedly appeared when imaging at a hospital using a conventional X-ray appliance and the examination had to be made again. Patients sustained additional radiation exposure from these repeated imaging sessions. About ten patient imaging sessions had to be repeated due to the fault, which was first observed in November 2009. It is suspected that the appliance creates an incorrect calibration file after high dose imaging, causing a ghost image in the next session. The appliance manufacturer is investigating the problem and the National Supervisory Authority for Welfare and Health (Valvira) has also been notified.

Incident 24

Unnecessarily large doses in CT angiograms of the neck were administered to some hospital patients owing to an error in servicing a CT scanner. The large doses were caused by incorrect settings of mA modulation and noise level controls. The doses were sustained by a few dozen patients attending examinations after the servicing session.

The dose yield of the appliance in question was measured before the servicing session and will be verified after servicing in future. Dose levels will also be monitored. No patient imaging will be performed unless doses can be successfully optimized.

Incident 25

When scanning PET-CT patients using ^{18}F-FDG the average imaging time per patient is 25 minutes and the FDG acquisition period is 60 minutes. FDG is administered to patients at 30 minute intervals to ensure that scans can be made consecutively. This means that in addition to the patient undergoing a scan, there will be two patients waiting their turn on the ward. A PET-CT scan was performed on several patients at a hospital using a trailer-mounted PET unit. A network traffic problem was detected in the image reconstruction phase of the PET-CT scanner after scanning the fourth patient. This fault could not be rectified and the patients waiting on the ward who had already received their dose of FDG could not be scanned. The patients sustained excessive radiation doses of 7.3 and 7.0 mSv due to the fault. The incident was recorded as a quality anomaly. STUK also recommended reporting the incident to Valvira.

Incident 26

Owing to a confused and error-prone computer system, a referral for CT scanning of the head and cervical spine was given to the wrong patient. The procedure was completed before the error was noticed. The effective dose sustained by the patient was about 3.6 mSv.

Incident 27

A bottle containing a radiopharmaceutical labelled with ^{99m}Tc (8 GBq) was kept in its lead jacket in a refrigerator. The lid of the lead jacket was not screwed down, but loosely positioned on top of the lead jacket. When a technician took the bottle from the refrigerator the lid of the lead jacket and the bottle fell to the floor, whereupon the bottle broke and radioactive material spread onto the floor. The technician cleaned the floor in the appropriate manner (soaking the liquid into cellulose pulp, disposing of the discarded materials as radioactive waste, washing the floor twice and covering it with absorbent paper). The technician then notified the radiation safety officer of the incident. The technician's hands and clothing were examined. No contamination was detected and no extraordinary radiation dose had been sustained. The floor was covered with a lead sheet. The incident was discussed at a ward meeting and the instructions for dealing with cases of contamination were updated.

Incident 28

An abdominal CT scan was performed on the wrong patient at a hospital. This error occurred because there were two patients with the same name on the ward and the slip given to the orderly only gave the patient's name and not the personal identity number. The patient's personal identity number was also not verified at the time of scanning. The effective dose sustained by the patient was about 23 mSv. Changes have been made in hospital practices. These include writing the initial digits of the patient's personal identity number on the slip given to hospital orderlies.

Incident 29

A cleaner remained in an X-ray room during irradiation. A radiographer had turned on the daily air calibration of a CT scanner and then left the room. Despite precautionary measures (locks, a radiation hazard warning sign) and guidelines, the cleaner had entered the X-ray room during the air calibration. It was estimated that the cleaner remained in the room for about 5 minutes, sustaining an effective dose of about 0.07 mSv.

Incident 30

A radiographer remained in the exposure room during contrast medium CT scanning. The radiogarpher was next to a poorly patient verifying intravenous administration of the contrast medium. After the contrast medium injection the radiographer remained to check the patient's condition. The scan was programmed to begin after a 60-second delay. The scan operator did not warn the radiographer in the room, nor did the said radiographer notice that scanning had begun. The radiographer was approximately 80 cm from the primary beam during the scan. It was estimated that the radiographer (a category A worker) sustained an effective dose of not more than approximately 0.2 mSv. This dose was estimated on the basis of imaging parameters and using a quality control phantom as a dummy object.

Incident 31

A patient was undergoing a full-body PET-CT scan using ^{18}F-FDG in a trailer-mounted PET-CT scanner. The examination comprised an initial CT scan followed by a PET scan. The CT scan was interrupted due to a hardware fault at the scout stage. The appliance was shut down and rebooted, after which it functioned normally. The scout scan of the patient had to be repeated, causing an excessive radiation dose of about 0.2 mSv to the patient.

Incident 32

A radiopharmaceutical injection of a hospital patient for the purpose of bone imaging failed and radioactive material spread into the patient's forearm in the vicinity of the injection site. The patient was sent for imaging immediately after the injection, at which point it was observed that there was insufficient activity for imaging in the patient's bloodstream. A repeat imaging session was scheduled for the patient and successfully completed.

Incident 33

Hospital patients were undergoing PET-CT scans using ^{18}F-FDG in a trailer-mounted PET-CT scanner. A software fault was detected in the apparatus on commencing the first patient scan. Efforts were initially made to correct the fault locally, and then with the aid of servicing staff from the hardware manufacturer. This fault could not be rectified and no patients could be scanned. Two patients sustained unnecessary radiation doses of 7.0 and 5.8 mSv from the FDG administered to them. STUK also recommended reporting this incident to Valvira.

Incident 34

Tracking sources (two ^{57}Co sources, each of activity 7.4 MBq) used in sentinel lymph node examinations went missing from a hospital in their lead jacket in spring 2011. These radiation sources were kept in the radiopharmacy laboratory of a nuclear medicine ward subject to restricted access. It was determined from patient images that the sources had last been used at the end of March 2011. A search for the sources was conducted and all staff were interviewed without result. STUK was not notified until August 2011. By this time the activity of the sources was approximately 1.5 MBq (the exemption limit for ^{57}Co is 1 MBq). STUK pointed out that radiation sources must be kept under lock and key when not in use.

Incident 35

A breast cancer patient was injected with a radiopharmaceutical (a ^{99m}Tc-labelled nanocolloid) for sentinel lymph node imaging. A surgeon nevertheless decided that no imaging was required. The estimated radiation dose sustained by the patient was about 0.1 mSv.

Incident 36

A fire occurred at a hospital. A blood irradiation appliance used for irradiating blood products was kept in a laboratory located above the burning department. The fire also caused significant damage to the laboratory. All surfaces, including the blood irradiation appliance, were covered with soot. The temperature was also high in the initial stages of the fire. The radiation dose rate measured in the vicinity of the appliance after the fire had been extinguished did not differ from the normal background rate. A representative of the appliance manufacturer visited the location and found that the appliance could not be cleaned and had to be replaced. The appliance was moved to a storeroom pending its return to the manufacturer.

Incident 37

A hospital patient underwent a conventional parathyroid examination using two radiopharmaceuticals (^{123}I labelled NaI and ^{99m}Tc-labelled MIBI). After the examination it was found that the patient suffered from hypothyroidism and iodine did not accumulate in the thyroid. This hypothyroidism was not specified on the referral, nor was the patient asked about it before the examination. The examination had to be repeated because of this incident. The patient sustained a radiation dose of about 4.7 mSv from the unnecessary examination. A requirement was added to the protocol governing parathyroid examinations to ensure that any hypothyroidism would be investigated before an examination. This point was also added to guidelines for referring physicians at the hospital.

Incident 38

The automatic exposure control unit of a health centre X-ray appliance user interface was accidentally disconnected in a thoracic PA projection. Two patients sustained an excessive radiation dose.

Incident 39

A patient underwent a CT scan of the jaw area in between parathyroid scanning sessions. The CT scan was incorrectly restricted to the thyroid area, whereupon the upper jaw did not fit in the image field. The scan had to be repeated. The excessive dose sustained by the patient was about 0.2 mSv.

Incident 40

A radiopharmaceutical (^{99m}Tc-HDP) was administered to a hospital patient in the morning for the purpose of bone imaging. When the patient was called for scanning some three hours later the attending physician reported that the patient was too frail for scanning. The dose sustained by the patient was about 3.4 mSv.

Incident 41

A screw was left loose in a hospital mammography appliance after servicing by the supplier. This screw obstructed the image in an oblique mammogram, which had to be repeated for this reason. A similar incident had occurred on a previous occasion of servicing. According to the appliance dose display, the patient sustained a surface dose of 8.7 mGy and an MGD of approximately 1.6 mGy. Expressed as an effective dose, the dose sustained was of the order of approximately 0.3 mSv (a typical dose sustained in mammography). The case was reported to a representative of the supplier. As a remedy the supplier promised to pay attention to securing all screws and to include oblique imaging in the appliance tests that are conducted after servicing.

Incident 42

A patient was inadvertently subject to two CT scans. The intention had been to perform a bronchial embolism examination, but the patient also received a referral for an abdominal CT scan that was intended for another patient on the same ward. The excessive effective dose sustained by the patient was about 3.3 mSv.

Incident 43

The images from a cardiac CT angiogram were deleted from a hospital CT scanner workstation before they had been analyzed. This deletion was due to lack of hard drive space in the appliance and an automatic image deletion function. The scan was repeated, causing an excessive effective dose of about 14.4 mSv to the patient.

3 Regulatory control of practices causing exposure to natural radiation

3.1 Radon at workplaces

During 2011 STUK received 285 radon measurement notifications concerning either a radon concentration exceeding the intervention level of 400 Bq/m^3 measured in a work area, or further investigations of previously reported excessive levels. Based on measurement results, 114 reports were sent to enterprises, requiring the performance of radon repairs or an investigation of radon concentration during working hours at 98 workstations, and a measurement at another time of year in order to determine an annual average at 42 workstations. Orders to investigate workplace radon concentrations were also sent to a further 31 enterprises. These enterprises are located in regions where high radon concentrations are known to occur.

Radon concentrations were successfully reduced at 37 workplaces during the year. STUK discontinued regulatory control in 42 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 69 work areas for other reasons (e.g. short working periods or discontinued use of premises). 288 work areas at 166 workplaces were subject to regulatory control by STUK during the year.

A statutory radon inspection was conducted at 7 subterranean mines, at all of which the average radon concentration fell below the action level.

Inspections were conducted at 17 underground quarries. About two-thirds of these were tunnelling projects for the western extension of the Helsinki Metro. While the average radon concentration exceeded the intervention level in initial measurements taken at one excavation site, this was brought down to the permitted level following improvements in ventilation. An order was also issued to record the working times of workers at one worksite of brief duration with a high radon concentration to ensure that the radiation exposure of workers was not excessive.

Radon exposure of workers was monitored by regular radon measurements and monitoring of working hours at 5 conventional workplaces where the radon concentration exceeded the action level. A total of 21 workers were subject to radon exposure monitoring during 2011.

No new approval decisions for radon measuring equipment were issued in 2011. A list of organizations with measuring methodologies that have been approved in accordance with the requirements of Guide ST 1.9 appears on the STUK website*. These organizations have given permission for their names to be published 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. 9 inspection reports on the radioactivity of construction materials were prepared during 2011. These reports imposed restrictions on the use of materials where necessary. Inspection reports on the radioactivity of water intended for human consumption were prepared for 3 waterworks or foodstuffs manufacturers. One of these was ordered to reduce the radon concentration of its water. An official opinion on 1 uranium mining claim application was issued during the year. STUK was also involved in preparing opinions on environmental impact assessment reports, environmental impact assessment programmes and licence applications for mining and enrichment operations.

2 inspections were conducted during 2011 of industrial facilities processing materials containing

*) www.stuk.fi/proinfo/valvonta/luonnonsateily/radon_tyopaikoilla/fi_FI/radonin_mittaaminen/ (in Finnish only)

naturally occurring radioactive materials. In both of these cases the radiation exposure of workers was found to be so minimal that no special additional measures were necessary to limit exposure.

3.3 Cosmic radiation

The doses sustained by employees of 6 airlines were entered in the Dose Register in 2011. 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 4.7 mSv sustained by a pilot and 5.3 mSv sustained by a cabin crew member. The average annual dose sustained by pilots in 2011 was 2.4 mSv and the average annual dose of cabin crew members was 2.6 mSv. The average doses over the period from 2007 to 2011 are shown in Figure 6.

The total number of workers in flight crews increased by about 6% and the total dose grew by nearly 10% compared to the preceding year. The number of workers subject to individual monitoring of radiation exposure and their total dose are shown in Table 19 of Appendix 1.

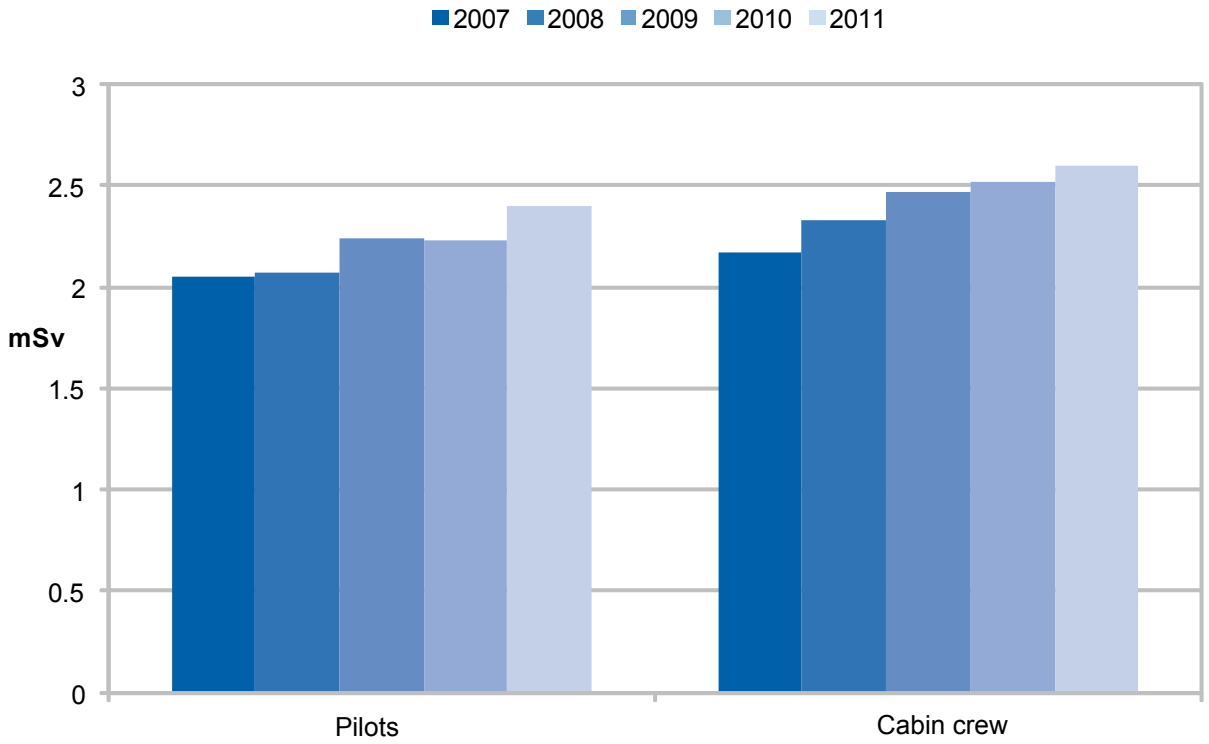

Figure 6. Average doses of air crews, 2007–2011.

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 2009 STUK also 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 (STM) and the Finnish Customs.
- Regulatory control of high power laser equipment used in public performances began back in the late 1980s. Their use has again increased due to advances in laser technology (semiconductor lasers) and falling prices.
- A bad case of skin burns arising in tattoo removal provided the impetus for enhancing regulatory control of tattoo removal lasers in 2011 (see Item 4.2 Regulatory control of laser devices and Item 4.4).
- 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 2002 and 2011 is shown in Table 20 of Appendix 1. Numerous (about 50) requests for clarification and enquiries concerning importation of laser devices submitted by the Customs and by importers (including private individuals) and comparable to regulatory inspections have increased the need for regulatory control of lasers, as in the preceding year.

4.2 Optical radiation

Regulatory control of sunbed equipment

7 sunbed facilities were inspected (see Table 21 of Appendix 1), of which 2 had nevertheless terminated their operations. A total of 19 sunbed appliances were inspected at five places of operation. 3 of these establishments were self-service units, 1 was operating as a beauty parlour, and 1 was attached to a small manicurist business. None of these establishments passed the inspection on all counts. A customer had sustained burns due to excessively powerful UV lamps used at one self-service unit. The UV intensity of other inspected appliances was within the permitted limits. Shortcomings in operating instructions were found at all establishments. Excessively long starting times were recommended in the operating instructions provided at two establishments and non-compliant cosmetics advertisements were found at one establishment.

STUK was involved in preparing an amendment to the Radiation Act led by the Ministry of Social Affairs and Health. This statutory amendment prohibits sunbed operators from exposing persons under 18 years of age to sunbed radiation, and also requires them to check the age of their customers and ensure that operating staff instruct customers in using sunbed appliances. The amendment is expected to take effect on 1 July 2012. The responsible parties must begin complying with their duties to provide guidance and display information within 6 months of the entry into force of the amendment. The duties with respect

to appointing a Responsible Person, liability for guidance and verification of age where required must be observed by no later than 36 months of the entry into force of the amendment. STUK will commence regulatory control of compliance by responsible parties with these duties after the phased transition periods (6 and 36 months) have elapsed.

Preparation of information materials concerning the statutory amendment began in 2011 and will be completed in 2012 before the amendment takes effect. Revisions will also be made to Guide ST 9.1 on radiation safety requirements and regulatory control of tanning appliances and to the sunbed establishment poster, display of which STUK has required in the vicinity of sunbed appliances. An 18 year age limit campaign section will be created for the STUK website, aimed primarily at the young people (young women) and sunbed business proprietors who will be most evidently affected by the statutory amendment.

Regulatory control of laser devices

Regulatory control of tattoo removal lasers was a priority in 2011. This priority was initially motivated by a case of skin burns sustained in the course of a tattoo removal procedure. The compliance with regulations and power of the laser equipment concerned in this incident were investigated. Although the radiation intensity data in the equipment operating instructions indicated that the appliance was rated in laser safety class 4, the markings on the appliance stated that it was a class 3B laser device and test reports for the appliance compliance certificate indicated a class of 2M. STUK submitted the appliance for testing at SP in Sweden. The appliance was assigned to safety class 4, and did not satisfy all of the safety requirements of standard EN 60825-1. The appliance importer voluntarily withdrew it from the market and used its customer records to recall all appliances sold. A total of 8 used appliances were recalled.

As a follow-up measure for the foregoing case, an enquiry was sent in the autumn to all 11 tattoo parlours that had advertised a laser tattoo removal service online. No further enquiries were sent to establishments that had been using appliances from the same supplier as in the incident described in the foregoing paragraph, as these had previously received a letter from STUK briefly outlining the requirements governing the use of laser equipment and explaining why the importer had recalled its appliances. The enquiry resulted in orders to cease operations at 5 establishments. The remaining tattoo parlours that received the enquiry had either already ceased their laser tattoo removal operations or returned their laser appliances to the importer.

On-site inspections were conducted at 10 laser show installations, and a further 11 notifications of shows were received from responsible parties that had received approval for mobile laser equipment. Further details of laser shows that had not been notified were requested in two cases on the basis of feedback from customers, with an accompanying explanation of the requirements governing laser shows. These shows were cancelled after STUK requested further details. Inspections indicated that physical protection and the orientation of laser beams largely complied with requirements.

Market control measurements were made for 3 laser indicators and one bow and arrow toy with laser sights. One indicator had been used for harassment (see Item 4.4). Measurements taken by STUK indicated that the device was a class 3B laser with a power of 18 mW. This was 18 times the maximum permitted power of a laser pointer. The police confiscated the device in question. The power of the toy bow and arrow laser sights was 1.36 mW, which is about 3 and a half times more powerful than the maximum permitted class 1 power for toys (0.39 mW). The Finnish Customs prevented marketing of the toy bow and arrow.

42 requests to remove advertisements from the huuto.net online sales forum were sent because of excessively powerful laser pointers. 5 enquiries were also submitted concerning online sales of laser pointers and light fittings. Some laser equipment was shown to be compliant by the importer/vendor, while some was withdrawn from sale due to non-compliance.

The Finnish Customs requested advice from STUK in 44 cases involving importation of lasers from outside of the European Union. In 14 of these cases the laser appliances or components thereof could be released for free circulation, because they fell outside the scope of type inspection under the

relevant government decree (291/2008). Most of the battery-operated laser devices not allowed into Finland were laser pointers. Their import permits were refused either due to a lack of type inspection certificate or to excessive power. The powers of the largest devices were 200 mW, whereas the maximum power allowed in devices for consumer use is only 1 mW.

4.3 Electromagnetic fields

Market control of wireless communication devices

STUK began market surveillance of mobile phones in 2003 and extended this to UMTS phones in 2007. Radiation tests have been conducted on a total of 115 mobile phones to date (see Table 22 of Appendix 1). A total of 5 GSM and UMTS type mobile phones were tested in 2011. The highest measured SAR value was 1.07 W/kg. This did not exceed the maximum value of 2 W/kg prescribed in the Decree of the Ministry of Social Affairs and Health (294/2002).

Other regulatory control

A base station measurement campaign gathered measurements of base station radio frequency radiation at a total of 30 sites. These data were used for preparing a draft recommendation on base station antenna installation and safety signs. This project will continue in 2012.

4.4 Abnormal incidents

The abnormal incident reporting required under section 17 of the Radiation Decree also applies to incidents arising in the use of non-ionizing radiation (see Item 2.9). STUK received 3 reports in 2011 concerning incidents caused by non-ionizing radiation that required immediate measures.

Figure 3 (in Item 1.1) shows abnormal incident numbers between 2002 and 2011.

Incident 1

A dermatologist in Tampere reported the use of an excessively powerful tattoo removal laser that had caused burns and scarring to the skin of a patient during a tattoo removal procedure. The Decree of the Ministry of Social Affairs and Health (94/2002) stipulates that laser radiation may not cause tissue damage, nor may the energy intensity and irradiance of laser radiation directed at the skin exceed the values specified in standard EN 60825-1. The maximum values stipulated in the Decree do not govern diagnostic or therapeutic measures prescribed by a medical practitioner or appropriately approved scientific studies supervised by a medical practitioner. In April 2011 the dermatologist submitted a petition for review of the activities of STUK to the Parliamentary Ombudsman, who found in September 2011 that STUK should have taken more extensive and concrete regulatory control measures based on the available evidence concerning the hazards of cosmetic laser appliances. In January 2012 STUK submitted a report to the Ombudsman concerning the concrete regulatory control measures that it had taken to inspect tattoo removal lasers (see Item 4.2 Regulatory control of laser devices).

Incident 2

A responsible party had replaced the UV lamps of an upright appliance in a small self-service sunbed establishment with excessively powerful lamps resulting in skin burns sustained by a customer. From a 12-minute session in the appliance this customer received a single dose of UV radiation amounting to approximately 680 J/m^2, which is about one-seventh of the annual dose permitted under the Decree of the Ministry of Social Affairs and Health (294/2002). The erythema effective dose rate of the appliance was about 3.1 times greater than the permitted rate of 0.3 W/m^2. The time taken to cause reddening of sensitive skin with compliant lamps would be not less than 11 minutes, but the corresponding time for the lamps that caused the customer's sunbed burns was only 3.5 minutes. A local health inspector prohibited use of the appliance until STUK had verified that its UV radiation power was within the permitted limits by measurement. Following an inspection by STUK compliant UV lamps were installed in the appliance, after which use of the appliance could continue.

Incident 3

The police of Pietarsaari notified STUK that a young man had been directing a green laser pointer from a motor vehicle in the city centre.

Although the laser beam hit one person in the eye, the incident probably did not cause any lasting injury. Measurements taken by STUK indicated that the device was a class 3B laser with a power of 18 mW. This was 18 times the maximum permitted power of a laser pointer. The power was also about 3.6 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 in question.

5 Regulation work

Radiation Safety Guides

To achieve a standard of safety that complies with the Radiation Act, STUK publishes 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 radiation safety guides were published in 2011:

- ST 1.4 Radiation user's organization
- ST 1.10 Design of rooms for radiation sources
- ST 2.1 Safety in radiotherapy
- ST 3.1 Dental X-ray examinations in health care
- ST 5.7 Shipments of radioactive waste and spent fuel
- ST 12.1 Radiation safety in practices causing exposure to natural radiation.

Other regulation work

The NIR Unit assisted in work led by the Ministry of Social Affairs and Health to prepare an amendment to the Radiation Act. The amendment is expected to take effect on 1 July 2012 and seeks to prohibit use of sunbed appliances by people under 18 years of age (see also Item 4.2).

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 the regulatory activities of STUK and the maintenance of the preparedness to respond to radiological and nuclear emergencies.

Research into uses of radiation also 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.

Extension of IAEA dosimetry guidelines (X-ray diagnostics)

The results were published from an IAEA research project to test diagnostic dosimetry guidelines that began in 2006 and ended in 2010.

A new project launched in 2010 is developing extensions to existing IAEA dosimetry guidelines for such areas as paediatric imaging, skin dose determination in interventional radiology and the latest imaging technologies. The project is also assessing methods of determining organ doses and their associated uncertainties. STUK arranged a survey in 2011 to review the patient dose determination methods used in hospitals. STUK has also reviewed the suitability of effective doses for estimating patient exposure and cancer risks. The project will continue until 2013.

European Metrology Research Programme (EMRP)

The co-financed radiotherapy research projects launched in 2008 came to an end. These projects developed and tested regulatory control methods for radiotherapy. Such methods are used for improving regulatory control of precision in internal radiotherapy and regulatory control of external radiotherapy in new therapeutic techniques such as intensity-modulated radiotherapy. Advances made in the external radiotherapy project included a model of the human pelvic region and a film dosimetry-based method of dose determination for use in regulatory control. Reports of project findings were given at the November-December concluding project conference in Germany.

A new co-financed metrology programme research project was launched in 2011 seeking to review the radioactive material detection methods used by smelting works that process recycled metals, and to develop methods for uniformly determining end-product activity concentrations of steel in steel manufacturing within the European Union. Reference sources are also being developed for this purpose. The project seeks to improve radiation safety at smelting works processing scrap metal and to establish a uniform method of determining the contamination level of steel.

Developing a neutron measuring method

Financed by the Scientific Advisory Board for Defence (MATINE), this project is studying alternatives to ^{3}He-based neutron detection. It has developed a method for indirectly detecting materials emitting neutron radiation using the excitation reactions caused by neutrons in a medium. The gamma radiation produced by these reactions is measured using a sodium iodide

scintillation detector. Studies have also been made of the prospects for using this method for neutron source recognition, with results suggesting that it is possible to distinguish fission sources (such as ^{252}Cf) and the AmBe sources that are typically used in industry. A sequel to the project seeking to develop spectrometric measurement of neutrons will begin in 2012.

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.

Forward-scattering caused by the compression paddle in mammography dosimetry

Compression effected using a compression paddle improves image quality in mammography and reduces subject radiation exposure. This Master's thesis investigated the optimal compression paddle positioning for dosimetry. The findings indicate that it is advisable to maximise the distance between the compression paddle and the meter, and to use a separate forward-scattering factor.

6.2 Non-ionizing radiation

Most of the research and development work on non-ionizing radiation was done in the course of the WIRECOM/RFDOS and EMRP-NIR co-financed research projects set out below.

The WIRECOM/RFDOS project

The WIRECOM/RFDOS project involved collaboration with the University of Turku (TY) and the Finnish Institute of Occupational Health (TTL). This project exposed human test subjects to mobile phone radiation and used various methods to study the effects of this exposure (including PET imaging, monitoring of temperature, and blood flow measurements using near-infrared spectroscopy). The apparatus used for test subject exposure was made at STUK and used in two studies conducted at TY and one test setting conducted at TTL. The precise exposure level of the test subjects was determined numerically using the FDTD method.

Although involvement of the NIR Unit in the project was officially concluded at the end of 2010, the final technical report was submitted to the Finnish Funding Agency for Technology and Innovation (TEKES: one of the project financiers) at the end of April 2011. Contributions describing the exposure apparatus and dosimetry were prepared for the manuscripts of the biological studies conducted by TY and TTL. A total of three peer-reviewed scientific articles have been published (a list of articles is attached as Appendix 2 to this report) and the manuscript of a fourth publication is under preparation. The concluding seminar for the project was arranged in Turku in March 2012.

The EMRP-NIR project

The role of STUK in the EMRP-NIR project was to develop a calibration method for SAR measurement probes at frequencies below 400 MHz and a calibration method for limb current measuring instruments at frequencies of 10-50 MHz. The effectiveness of the methods was tested by making comparison measurements together with a British project partner, the National Physical Laboratory (NPL). The NPL SAR measurement probe was calibrated using STUK apparatus in summer 2010 and returned to the NPL in autumn 2010. NPL did not report the results of the calibration during 2011, and so the comparison of calibrations is still pending. The calibration comparison of limb current measuring instruments was performed in autumn 2010 with a result discrepancy that was clearly less than 10%. Measurements were made at STUK in early 2011 investigating the effects of a ferrite core transformer on currents in the ankle. These measurements indicated that the transformer had no significant impact on ankle current. Although the intention was to repeat the measurement using a purpose-built limb phantom at the NPL, the NPL did not have time to complete this assignment.

The project officially ended in March 2011. STUK participated in a concluding workshop and conference held in Rome in February. The final report and other required documents were sent to the co-ordinator in May. Although the project has ended co-operation with the NPL will continue at least with studies of methods of measuring radio frequency currents induced in the body. The aim is to release a joint scientific publication on limb current measurements in 2012. The first draft

of a scientific article on the SAR-TEM chamber was completed, with a view to finalizing this for publication during 2012.

Preparation of projects

A research project on safety in magnetic resonance imaging work prepared in association with TTL

STUK and TTL submitted a joint application to the Finnish Work Environment Fund for financial support for a research project entitled "Practices promoting staff job satisfaction in magnetic resonance imaging work". This project will seek to determine the exposure of workers to magnetic fields, and to prepare general safety guidelines for magnetic resonance imaging work. The application and research plan were submitted in September to the Finnish Work Environment Fund, which granted finance to the research project for three years in December 2011. The project will begin in March 2012.

Finance requested from TEKES for the INNO-RF project studying the effects of mobile phones

An application for finance for the INNO-RF project – a sequel to the WIRECOM project – was submitted to TEKES at the beginning of September. This project sought to continue collaboration with TTL and TY on research into the biological effects of mobile phones. The other candidate partners of STUK in this research project application were the University of Kuopio and Tampere University of Technology. TEKES nevertheless declined to grant finance for the project.

Application to MATINE seeking financial support for a project to study variable electromagnetic exposure limits

TTL and STUK submitted an application to MATINE seeking financial support for a research project entitled "Variable exposure limits of electromagnetic fields in the armed forces". MATINE did not award financial support to the project.

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.

6.3 Evaluation of research

An international group of experts evaluated STUK research activities in 2011. This evaluation is carried out approximately every five years (the last assessment was in 2005).

The evaluation team found that the research activities of STO are of major social importance in the fields of health services and the industrial use of radiation. The research work, international co-operation and publishing activities of STO are of a high standard and successfully integrated into European research projects. The team recommended maintaining and further reinforcing the standard of operations. It proposed improving these operations by developing a mechanism for more effectively disseminating research findings and a strategy for ensuring that high standards of expertise are conserved in research work.

The NIR Unit participated in evaluating the research work of STUK by describing its progress over a period of six years and reporting on implementation of the proposals for improvement that were made in the 2005 evaluation.

In the 2011 evaluation the NIR Unit was assigned the new development priority of more clearly defining the role of the Unit in information activities, research and measurement technology, and developing a research strategy (prioritizing relevant research interests more clearly). The Unit was also urged to increase the degree of collaboration in epidemiological and biological research programmes, and to increase the number of peer-reviewed publications.

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 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 2011 representatives of STUK took part in meetings of the following international organizations and working groups:

- The working group referred to in Article 31 of the Euratom Treaty and its subordinate working group on medical uses of radiation
- HERCA (Heads of the European Radiological Protection Competent Authorities) and its working groups
- Annual meeting and subordinate working groups of the European Radiation Dosimetry Group (EURADOS)
- European Alara Network (EAN) meeting
- Nordic sunbed conference
- Meeting of the Nordic laser and light pulse device working group (organized by STUK).

Participation in other international conferences

Representatives of STO and the NIR Unit participate annually in several international conferences, congresses and training events in the field of radiation safety and give presentations and lectures at these events (organizers include e.g. IAEA, EANM, ESTRO, EURAMET, CIPM and the European Commission).

Other international co-operation

A report on paediatric CT scan patient doses prepared in Finland and the Baltic countries was published. The findings indicate that setting reference levels for paediatric CT scans of the lungs and head region appears to be possible, but still requires more extensive patient data. The study was continued under a new project involving Finland and the Baltic countries, but also hospitals from Sweden, Norway and Denmark.

A representative from the NIR Unit took part in two Main Commission meetings of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) held in Ljubljana in May and Manila in November. The person concerned is responsible for preparing ICNIRP guidelines for limiting the exposure sustained by a person moving in a static magnetic field.

The ICNIRP guidelines on motion induction were fit for public consultation on the ICNIRP website by the end of the year. They are based on an article submitted to the radiation safety journal Health Physics (see Appendix 2, Jokela and Saunders 2011).

STUK assisted the occupational health and safety department of the Ministry of Social Affairs and Health in drafting an occupational safety Directive on electric and magnetic fields. This Directive was still under preparation at the European Commission at the beginning of 2011. STUK prepared a new proposal for amending annex 2 of the Directive to comply more closely with the latest ICNIRP guideline values. The Commission draft had become confused with limiting values prepared by the German occupational safety authorities that were too high in some respects and had not been (peer) assessed internationally. The German amendments were deleted from the proposal issued by the Commission in June 2011,

and so the changes proposed by STUK may have had some impact.

A lecture was delivered at a seminar of TTL and NIVA (the Nordic Institute for Advanced Training in Occupational Health) on the subject of "Occupational Exposure to Electromagnetic Fields and Optical Radiation" (Saariselkä, 21–25 March 2011).

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 Advisory Committee on 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 2011:

- Radiation Safety Conference, 3–4 November 2011, Tampere, in association with the Radiological Society of Finland
- Radiation safety and quality in X-ray diagnostics conference, 31 March–1 April 2011, Seinäjoki
- Conference for specialists in medical X–ray technology, 8–9 September 2011, Asikkala
- SESKO SK 106 committee meeting (Exposure to electromagnetic fields).

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 committee (Safety of domestic electrical appliances)
- SESKO SK 106 committee (Exposure to electromagnetic fields)
- National RAPEX network (Rapid alert system for non-food consumer products; European Union notification system for consumer products causing serious danger)
- Armed Forces Radiation Safety Committee (considering safety in the use of non-ionizing radiation from Armed Forces radio and radar equipment).

Participation in other Finnish conferences

Representatives of STO and the NIR Unit participate annually in several radiation safety sector conferences in Finland and give presentations and lectures at these events.

Other co-operation in Finland

The findings of a review conducted jointly by STUK, the Ministry of Education and Culture and the National Board of Education in 2010 of the radiation safety training included in the basic and further education of health service staff were published in 2011 (report STUK-B 133). They were also circulated to professional journals in the field. The review revealed shortcomings in the radiation safety training of many professional groups. It was also found that some educational institutions provided no radiation safety training at all in the basic training of certain professional groups that use radiation. Responses to the findings of the review included a written parliamentary question by an MP concerning measures to rectify the state of radiation safety training. STUK and the Ministry of Social Affairs and Health sent a letter to educational institutions urging them to implement the radiation safety training objectives issued by STUK in Guide ST 1.7. The survey findings also served as a basis for initiating a revision of this guide.

STUK participated in a training event organized by TTL and the Army Material Command on the subject of safety aspects of electromagnetic fields.

Specialists from STUK gave a course of lectures in the autumn at Aalto University School of Electrical Engineering on the biological effects and measurement of electromagnetic fields and optical radiation.

9 Information activities

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 also came from members of the public through the STUK website every day and telephone calls were received on a very wide range of radiation concerns.

A review concerning power lines provided information on low frequency magnetic field risks and detailed the recommendation of STUK with respect to building construction in the vicinity of power lines.

A revision of information materials concerning the ban on sunbed use by persons under 18 years of age began in 2011 and will be completed in 2012.

For the last nine consecutive years STUK has organized a UV press event in association with the Finnish Meteorological Institute and the Cancer Society of Finland. The key message of STUK was that vitamin D provides no special justification for sunbathing, as people get an adequate amount of ultraviolet radiation for vitamin D production simply through outdoor activities on a sunny summer day. It was pointed out that this vitamin comes not only from sunshine, but also from a balanced diet and vitamin D preparations.

Press releases were prepared on the following subjects:

- The hands of radiation workers are prone to exposure
- Radiation doses and dose rates: How much is a lot?
- Vitamin D comes from sunshine, but also from food and the pillbox
- Cancer research centre classifies mobile phone radiation as a potential carcinogen
- STUK has measured the SAR values of more than one hundred mobile phones
- Physicians and nurses need more radiation safety training
- More research required into the effects of mobile phone radiation on living cells
- COSMOS research into the health impacts of mobile phones continues in Finland.

10 Metrological activities

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. STUK calibrates its own standards at regular intervals at the International Bureau of Weights and Measures (BIPM) or other primary laboratories. In the field of radiation metrology STUK is involved in the work of the Advisory Committee on Metrology and of the European Association of National Metrology Institutes (EURAMET).

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.

10.2 Ionizing radiation

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

A ^{60}Co unit acquired for the DOS Laboratory at the end of 2010 was installed and taken into use following commissioning measurements. The required radiation safety precautions were also made for the new device.

Four beta and two alpha extended area sources were acquired for testing and calibrating contamination meters. A comprehensive set of reception measurements was made for the devices.

Meter and measurement comparisons

In 2011 the DOS Laboratory took part in a joint comparison of patient dosemeter calibrations for X-ray diagnostics together with EURAMET, EURADOS and the IAEA. The results of this comparison are not yet available.

The DOS Laboratory also took part in the annual TLD comparison measurement of the absorbed dose of ^{60}Co radiation (radiotherapy accuracy level) between calibration laboratories belonging to the laboratory network maintained by the IAEA/WHO. The deviation of the laboratory result from the IAEA reference value was 1.3%. This result is well within the IAEA acceptable variation of results.

Figure 7 shows the deviations in the measurement results of STUK from the reference value in IAEA/WHO measurement comparisons over the period from 2002 to 2011.

10.3 Non-ionizing radiation

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

A Narda SRM-3000 meter used for measuring the electromagnetic fields of mobile phone base stations was sent to the manufacturer for calibration. The functioning of other electromagnetic field measuring instruments was checked using calibration apparatus of the NIR Unit radio laboratory.

Meter and measurement comparisons

In association with the Swiss SPEAG Laboratory, the NIR Unit performed a calibration comparison of SAR-measurement probes in a fluid simulating brain tissue at frequencies of 900, 1800 and 2450 MHz. These measurements were made using the same fluid and measurement probes as a corresponding comparison in 2010, thereby enabling an assessment of the source of the calibration discrepancy (30%) observed in the previous comparison. An analysis of the results will be completed in 2012.

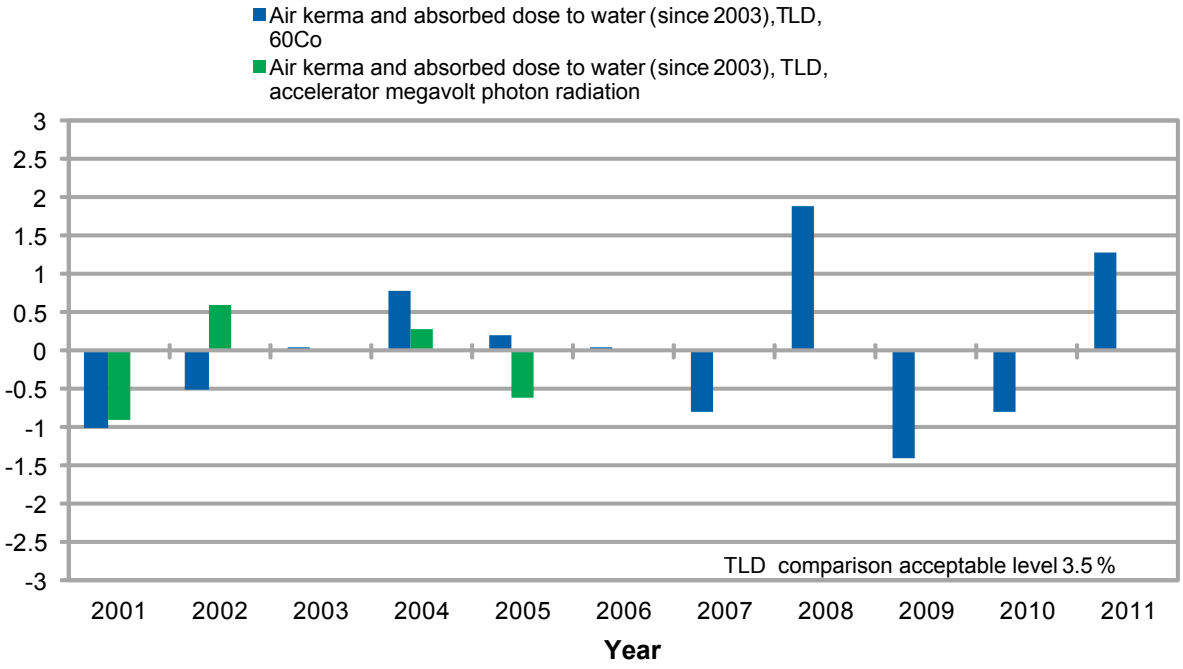

Figure 7. Deviations (%) in measurement results of STUK from the reference value in IAEA/WHO measurement comparisons, 2001–2011.

11 Services

11.1 Ionizing radiation

Calibration, testing and irradiation

The DOS Laboratory performed radiation meter calibrations and testing on request. 116 radiation meter calibration, inspection and testing certificates and 21 irradiation certificates were issued. About 20% of the calibrations and about 10% of the irradiations were performed for STUK´s own instruments and samples.

Other services

STUK co-ordinated a two-year European Commission project entitled "Study on European Population Doses from Medical Exposure" (Dose Datamed 2, begun in 2011). The project is collecting information from European countries on radiation exposure arising from radiological examinations, and will assess the radiation dose sustained by the population of Europe for the first time. The information was collected using the Commission's published RP 154 guidelines. A questionnaire was sent to 41 countries, of which about 30 had responded by the end of the year. An interim project report was sent at the end of the year and approved.

STUK will also be involved as a work package leader in a two-year European Commission project entitled "Guidelines of Risk Analysis and Unintended Accidental Exposures in Radiotherapy" (ACCIRAD), and an agreement was signed to this effect. This project will collate data from European countries on methods of forecasting and processing abnormal incidents in radiotherapy, and will make a recommendation for performing a risk analysis. Project is timetabled for 2012–2013.

A PCXMC computer application designed for calculating patient doses in X-ray diagnostics was maintained and sold in 60 copies. 6 tests and reports were prepared on compliance of X-ray equipment with standards.

STUK arranged the following events as training services in 2011:

- Radiation safety and quality in X-ray diagnostics, training event in Seinäjoki, 31 March–1 April 2011
- Conference on radiation safety in industry, arranged between 13 and 15 April 2011 aboard the m/s Mariella cruise ferry.

External assessments

The X-ray equipment compliance testing service provided by the DOS Laboratory was the subject of an external assessment by VTT Expert Services Oy. The Laboratory met the prescribed quality requirements.

11.2 Non-ionizing radiation

Calibration, testing and irradiation

The NIR Unit performed a total of 4 radiation meter calibrations and tests and 10 safety assessments and radiation measurements. The service work of the NIR Unit between 2002 and 2011 is shown in table 20 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 2011.

Use of radiation	Number of practices
X-ray practices	300
Veterinary X-ray practices	235
Extensive X-ray practices	100
C-arm practices	88
Minor X-ray practices	93
X-ray practices outside X-ray departments	64
Screenings with X-rays	51
Use of unsealed sources	38
Use of sealed sources	27
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 2011.

Appliances/Sources/Laboratories	Number
X-ray diagnostic appliances (generators)[*)]	**1458**
fixed conventional X-ray appliances	495
portable fluoroscopy appliances	215
portable conventional X-ray appliances	214
mammography appliances, of which	160
• screening mammography	74
• tomosynthesis	1
fixed fluoroscopy appliances	115
• angiography	49
• fluoroscopy	38
• cardioangiography	28
CT-appliances, of which	103
• SPECT-CT	25
• PET-CT	10
dental X-ray appliances (licensed)	84
• CBCT appliances	37
• panoramic scanners	31
• conventional dental X-ray appliances	15
• cephalostats	1
bone mineral density measurement appliances	68
other appliances	4
Dental X-ray appliances (notifiable)	**5573**
conventional dental X-ray appliances	4935
panoramic scanners	638
Radiotherapy appliances	**118**
accelerators	41
X-ray imaging appliances	26
afterloading appliances	7
manual afterloading appliances	3
X-ray therapy appliances	2
radiotherapy simulators	17
sealed sources (check sources)	21
BNCT therapy unit	1

Sealed sources	**231**
calibration and testing equipment	209
attenuation correction units	17
gamma irradiators	4
other sealed sources in health care	1
X-ray appliances in veterinary practices	**279**
conventional X-ray appliances	233
bone mineral density measurement appliances	5
fluoroscopy appliances	4
dental X-ray appliances	28
CT scanners, of which	5
• SPECT-CT	2
• PET-CT	1
other appliances	4
Radionuclide laboratories	**47**
B-type laboratories	23
C-type laboratories	24

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

Table 3. Number of days used by various professional groups for operator training provided by equipment manufacturers in nuclear medicine.

Professional group	Average operator training (days)
Physicians	5
Hospital physicists	7.6
Other staff	7.8

Table 4. Quality control tests of SPECT-CT and PET-CT appliances.

Quality control test	Test interval recommended by STUK	Average test interval notified by hospitals	Number of appliances tested
CT numbers	1 week, 6 months	1 month	6
Noise	1 week	2 weeks	6
Uniformity	6 months	1 month	6
Spatial accuracy of slice	6 months	-	0
Geometric accuracy of CT image	6 months	-	0
Slice width	12 months	3 months	4
High contrast resolution	6 months	1 month	3
Radiation dose/accuracy of dose display	6 months	7 months	11
Patient table movement	3 months	-	0

Table 5. The most common SPECT-CT and PET-CT scans and the estimated patient doses caused by CT scanning (the bracketed figure in the "Examination" column specifies the number of responses used for reckoning the average and standard deviation, see Item 2.1 *Nuclear medicine*).

Examination	Patient dose (mSv)	
	Average	Standard deviation
SPECT-CT		
Lungs (3)	1.9	0.2
Parathyroid glands (3)	0.7	0.3
Bones (8)	1.8	1.4
Somatostatin receptors	1.4	0.5
Heart (8)	1.7	1.2
PET-CT		
Whole body (6)	3.6	2.1
Head (7)	0.1	0.1
Heart (4)	1.0	0.3

Table 6. Radiation practices in the use of radiation in industry, research and education at the end of 2011.

Use of radiation	Number of practices
Use of sealed sources	639
Use of X-ray appliances	499
Installation, test operations and services	131
Importing and exporting of radioactive materials or trading in them	126
Use of unsealed sources	118
Use of particle accelerators	19

Table 7. Radiation sources and appliances and radionuclide laboratories in the use of radiation in industry, research and education at the end of 2011.

Appliances/Sources/Laboratories	Number
Appliances containing radioactive materials	**6277**
level switches	2148
continuous level gauges	1103
density gauges	1017
basis weight meters	608
weight scales	587
appliances or sources used for calibration, testing or education	190
moisture and density gauges	134
fluorescense analyzers	84
radiography appliances	24
other appliances	382
X-ray appliances and accelerators	**1510**
X-ray screening appliances	535
diffraction and fluorescense analyzers	400
radiography appliances	387
basis weight meters	48
particle accelerators	23
other X-ray appliances	117
Radionuclide laboratories	**164**
A-type laboratories	4
B-type laboratories	30
C-type laboratories	127
activities outside laboratories (tracer element tests in industrial plants)	3

Table 8. Radionuclides most commonly used in sealed sources in industry, research and education at the end of 2011.

Radionuclide	Number of sources
Other than high-activity sealed sources	
Cs-137	3993
Co-60	1134
Kr-85	369
Am-241 (gamma sources)	349
Pm-147	127
Am-241 (AmBe neutron sources)	125
Fe-55	104
Ni-63	59
Sr-90	59
High-activity sealed sources	
Cs-137	52
Co-60	47
Ir-192	11
Am-241 (gamma sources)	8
Sr-90	5

Table 9. Inspections of licensed practices in 2011 (itemized by type of inspection).

Type of inspection	Number of inspections	
	Industry, research and education	Health care and veterinary practices
Initial inspection	0	112
Periodic inspection	229	224
Repeat inspection	1	7
Other inspection or measurement	2	0
Total	**232**	**343**

Table 10. Inspections of licensed practices in 2011 (itemized by type of practice).

Type of practice	Number of inspections
Use of radiation in health care and veterinary practices	
X-ray diagnostics	242
radiotherapy	47
veterinary X-ray practices	47
nuclear medicine	7
other uses of radiation	0
Use of radiation in industry, research and education*)	
industry	156
research and/or education	53
trading in radioactive materials	16
installation and/or servicing	14
other uses of radiation	19
Total	**601**

*) The total number of these inspections is larger than in Table 9, because in some cases one inspection (initial, periodic, repeat) concerned two types of practice.

Table 11. Deliveries of sealed sources to and from Finland in 2011.

Radionuclide	Deliveries to Finland		Deliveries from Finland	
	Activity (GBq)	Number	Activity (GBq)	Number
Ir-192	72 783	22	9335	25
Se-75	3700	2	499	2
Kr-85	1167	84	1287	90
Pm-147	173	42	78	20
Fe-55	106	33	115	19
I-125	95	*)	-**)	-
Cs-137	73	107	< 1	1
Gd-153	31	14	-	-
Am-241 (AmBe neutron sources)	26	2	-	-
Am-241 (gamma and alpha sources)	14	36	3	280
Sr-90	6	13	5	6
Co-57	5	27	-	-
Co-60	3	6	1062	1
others total ***)	5	542	5	708
Total	**78 187**	**930**	**12 389**	**1152**

*) The exact number of small sources of I-125 used in radiotherapy is not known.
**) The symbol "-" indicates no deliveries from Finland.
***) Deliveries to Finland, nuclides: H-3, Ni-63, Po-210, Cd-109, Ge-68, Cs-136, Na-22 and Co-58.
Deliveries from Finland, nuclides: Ni-63, H-3 ja Cd-109.

Table 12. Deliveries of unsealed sources to and from Finland in 2011.

Radionuclide	Activity (GBq)	
	Deliveries to Finland	Deliveries from Finland
Mo-99	35 675	2631
I-131	7117	1941
Lu-177	2698	1498
I-123	1177	27
Sm-153	392	-*)
P-32	180	45
Y-90	152	-
Tl-201	105	-
In-111	42	-
H-3	20	9
S-35	20	-
Cr-51	5	-
Ga-67	2	-
I-125	1	4
F-18	-	1433
others total **)	2	-
Total	**47 588**	**7588**

*) The symbol "-" indicates no deliveries to or from Finland.
**) Nuclidies: Re-186, Sr-89, Se-75, Sr-85,Tc-99m, Co-57, Cs-137, Cm-244, Am-241 and Pb-210.

Table 13. Manufacturing of radioactive materials (unsealed sources) in Finland in 2011.

Radionuclide	**Activity (GBq)**
F-18	121 544
C-11	9652
O-15	3560
Br-82	3192
others total*)	181
Total	**138 129**

*) Nuclides, such as: Au-198, Cu-64, La-140.

Table 14. Number of workers subject to individual monitoring in 2007–2011.

Year	**Number of workers in various sectors**								
	Health care		**Veterinary practices**	**Industry**	**Research and education**	**Manufacturing of radioactive materials**	**Others*)**	**Use of nuclear energy**)**	**Total***)**
	Exposed to X-radiation	**Exposed to other radiation sources**							
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
2010	4467	989	491	1192	817	21	73	4151	12 062
2011	4320	1050	550	1209	742	22	79	3830	11 659

*) 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 15. Total doses (sums of $H_p(10)$ values) of workers subject to individual monitoring in 2007–2011.

Year	**Total dose in various sectors (Sv)**								
	Health care		**Veterinary practices*)**	**Industry**	**Research and education**	**Manufacturing of radioactive materials**	**Others**)**	**Use of nuclear energy***)**	**Total**
	Exposed to X-radiation*)	**Exposed to other radiation sources**							
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
2010	1.25	0.08	0.08	0.15	0.09	0.004	0	2.59	4.25
2011	1.33	0.11	0.09	0.13	0.07	0.007	0.001	1.83	3.56

*) $H_p(10)$ 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 $H_p(10)$ values 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 16. Data ($H_p(10)$ values) on certain occupational groups in 2011.

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**)	210	0.61	3.4	2.9	16.9
Interventional radiologists**)	38	0.30	9.4	7.9	33.1
Radiologists**)	443	0.22	2.4	0.5	19.7
Consultant physicians**) ***)	265	0.08	1.8	0.3	9.3
Radiographists (X-rays)**)	1763	0.06	0.4	0.0	2.4
Nurses**)	1113	0.05	0.4	0.0	2.2
Radiographers (other than X-rays)	425	0.06	1.0	0.2	3.6
Veterinary nurses and assistants**)	303	0.05	1.3	0.2	8.6
Veterinary surgeons**)	233	0.03	1.2	0.2	9.5
Industrial material inspection technicians****)	475	0.07	0.5	0.1	3.6
Researchers	558	0.06	1.8	0.1	12.2
Industrial tracer testing technicians	26	0.05	2.7	1.7	7.2
Nuclear power plant workers					
• mechanical duties and machine maintenance	898	0.62	1.1	0.7	9.9
• cleaning	219	0.24	1.7	1.1	9.3
• electrical and automation work	747	0.15	0.6	0.2	3.2
• insulation work	63	0.13	3.0	2.1	7.5
• material inspection	181	0.12	1.0	0.7	4.9

*) Recording level is 0.1 mSv per month or 0.3 mSv per 3 months.

**) $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the dose sustained by these working 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 and gastroenterologists.

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

Table 17. The principal radioactive waste in the national storage facility for low-level waste (December 2011).

Radionuclide	Activity (GBq) or mass
H-3	11 989
Cs-137	2608
Am-241	2122
Kr-85	1728
Pu-238	1546
Ra-226	236
Sr-90	232
Co-60	121
Cm-244	90
U-238	1270 kg

Table 18. Radioactive waste consigned to the national storage facility for low-level waste in 2011.

Radionuclide	Activity (GBq)
Am-241	461
Cs-137	255
Kr-85	169
Pm-147	66
Fe-55	26
Co-60	15.5
Ra-226	4.5
Sr-90	2.5
C-14	1.5

Table 19. Number of air crew members subject to individual monitoring of radiation exposure and total dose of crew members (sum of effective doses) in 2007–2011.

Year	Number of workers		Total dose (Sv)	
	Pilots	Cabin crew	Pilots	Cabin crew
2007	1125	2583	2.30	5.61
2008	1206	2562	2.45	5.93
2009	1195	2460	2.68	6.07
2010	1147	2281	2.56	5.75
2011	1208	2423	2.85	6.23

Table 20. Work of the NIR Unit in 2002–2011.

Year	Regulatory inspections	Decisions	Statements	Calibrations and tests	Safety assessments and radiation measurements	Total
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	47 (108*))	2	9	31	12	101 (162*))
2010	55 (182**))	3	9	36	13	116 (243**))
2011	56 (142***))	6	3	4	10	79 (165***))

*) The number includes requests for advice by the Finnish Customs concerning the admission to Finland of lasers (46) and requests by the NIR Unit to remove laser pointer advertisements from the huuto.net online sales forum (15).

**) The number includes requests for advice by the Finnish Customs concerning the admission to Finland of lasers (96) and requests by the NIR Unit to remove laser pointer advertisements from the huuto.net online sales forum (31).

***) The number includes requests for advice by the Finnish Customs concerning the admission to Finland of lasers (44) and requests by the NIR Unit to remove laser pointer advertisements from the huuto.net online sales forum (42).

Table 21. Inspections of sunbed facilities in 2002–2011.

Year	Number of inspections
2002	36
2003	31
2004	30
2005	36
2006	25
2007	31
2008	26
2009	19
2010	16
2011	7

Table 22. Mobile phone SAR tests in 2003–2011.

Year	Number of tests
2003	12
2004	18
2005	15
2006	15
2007	15
2008	10
2009	15
2010	10
2011	5

APPENDIX 2

PUBLICATIONS IN 2011

The following publications completed in 2011 were authored by one or more empoyees of STO or the NIR Unit.

International publications

Alanko T, Puranen L, Hietanen M. Assessment of exposure to intermediate frequency electric fields and contact currents from a plasma ball. Bioelectromagnetics 2011; 32: 644–651.

Jokela K, Saunders R. Physiologic and dosimetric considerations for limiting electric fields induced in the body by movement in a static magnetic field. Health Phys. 2011; 100: 641–653.

Järvinen H, Merimaa K, Seuri R, Tyrväinen E, Perhomaa M, Savikurki-Heikkilä P, Svedström E, Ziliukas J, Lintrop M. Patient doses in paediatric CT: feasibility of setting diagnostic reference levels. Radiation Protection Dosimetry 2011; 147 (1–2): 142–146. (doi 10.1093/rpd/ncr293).

Kapanen M, Bly R, Sipilä P, Järvinen H, Tenhunen M. How can a cost/benefit ratio be optimized for an output measurement program of external photon radiotherapy beams? Phys. Med. Biol. 2011; 56: 2119–2130. (doi 10.1088/0031-9155/56/7/014).

Keyriläinen J, Fernández M, Bravin A, Karjalainen-Lindsberg M-L, Leidenius M, von Smitten K, Tenhunen M, Kangasmäki A, Sipilä P, Nemoz C, Virkkunen P, Suortti P. Comparison of in vitro breast cancer visibility in analyser-based computed tomography with histopathology, mammography, computed tomography and magnetic resonance imaging. J. Synchrotron Rad. 2011; 18: 689–696. (doi: 10.1107/S090904951102810X).

Kwon MS, Vorobyev V, Kännälä S, Laine M, Rinne JO, Toivonen T, Johansson J, Teräs M, Lindholm H, Alanko T, Hämäläinen H. GSM mobile phone radiation suppresses brain clucose metabolism. Journal of Cerebral Blood Flow & Metabolism 2011; 31: 2293–2301.

Lindholm H, Alanko T, Rintamäki H, Kännälä S, Toivonen T, Sistonen H, Tiikkaja M, Halonen J, Mäkinen T, Hietanen M. Thermal effects of mobile phone RF-fields on children: a provocation study. Progress in Biophysics and Molecular Biology 2011; 107(3): 399–403.

Pastila RK, Heinävaara S, Ylianttila L, Leszczynski D. In vivo UVA irradiation of mouse is more efficient in promoting pulmonary melanoma metastasis than in vitro irradiation of melanoma cells. Cancer Cell Int. 2011; 11: 16.

Pluder F, Barjaktarovic Z, Azimzadeh O, Mörtl S, Krämer A, Steininger S, Sarioglu H, Leszczynski D, Nylund R, Hakanen A, Shiharshan A, Atkinson MJ, Tapio S. Low-dose irradiation causes rapid alterations to the proteome of the human endothelial cell line EA.hy926. Epub 2010 Nov 23. Radiation and Environmental Biophysics 2011; 50 (1): 155–166. (doi:10.1007/s00411-010-0342-9).

Pöllänen R, Siiskonen T, Ihantola S, Toivonen H, Pelikan A, Inn K, La Rosa J, Bene B. Activity determination without tracers in high-resolution alpha-particle spectrometry. Journal of Radioanalytical and Nuclear Chemistry 2011; 290: 551–555.

Siiskonen T, Kettunen H, Peräjärvi K, Javanainen A, Rossi M, Trzaska WH, Turunen J, Virtanen A. Energy loss measurement of protons in liquid water. Phys. Med. Biol. 2011; 56: 2367–2374. (doi:10.1088/0031-9155/56/8/003).

Siiskonen T, Pöllänen R. New approach to alpha spectrum analysis: Iterative Monte Carlo simulations and fitting. Progress in Nuclear Science and Technology 2011; 2: 437–441.

Abstracts, conference proceedings, series

Aallos-Ståhl S-M, Venelampi E, Annanmäki M, Oksanen E, Markkanen M. Radon in Finnish mines 1972–2010. In: Current Challenges in Radiation Protection. Conference Proceedings. XVI Conference of the NSFS. Reykjavík, August 22nd–25th, 2011. (http://nsfs.org/NSFS-2011).

Aarnio P, Ala-Heikkilä J, Hoffman I, Ilander T,

Klemola S, Mattila A, Kuusi A, Moring M, Nikkinen M, Pelikan A, Ristkari S, Salonen T, Siiskonen T, Smolander P, Toivonen H, Ungar K, Vesterbacka K, Zhang W. Linssi – SQL database for gamma-ray spectrometry, Part I: Database. Version 2.3. Helsinki University of Technology Publications in Engineering Physics, TKK-F-A861. Espoo: Aalto University; 2011.

Aroua A, Aubert B, Back C, Biernaux M, Einarsson G, Frank A, Friberg EG, Griebel J, Hart D, Järvinen H, Leitz W, Muru K, Nekolla E, Olerud HM, Tenkanen-Rautakoski P, Trueb P, Valero M, de Waard I, Waltenburg H, Ziliukas J. Collective doses from medical exposures: an inter-comparison of the "TOP 20" radiological examinations based on the EC guidelines RP 154. In: Proceedings – Third European IRPA Congress, 14–18 June 2010, Helsinki, Finland. Helsinki: Nordic Society for Radiation Protection; 2011 [PDF publication]. Web version online 2010 June 16. [S02-03, 10 pp.].

Bly R, Cederlund T, Einarsson G, Friberg EG, Järvinen H, Leitz W, Muru K, Waltenburg HN, Widmark A, Ziliukas J. Diagnostic reference levels for diagnostic x-ray examinations in the Baltic and Nordic countries. In: Proceedings – Third European IRPA Congress, 14–18 June 2010, Helsinki, Finland. Helsinki: Nordic Society for Radiation Protection; 2011 [PDF publication]. Web version online 2010 June 16. [P02-17, 9 pp.].

Bly R, Jahnen A, Järvinen H, Olerud H, Vassileva J, Vogiatzi S. European population dose from radiodiagnostic procedures – early results of Dose Datamed 2. In: Current Challenges in Radiation Protection. Conference Proceedings. XVI Conference of the NSFS. Reykjavík, August 22nd–25th, 2011. (http://nsfs.org/NSFS-2011/).

Einarsson G, Bly R, Järvinen H, Leitz W, Cederlund T, Olerud HM, Widmark A, Friberg EG, Waltenburg HN. Cooperation of the Nordic radiation protection authorities in the field of X-ray diagnostics. In: Proceedings – Third European IRPA Congress, 14–18 June 2010, Helsinki, Finland. Helsinki: Nordic Society for Radiation Protection; 2011 [PDF publication]. Web version online 2010 June 16. [P02-16, 6 pp.].

Järvinen H. Clinical auditing and quality assurance. In: Proceedings – Third European IRPA Congress, 14–18 June 2010, Helsinki, Finland. Helsinki: Nordic Society for Radiation Protection; 2011 [PDF publication]. Web version online 2010 June 16. [R05, 10 pp.].

Järvinen H, Alanen A, Ahonen A. Ceder K, Lyyra-Laitinen T, Paunio M, Sinervo T, Wigren T. Guidance on internal audits and self-assessments: support to external clinical audits. In: Current Challenges in Radiation Protection. Conference Proceedings. XVI Conference of the NSFS. Reykjavík, August 22nd–25th, 2011. (http://nsfs.org/NSFS-2011/).

Kelaranta AE, Hakanen AT. Thermoluminescence dosimetry used as a postal quality audit in intraoral radiology. In: Current Challenges in Radiation Protection. Conference Proceedings. XVI Conference of the NSFS. Reykjavík, August 22nd–25th, 2011. (http://nsfs.org/NSFS-2011/).

Koskelainen M. Stakeholder involvement and engagement. In: Proceedings – Third European IRPA Congress, 14–18 June 2010, Helsinki, Finland. Helsinki: Nordic Society for Radiation Protection; 2011 [PDF publication]. Web version online 2010 June 16. [R14, 9 pp.].

Koskelainen M. Comparison of current clearance standards and their brief history. In: Proceedings – Third European IRPA Congress, 14–18 June 2010, Helsinki, Finland. Helsinki: Nordic Society for Radiation Protection; 2011 [PDF publication]. Web version online 2010 June 16. [S18-02, 11 pp.].

Koskelainen MO. Use of deliberative stakeholder involvement in preparation of radiological emergency operating procedures at a steel mill. In: Current Challenges in Radiation Protection. Conference Proceedings. XVI Conference of the NSFS. Reykjavík, August 22nd–25th, 2011. (http://nsfs.org/NSFS-2011/).

Kosunen A, Toroi P. Calibration of the working standard with RQR-radiation qualities. In: Implementation of the international code of practice on dosimetry in diagnostic radiology (TRS 457): Review of test results. IAEA human health reports no 4. Vienna: IAEA; 2011. p. 106–108.

Könönen N, Toroi P, Timonen M, Kortesniemi M. Forward scattering from the compression paddle in the dosimetry of mammography. In: Proceedings of the XLV annual conference of the Finnish Physical Society and the second Nordic physics meeting, March 29–31, 2011, Helsinki, Finland. University of Helsinki, Report Series in Physics, HU-P-D178, Helsinki 2011.

Markkanen M. Natural radiation environment and NORM. In: Proceedings – Third European IRPA Congress, 14–18 June 2010, Helsinki, Finland. Helsinki: Nordic Society for Radiation Protection; 2011 [PDF publication]. Web version online 2010 June 16. [R06, 7 pp.].

Nylund R, Lemola E, Hakanen A, Leszczynski D. Short-term response of human endothelial cell line EA.hy926 to low-dose ionizing radiation: a proteomics analysis [abstract]. In: Cardiorisk Symposium. 2011 Jun 6–7; Munich, Germany.

Siiskonen T, Peräjärvi K, Kosunen A, Turunen J, Kettunen H, Laitinen M, Rossi M, Sajavaara T, Trzaska W, Virtanen A. Towards more accurate dosimetry in proton, neutron and heavy ion exposures. In: Abstract book of ACTA/NACP 2011 Symposium, April 13–15, 2011, Uppsala, Sweden.

Soimakallio S, Järvinen H, Ahonen A, Ceder K, Lyyra-Laitinen T, Paunio M, Sinervo T, Wigren T. National coordination of Clinical Audits for medical radiological procedures. In: Proceedings – Third European IRPA Congress, 14–18 June 2010, Helsinki, Finland. Helsinki: Nordic Society for Radiation Protection; 2011 [PDF publication]. Web version online 2010 June 16. [S02-11, 7 pp.].

Toroi P, Husso M, Kosunen A. Calibration of kerma area product meters with a patient dose calibrator. In: Standards, applications and quality assurance in medical radiation dosimetry (IDOS). Vol. 2. Proceedings of an International Symposium, Vienna, 9–12 November 2010. p. 3–19.

Research publications in STUK publication series

Toroi P, Järvinen H, Könönen N, Parviainen T, Pirinen M, Tapiovaara M, Tenkanen-Rautakoski P. Potilaan säteilyaltistuksen määrittäminen mammografiassa. (Determination of patient radiation exposure in mammography). STUK-TR 11. Helsinki: STUK; 2011.

Regulatory control reports

Paasonen Timo. Terveydenhuollon henkilöstön perus- ja jatkokoulutukseen sisältyvä säteilysuojelukoulutus Suomessa 2010. (Radiation safety training included in basic and further training of health care staff in Finland in 2010). STUK-B 133. Helsinki: STUK; 2011.

Rantanen Erkki (toim.). Säteilyn käyttö ja muu säteilylle altistava toiminta. Vuosiraportti 2010. (Use of radiation and other practices involving exposure to radiation. Annual report 2010). STUK-B 131. Helsinki: STUK; 2011.

Rantanen Erkki (ed.). Radiation practices. Annual report 2010. STUK-B 137. Helsinki: STUK; 2011.

Regulatory guides

Finnish language

Säteilyn käyttöorganisaatio. Ohje ST 1.4 (Radiation user´s organization. Guide ST 1.4). STUK (2 Nov. 2011).

Säteilylähteiden käyttötilojen suunnittelu. Ohje ST 1.10 (Design of rooms for radiation sources. Guide ST 1.10). STUK (14 July 2011).

Sädehoidon turvallisuus. Ohje ST 2.1 (Safety in radiotherapy. Guide ST 2.1). STUK (18 April 2011).

Hammasröntgentutkimukset terveydenhuollossa. Ohje ST 3.1 (Dental X-ray examinations in health care. Guide ST 3.1). STUK (20 Aug. 2011).

Radioaktiivisen jätteen ja käytetyn ydinpolttoaineen siirrot. Ohje ST 5.7 (Shipments of radioactive waste and spent fuel. Guide ST 5.7). STUK (6 June 2011).

Säteilyturvallisuus luonnonsäteilylle altistavassa toiminnassa. Ohje ST 12.1 (Radiation safety in practices causing exposure to natural radiation. Guide ST 12.1). STUK (2 Feb. 2011).

Swedish language

Planering av strålkällors användningsutrymmen. Direktiv ST 1.10 (Design of rooms for radiation sources. Guide ST 1.10). STUK (14 July 2011).

Säkerhet vid strålbehandling. Direktiv ST 2.1 (Safety in radiotherapy. Guide ST 2.1). STUK (18 April 2011).

Tandröntgenundersökningar inom hälsovården. Direktiv ST 3.1 (Dental X-ray examinations in health care. Guide ST 3.1). STUK (20 Aug. 2011).

Strålsäkerheten vid verksamhet som medför exponering för naturlig strålning. Direktiv ST 12.1 (Radiation safety in practices causing exposure to natural radiation. Guide ST 12.1). STUK (2 Feb. 2011).

English language (translations)

Radiation safety in practices causing exposure to natural radiation. Guide ST 12.1. STUK (2 Feb. 2011).

Other publications

Havukainen R, Henner A. Hoitajien säteilysuojelukoulutuksessa kehitettävää (Radiation safety training of nurses must be improved). Radiografia 2011; 4: 6–9.

Havukainen R, Paunio M, Halila H. Lääkärien koulutus säteilysuojelussa on puutteellista (pääkirjoitus) (Shortcomings in radiation safety training of medical practitioners (editorial)). Suomen lääkärilehti 2011; 39: 2817.

Henner A, Havukainen R. Hoitajien säteilysuojelukoulutuksessa kehitettävää (Radiation safety of nurses must be improved). Pinsetti 2011; 4: 21–23.

Järvinen H. Hyvän käytännön kriteerit ja kliininen auditointi, Kliinisen auditoinnin asiantuntijaryhmän tekemä selvitys. Kirjassa: XXXV Sädeturvapäivät 3.–4.11.2011 Tampere-talo (Criteria of good practice and clinical auditing, Study of the clinical auditing expert group. In the book: XXXV Radiation Safety Conference at Tampere Hall 3–4 Nov. 2011). Tampere: Sädeturvapäivä-toimikunta (Radiation Safety Conference Committee); 2011. p. 40–41.

Karppinen J. TT-annokset – missä ollaan ja miten on tähän tultu. Kirjassa: XXXV Sädeturvapäivät 3.–4.11.2011 Tampere-talo (CT doses – where are we and how did we get there. In the book: XXXV Radiation Safety Conference at Tampere Hall 3–4 Nov. 2011). Tampere: Sädeturvapäivätoimikunta (Radiation Safety Conference Committee); 2011. p. 37–39.

Kelaranta A, Toroi P. Sikiön saamat sädeannokset eri kuvauksissa. Kirjassa: XXXV Sädeturvapäivät 3.–4.11.2011 Tampere-talo (Foetal radiation doses in various imagings. In the book: XXXV Radiation Safety Conference at Tampere Hall 3–4 Nov. 2011). Tampere: Sädeturvapäivätoimikunta (Radiation Safety Conference Committee); 2011. p. 17–19.

Lajunen A. Säteilyturvakeskuksen ohjeistus uudistuu (STUK guidelines revised). Suomen eläinlääkärilehti 2011; 9: 602–605.

Pirinen M, Tenkanen-Rautakoski P. Säteilyannokset ja säteilyannoksen hallinta toimenpideradiologiassa. Kirjassa: XXXV Sädeturvapäivät 3.–4.11.2011 Tampere-talo (Radiation doses and radiation dose control in interventional radiology. In the book: XXXV Radiation Safety Conference at Tampere Hall 3–4 Nov. 2011). Tampere: Sädeturvapäivätoimikunta (Radiation Safety Conference Committee); 2011. p. 47–48.

Tenkanen-Rautakoski P. STUKin ohjeistusta hammasröntgentoimintaan (STUK guidelines for dental X-ray practices). Hammaslääkäri 2011; 7: 32–33.

Tenkanen-Rautakoski P. Hoitajan kirjoittama röntgenlähete on lain vastainen (X-ray referrals from nurses are unlawful). Radiografia 2011; 2: 28.

Alara magazine

Aallos-Ståhl S-M. Altistuuko kaivoksissa radonille? (Are workers exposed to radon in mines?). Alara 2011; 3: 19–21.

Hallinen E. Röntgenin sattumuksista enemmän ilmoituksia (Notifications to STUK of abnormal incidents in X-ray practices have increased). Alara 2011; 3: 26–28.

Paasonen T. Säteilysuojelukoulutuksessa on parannettavaa (Radiation safety training must be improved). Alara 2011; 3: 29–30.

Toroi P, Kelaranta A. Röntgentutkimus on pieni riski sikiölle (X-ray examination is a minor risk to a foetus). Alara 2011; 3: 4–6.

Academic thesis works

Könönen N. Kompressiolevyn aiheuttama eteenpäinsironta mammografian dosimetriassa. Pro Gradu –tutkielma. Jyväskylän yliopisto, Fysiikan laitos (Forward scattering from the compression paddle in mammography dosimetry. Master´s thesis. University of Jyväskylä, Department of Physics), 2011.

Bulletins and brochures

Quality control guidance for nuclear medicine equipment. Advice from STUK 1/2010. Helsinki: STUK; 2011.

Hammasröntgentoiminnan laadunvalvonta ja kuvaushuoneen säteilysuojaus (Quality control in dental X-ray practices and radiation shielding of the examination room). STUK opastaa/Syyskuu 2011 (Advice from STUK/September 2011). Helsinki: STUK; 2011.

KKTT-laitteen käyttö (Use of CBCT appliances). STUK opastaa/Lokakuu 2011 (Advice from STUK/October 2011). Helsinki: STUK; 2011.

Voimajohdot ympäristössämme (Electric power lines in our environment). Säteily- ja ydinturvallisuuskatsauksia (Radiation and nuclear safety leaflet). Helsinki: STUK; 2011.

Varo säteilylähteitä metallikierrätyksessä (Beware of radiation sources in metal recycling). Esite (Brochure). Helsinki: STUK; 2011.

APPENDIX 3

ST GUIDES PUBLISHED BY STUK. SITUATION AS OF 1 JUNE 2012.

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, 2 November 2011 (in Finnish)
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, 17 February 2012 (in Finnish)
ST 1.9 Radiation practices and radiation measurements, 17 March 2008
ST 1.10 Design of rooms for radiation sources, 14 July 2011

Radiation therapy

ST 2.1 Safety in radiotherapy,18 April 2011 (in Finnish)

Diagnostic radiology

ST 3.1 Dental X-ray examinations in health care, 20 August 2011
ST 3.2 Mammography equipment and their use, 13 August 2001
ST 3.3 X-ray examinations in health care, 20 March 2006
ST 3.7 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, 9 March 2012 (in Finnish)
ST 5.7 Shipments of radioactive waste and spent fuel, 6 June 2011 (in Finnish)
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

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ST 8.1 Radiation safety in veterinary X-ray examinations, 20 March 2012 (in Finnish)

Non-ionizing radiation

ST 9.1 Radiation safety requirements and regulatory control of tanning appliances, 1 December 2003 (in Finnish)
ST 9.2 Radiation safety of pulsed radars, 2 September 2003 (in Finnish)
ST 9.3 Radiation safety during work on masts at FM and TV stations, 2 September 2003 (in Finnish)
ST 9.4 Radiation safety of high power display lasers, 28 February 2007 (in Finnish)

Natural radiation

ST 12.1 Radiation safety in practices causing exposure to natural radiation, 2 February 2011
ST 12.2 The radioactivity of building materials and ash, 17 December 2010
ST 12.3 Radioactivity of household water, 9 August 1993
ST 12.4 Radiation safety in aviation, 20 June 2005