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Radiation practices

Annual report 2010

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Abstract

1760 safety licences for the use of radiation were current at the end of 2010. 1789 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 384 inspections of licensed practices in 2010. 447 repair orders and recommendations were issued in the course of inspections.

A total of nearly 12 100 workers were subject to individual monitoring in 2010. Just under 160 000 dose entries were made in the Dose Register maintained by STUK.

Regulatory control of natural radiation focused on radon at workplaces and exposure of aircrews to cosmic radiation. 140 workplaces including a total of 348 work areas were subject to radon monitoring during 2010. 3428 cockpit and cabin crew members were monitored for exposure to cosmic radiation.

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

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

Regulatory control of the use of non-ionizing radiation in 2010 focused particularly on mobile phones, sunbeds and lasers. 16 sunbed facilities were inspected and 8 on-site laser display inspections were performed. Ten mobile phone types were tested in market surveillance of wireless communication devices.

There were 32 abnormal incidents involving the use of radiation in 2010. 22 of these incidents concerned the use of radiation in industry, research and education, nine involved medical uses of radiation and one concerned the use of non-ionizing radiation. None of these incidents had serious consequences.

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Management foreword

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

The total radiation dose sustained by workers from uses of ionizing radiation remained at the level to which it had fallen in the preceding year from higher levels recorded in earlier years. This favourable development reflects an emphasis on radiation protection both in operational planning and in practical work.

The personal doses of radiation workers remained below the assigned limits with the exception of one abnormal incident in which a person conducting inspections of industrial radiography sustained a dose somewhat exceeding the annual limit due to neglect of safety precautions.

A large group of workers subject to monitoring of radiation exposure at work are flight crews, whose aggregate radiation dose was about twice that of all persons engaged in radiation work proper. The aggregate radiation dose of flight crews returned to the level of 2008.

The approval of a dosemeter developed in Finland using new technology was an important step in individual monitoring of workers engaged in radiation work.

Use of radiation in the year under review remained at the same level as the preceding year. An increase in the number of urgent applications has been noticed in the regulatory control operations of STUK. More unlicensed appliances were found in the course of inspections and regulatory control surveys. This may be an indication of a deteriorating safety culture that should be tackled more effectively at places of use.

31 abnormal incidents in the use of ionizing radiation were reported during the year under review, which was two more than in the preceding year. 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. Abnormal incidents are discussed at training days and conferences arranged by STUK. The radiation exposure of 55.7 mSv sustained by a worker in one of these incidents exceeded the annual dose limit. The incident was classified at level 2 on the 7-level International Nuclear Event Scale (INES).

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. A joint conference was arranged with the enterprises concerned and an emergency exercise was organized with one enterprise. Stakeholders in the industry have expressed a wish to continue this new co-operation.

The number of radiotherapy accelerators in Finland increased by one. There is a problem in ensuring the patient dose in new therapy techniques. STUK has conducted dose verification research work as part of the European EMRP project. The research findings will be applied in fieldwork.

The largest source of exposure to man-made radiation remains the use of radiation in health services, amounting to approximately 0.48 mSv per year. The growing use of CT scanning using X-radiation for diagnostics involves a risk of increased patient doses. Statistics on the number of examinations in 2008 indicate a 23% increase in the number of CT scans since 2005. While CT scans account for only 8.3% of all X-ray examinations performed in Finland, they are the source of 58 % of the collective population dose. The trend is similar in all European countries. During 2010 the European radiation safety authorities also initiated discussions with the manufacturers of CT scanners and measures to limit the increase in radiation doses.

The continually growing popularity in dental X-ray imaging of cone beam CT scanning appliances (dental CBCT) has brought new challenges for regulatory control of dental X-ray practices. Dental CBCT appliances are more difficult to use than conventional dental X-ray appliances, and a safety licence is required for their use. This is causing a significant change in operating context, including special skills requirements for appliance operators. STUK has been involved in negotiations at the Ministry of Social Affairs and Health over the minimum qualifications of persons responsible for dental CBCT appliances and of the operators of such appliances.

To improve the effectiveness of regulatory control, a transition to risk-based assessment prioritizing resource allocation according to risk was made in inspections at places of radiation use and in processing of safety licences.

The Radiation Metrology Laboratory of STUK acquired a new ^{60}Co radiation source for the purpose of maintaining the accuracy and reliability of radiation measurements. This continued an ongoing programme of replacing radiation sources. The new apparatus will ensure the capacity of STUK to verify the accuracy of radiotherapy appliances and radiation dosemeters.

The staff responsible for regulatory control of ionizing radiation continue to change as specialists retire or leave for other reasons. New specialists require on-the-job training, and more experienced specialists have taken time away from their own regulatory control duties to assist in this training.

The Non-Ionizing Radiation Surveillance 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 sunbed facilities, lasers 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.

Significantly more information concerning the carcinogenicity of sunbed use has become available in recent years and the International Agency for Research on Cancer (IARC) has accordingly assigned sunbeds to its highest cancer risk category. On the other hand, evidence increasingly suggests that for some reason sunbed tanning has become fashionable around the world, and particularly appealing to young girls. This trend has been exacerbated by the emergence of self-service tanning salons that anyone may enter without supervision. STUK has checked this disturbing trend by submitting a draft amendment to the Radiation Act to the Ministry of Social Affairs and Health that would prohibit the use of sunbeds by persons under 18 years of age and require age checks by an on-site supervisor.

The NIR Unit continued its successful collaboration with the Finnish Customs to enforce regulatory control of laser pointers. 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. Shining such a device into the eyes at close range can destroy the fovea centralis area of the retina responsible for maximum acuity of vision.

Regulatory control of electromagnetic fields focused on mobile phones and fields generated by new technology. The largest mobile phone SAR value measured was 0.94 W/kg, which did not exceed the maximum value prescribed in the Decree of the Ministry of Social Affairs and Health (294/2002). Measurements of the magnetic field generated by a wireless recharging device indicated that this field is clearly smaller than the maximum value prescribed in the said Decree.

Research by the NIR Unit focused on EMF dosimetry. The dosimetric analyses required for mobile phone radiation studies at the University of Turku and the Finnish Institute of Occupational Health were successfully completed. Top class dosimetry is essential when bioelectromagnetic research reports are cleared for publication in high quality scientific journals. The EMRP metrology project compared SAR measurement probe calibration results obtained from apparatus at STUK and the National Physical Laboratory in Britain (NPL) at frequencies of 30, 150, 300, 380 and 450 MHz, and calibration results at frequencies of 10–110 MHz for meters used in measuring currents in limbs. Such comparisons have not previously been performed anywhere. The compatibility of calibrations was generally high.

A doctoral dissertation was completed on SAR dosimetry in biological research.

Moving in the static magnetic field generated by a magnetic resonance imaging device induces powerful electric fields in a person's head. An article on the principles for limiting these motion induction fields was approved for publication in the journal Health Physics. This work forms part of the programme of the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

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 burden of customer questions addressed to qualified experts was reduced by improving the website with particular attention paid to frequently asked questions, and by transferring some of the service to STUK information officers.

Various development meetings during the year considered the purpose, basic functions, outlook and strategy of the NIR Unit. 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 substances, 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.

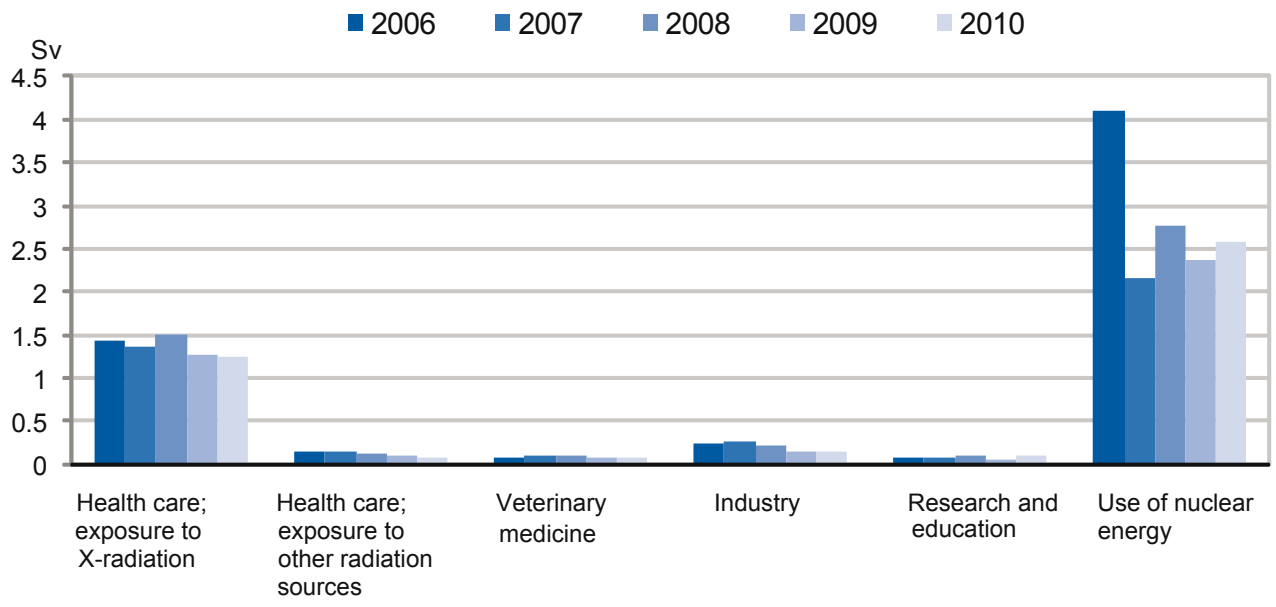

Figure 1. Combined doses ($H_p(10)$) of workers subject to individual monitoring by occupational category, 2006–2010. $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the use of X-rays in health care and veterinary practices, in which workers use personal protective shields and in which the dose is measured by a dosemeter on the exposed side of the shield. The effective dose is then obtained by dividing the $H_p(10)$ value by a factor between 10 and 60. Besides the workers specified in the graph, a small number of people subject to individual monitoring also work in the following sectors: manufacturing, installation/servicing/technical test operation, trade/import/export and services pertaining to radioactive substances (see Tables 12 and 13 in Appendix 1).

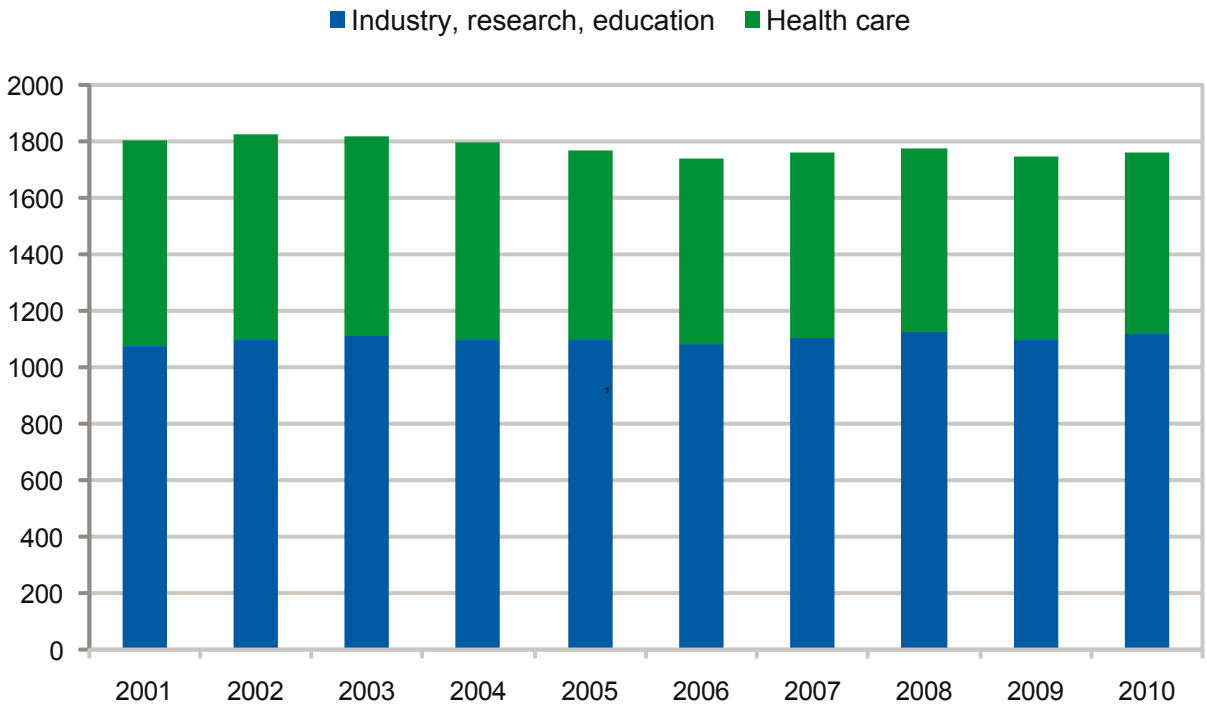

Figure 2. Current safety licences, 2001–2010.

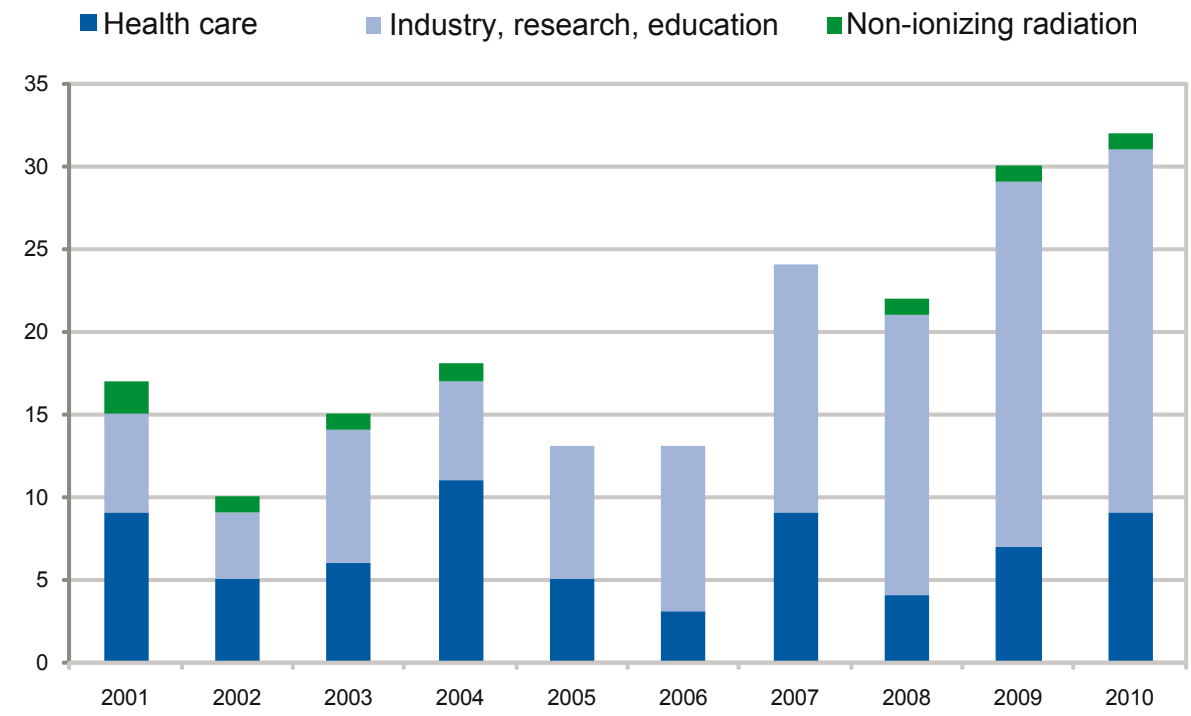

Figure 3. Abnormal incidents, 2001–2010.

2 Regulatory control of the use of ionizing radiation

2.1 Use of radiation in health care

Safety licences

At the end of 2010 there were 648 current safety licences for the use of radiation in health care (see also Figure 2), of which 226 concerned veterinary practices. A total of 382 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 services was 19 days. One fifth (22%) 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 an appliance had already been taken into use.

Radiation appliances and sources and laboratories

Table 2 in Appendix 1 shows details of radiation appliances and sources, and of radionuclide laboratories used in health care and veterinary practices at the end of 2010.

Requirement classes for X-ray practices in health care

STUK amended regulatory control activities for health care X-ray practices in 2010 on the basis of a risk assessment. The following regulatory control classification was introduced, based on the exposure sustained by patients and staff from various X-ray practices and appliances:

- requirement class I (bone mineral density measuring appliances, conventional dental X-ray appliances, panoramic scanners and cephalostats),
- requirement class II (conventional X-ray appliances, portable fluoroscopy appliances, mammography appliances and CBCT appliances),
- requirement class III (CT scanners and fixed fluoroscopy appliances).

This classification will help STUK to allocate regulatory control work more effectively to each practice.

Studies of X-ray examination statistics and population doses

Recording of data on medical procedures causing exposure to radiation is governed by section 43 of the Decree of the Ministry of Social Affairs and Health on the medical use of radiation (423/2000). It is also prescribed that a summary of the number of examinations and of radiation doses must be prepared according to separately issued instructions, on the basis of which summary STUK prepares national appraisals of the radiation exposure caused by the medical use of radiation and of trends in this exposure.

Pursuant to the said Decree, STUK studied the number of X-ray examinations in Finland in 2000, 2005 and 2008 (see also next item). Similar studies were also conducted in 1984 and 1995. Some 3.9 million X-ray examinations, or about 717 examinations per 1000 residents, were performed in Finland in 2008. Although this figure excludes dental X-ray examinations, it includes CT scans (about 60 examinations per 1000 residents) and interventional fluoroscopy/computed tomography (about 5 examinations per 1000 residents). Conventional X-ray examinations and examinations with contrast media accounted for about 90.1% of all X-ray examinations, CT scans for 8.3 %, angiography for 0.8% and interventional fluoroscopicy/computed tomography for 0.8%. The greatest change since 2005 has occurred in X-ray

examinations with contrast media (about 30% fewer) and CT scans (about 23% more).

7.5% of X-ray examinations in 2008 were of children (aged 0–16 years). About 8% of X-ray examinations with and without contrast media and about 2% of CT scans and angiographic examinations were of children.

Just over half a million ultrasound examinations and slightly more than 190 000 magnetic examinations were performed in 2008.

The findings of the 2008 study were published in report no. STUK-B 121. The figures for radiological examinations in 1995–2008 are shown in Figure 4.

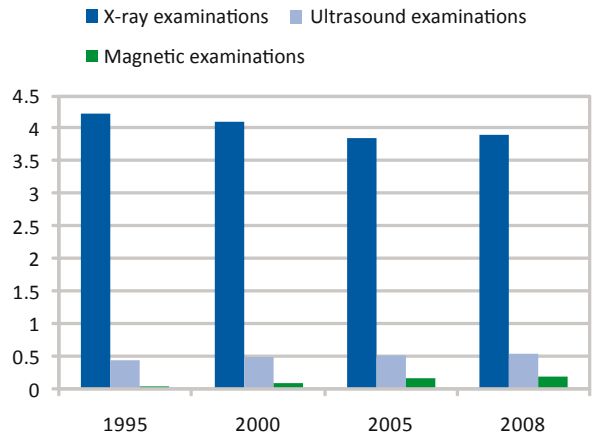

Figure 4. Radiological examinations in 1995–2008 (The figures for ultrasound and magnetic examinations are indicative, but not entirely comprehensive).

The per capita average effective dose from X-ray examinations and interventional radiology was 0.45 mSv. While the average dose has not changed substantially over the last decade, the proportion of the dose sustained by the population from CT scans out of the total collective population dose from all X-ray examinations and interventional radiology has substantially increased, now standing at 58% compared to 50% in 2005.

The assessment of population radiation dose also reviewed the serviceability of the European Commission recommendation on this subject (Radiation Protection Report RP 154, 2008) and the impact of new tissue weighting factors published by the International Commission on Radiological Protection (ICRP) (publication ICRP 103, 2007) on the estimate of collective effective dose. Although the "TOP 20" method published by the Commission provides a good estimate of the collective dose to the population from conventional X-ray examinations, it underestimates the said dose by about 22%, which is compatible with the information provided in the Commission report. Adoption of the new tissue weighting factors published by the ICRP (ICRP 103) increases the collective dose sustained by the population from conventional X-ray examinations by about 22%.

Report on use of radiopharmaceuticals

In 2010 STUK conducted an investigation into the use of radiopharmaceuticals in Finland in 2009. For this purpose a questionnaire was sent to all hospitals in which nuclear medicine examinations and/or radionuclide therapies were administered in the said year.

42 028 nuclear medicine examinations were performed in Finland in 2009, of which 2421 were paediatric examinations and 1088 were conducted for scientific research. 1786 radionuclide therapies were performed in 2009. Figure 5 shows the number of nuclear medicine examinations performed between 1975 and 2009. Figure 6 shows the number of PET scans performed in 2003, 2006 and 2009.

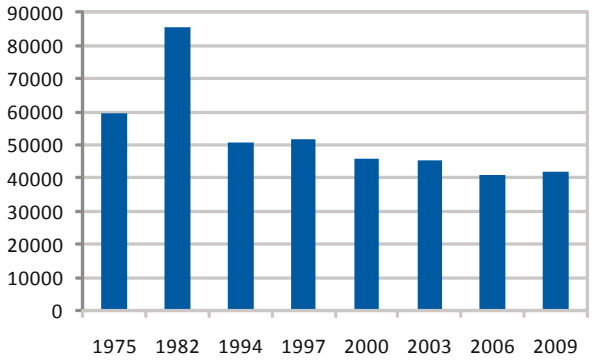

Figure 5. Nuclear medicine examinations in Finland, 1975–2009.

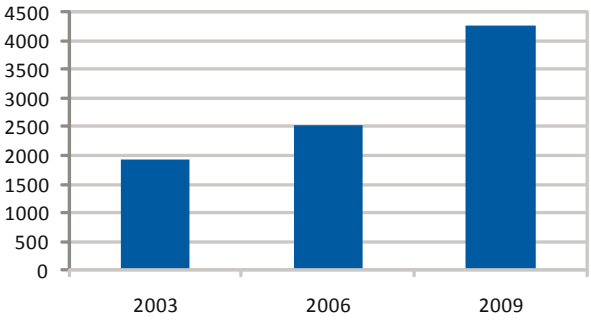

Figure 6. PET scans in 2003, 2006 and 2009.

The number of nuclear medicine examinations increased by about 3% and the number of radionuclide therapies fell by about 9% compared to 2006. There were 7.9 nuclear medicine examinations and 0.03 radionuclide therapies per 1000 residents in 2009. The number of PET scans has increased by about 70% since 2006.

The collective effective dose sustained from nuclear medicine examinations in 2009 was 172 manSv, and the consequent per capita average effective dose was 0.03 mSv. The average effective dose per nuclear medicine examination (clinical examinations of adults) was 4.1 mSv.

The average activities of radiopharmaceuticals administered to patients undergoing various nuclear medicine examinations, as notified by hospitals, are used for determining nuclear medicine examination reference levels. Table 3 of Appendix 1 shows the current reference levels issued by STUK for various examinations and the average activity administered in these examinations in 2009, which is the average weighted according to the number of examinations.

Radiotherapy

The total number of radiotherapy accelerators increased by one, arc treatments became more popular as a therapeutic technique, and one new type accelerator specially designed for 3-D arc treatments was taken into use. Arc treatment involves rotating the accelerator gantry around the patient along a predetermined arc during therapy. In intensity-modulated techniques certain fixed therapy angles are selected, of which there may be several in a single treatment. The shape of the therapy field may also be adjusted in both techniques. Verifying the patient dose is a problem in complex therapies, and new regulatory control methods have been developed at STUK for this purpose in the course of EMRP projects (see item 6.1).

Comparison measurements taken between STUK and hospitals indicated that radiotherapy dose accuracy is very good: the average discrepancy in measurements was -0.3% in photon beams and 0.5% in electron beams. No overdoses jeopardizing safety in treatment were detected in these measurements.

Based on regulatory control risk assessment, STUK began inspecting radiotherapy practices separately from appliance inspections. Inspections will be performed every two years. At the same time the interval between inspections of radiotherapy X-ray simulators was extended to three years.

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 and installation and maintenance work and the trade and manufacture of radioactive substances.

Safety licences

There were 1112 current safety licences for the use of radiation in industry, research and education at the end of 2010 (see also Figure 2). The numerical distribution of radiation practices referred to in these licences is shown in Table 4 of Appendix 1.

In 2010 STUK requested an annual notification from all known vendors of X-ray appliances (47 vendors) concerning appliances sold and their custodians. These notifications disclosed 8 responsible parties who had failed to request a safety licence on taking the X-ray appliance into use. It was also discovered that 14 licensees had acquired new X-ray equipment without notifying this to STUK.

Radiation appliances and sources and laboratories

Table 5 in Appendix 1 shows details of radiation appliances and sources, and of radionuclide laboratories operating in industry, research and education at the end of 2010.

Table 6 in Appendix 1 shows details of radionuclides used in sealed sources.

High Activity Sealed Sources

There were 205 high activity sealed sources (HASS) in Finland at the end of 2010. 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 7 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.

2.3 Inspections of licensed radiation practices

181 inspections were made of the use of radiation in health care and veterinary practices. These inspections resulted in 73 repair orders or recommendations issued to the responsible parties. One portable fluoroscopy appliance with no safety licence was also found. Some appliance start-up inspections of X-ray practices in health services were discontinued on the basis of the risk assessment and new requirement classification. Start-up inspections were discontinued entirely for appliances in requirement class I. Some start-up inspections of appliances in requirement class II were replaced with notifications of patient radiation exposure submitted to STUK by the responsible party.

203 inspections were made of the use of radiation in industry, research and education. These inspections resulted in 374 repair orders or recommendations.

Table 7 in Appendix 1 shows the number of inspections itemized by type of inspection. Table 8 in Appendix 1 shows the number of inspections itemized by type of practice.

2.4 Inspections of notifiable dental X-ray practices

1789 responsible parties were engaged in dental X-ray practices. Patient radiation exposure due to dental X-ray imaging was measured in 1336 appliances. The average dose was 1.5 mGy. This dose corresponds to the dose at the surface of the cheek (entrance surface dose, ESD) when imaging a tooth. The reference level of 5 mGy was exceeded in 7 imaging appliances.

47 inspections of notifiable dental X-ray practices were made. 28 repair orders were issued. Inspections disclosed a total of 33 dental X-ray appliances that had not been duly notified to STUK for registration.

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 2010 are shown in Tables 9–11 of Appendix 1. The figures in the tables are based on data gathered from radiation safety licensees engaged in trading, importing, manufacturing and exporting. The statistics exclude radioactive substances 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. The statistics also exclude radioactive substances supplied to other countries via Finland.

Table 9 of Appendix 1 excludes smoke detectors and fire alarm system ion detectors containing americium (^{241}Am). 271 000 devices of this kind were imported with a combined activity of about 8.7 GBq. 9600 smoke detectors with a combined activity of 0.3 GBq were exported from Finland. The data in the tables also exclude imported lamps and fuses containing radioactive substances. 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 12 100 workers engaged in radiation work were subject to individual monitoring in 2010. Including doses falling below the registration threshold, about 160 000 dose records were entered in the Dose Register maintained by STUK (this figure also includes the dose records of workers exposed to natural radiation, see Chapter 3).

The effective dose of a worker exceeded the annual dose limit of 50 mSv in one case. In no case did a radiation dose exceed 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 dose recorded was 1.7 Sv in the use of radiation and 2.6 Sv in the use of nuclear energy. There was no change in the total recorded dose for uses of radiation compared to the previous year. The total recorded dose from the use of nuclear energy was about 9% greater than in 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 personal dose equivalent $H_p(10)$ in health services was 26 mSv recorded in the case of an interventional radiologist. This corresponds to an effective dose of 0.4–2.6 mSv. The largest $H_p(10)$ in veterinary practice was 10 mSv recorded in the case of an animal attendant participating in X-ray examinations. This corresponds to an effective dose of 0.2–1.0 mSv. The largest effective dose in industry was 56 mSv sustained by a person performing radiography in the course of an abnormal incident (see incident 12 in item 2.9). The largest dose in research was 22 mSv sustained by a person using a wide range of radiation sources.

The largest dose to the fingers was 356 mSv, recorded in the case of a laboratory assistant working in health services.

Table 12 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 13. Table 14 shows the doses in 2010 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

New dosimetry method

A dosimetry method using a DIS-dosemeter (Direct Ion Storage) was approved for use in individual monitoring. The approved dosimetry service originally sought approval for the method back in 2006. This approval was finally granted at the end of 2010 after further evidence obtained from the dosimetry service showed that the method had been adequately tested and met the international standard requirements for methods used in individual monitoring.

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 examinations for radiation safety officers must apply to STUK for the right to arrange such examinations. Approval for arranging radiation safety officer interviews and training was granted to nine training organizations in 2010. A total of 19 such approval decisions were current at the end of 2010.

The number of competence fields provided by training organizations increased in 2010 when STUK approved a training organization that arranges radiation safety officer training and interviews also for veterinary X-ray practices.

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 319 STUK-accredited responsible medical practitioners in Finland at the end of 2010, of whom 32 were accredited during the year under review.

2.8 Radioactive waste

214 waste packages had been consigned to the national storage facility for low-level radioactive waste maintained by STUK by the end of 2009. There were no further consignments in 2010. The activities or masses of the most significant waste held in the storage facility are shown in Table 15 of Appendix 1.

2.9 Abnormal incidents

Under section 17 of the Radiation Decree (1512/1991), STUK must be notified of any abnormal event involving the use of radiation that is substantially detrimental to safety at the place where the radiation is used or in its environs. The disappearance, theft or other loss of a radiation source such that it ceases to be in the possession of

the licensee must likewise be reported. Any other abnormal observation or information of essential significance for the radiation safety of workers, other persons or the environment must also be notified.

There were 31 cases in 2010 in which abnormal incidents or situations occurred or were suspected in the use of ionizing radiation, of which 22 concerned the use of radiation in industry, research and education and 9 involved medical uses of radiation (see also item 4.4 for abnormal incidents in the use of non-ionizing radiation). Figure 3 (in item 1.1) shows abnormal incident numbers between 2001 and 2010.

The case histories set out below specify the abnormal incidents in the use of ionizing radiation that occurred in 2010 and the reasons for them, together with the measures taken on account of each incident.

Incident 1

A level gauge for liquefied gas containers disappeared from the storehouse of an industrial plant. The device included a ^{60}Co radiation source with an activity of less than 1 MBq. It had not been used, as it did not provide reliable measurements. The device may have been lost when moving the stores, and could not be found despite a search.

Incident 2

For a period of ten years during maintenance work on a mill timber line workers continually passed under a timber weight scale containing four radiation sources (each of 740 MBq ^{137}Cs) without shutting off the sources. Although the radiation safety officer prohibited this practice in instructions issued two years ago, the ban was not communicated to the maintenance staff concerned. The matter came to light when a new measuring device (not containing radioactive substances) was installed on the timber line, concealing the radiation hazard warning signs on the old devices, so that new signs had to be added in more prominent positions. The operating staff then became concerned on supposing that new radiation-emitting devices had been installed at the site.

STUK ordered the placement of a sign next to the weight scale requesting that the radiation sources be shut off during maintenance work. The doses sustained by the exposed workers did not exceed 20 µSv.

Incident 3

To perform maintenance work, a worker at a paper and paperboard mill entered a storage container where level gauge radiation sources were operating. The radiation source shutters had not been turned to the closed position before commencing servicing work. The worker was on the floor of the container and the nearest radiation sources (7.4 GBq ^{137}Cs) were at a height of more than five metres. The radiation sources directed a cone-shaped radiation beam onto a detector on the opposite side of the container. The container was five metres in diameter. The worker suspected that some exposure to radiation had occurred. Measurements taken after the incident found that the dose rates on the floor of the container did not differ from normal background radiation, and that the worker had therefore not sustained any extraordinary exposure to radiation.

Incident 4

A device containing ^{137}Cs isotope was found when cleaning an underground bunker constructed for gamma imaging at an industrial plant. The device was probably the source component of an old radiometric device, but its original purpose was not further clarified. The device had evidently been in the bunker for between 10 and 20 years. The external radiation dose rate at a distance of one metre from the device did not exceed 5 µSv/h. The device was sent to Suomen Nukliditekniikka (an enterprise specializing in processing and final disposal of nuclear waste).

Incident 5

A metal tube approximately three metres long filled with radioactive sediment or other corresponding process waste was found at a steel factory. On visiting the plant to identify the said material and take samples of it for further analysis, inspectors from STUK also found a container with a capacity of a few tens of litres that contained a small amount of unknown radioactive substance, and a metal bar about two metres long and radioactive substance on its surface. Investigations revealed that:

- the sediment in the metal tube contained natural uranium and phosphorus. The tube probably came from the fertilizer industry, as many phosphate ores are contaminated with uranium. The tube was consigned to a landfill site.
- the substance found in the container contained a radioactive isotope of silver (^{108m}Ag). Procedures were agreed with Suomen Nukliditekniikka whereby the container was consigned to the STUK national storage facility for low-level radioactive waste.
- the metal bar had enriched uranium on its surface, which suggests that the bar came from a uranium enrichment or reprocessing facility. STUK assumed custody of the metal bar and will arrange for its safekeeping and storage.

Incident 6

A radiation source (185 kBq ^{90}Sr) that had evidently been used at a school was sent to a provincial waste management company together with hazardous waste. STUK advised the company to contact Suomen Nukliditekniikka to ensure that the source was disposed of in an appropriate manner.

Incident 7

A haulage company driver collected an obsolete Tc generator from a laboratory. The generator packaging was poorly sealed and inadequately labelled. The driver had not received the required training in transporting hazardous materials, and the matter was only noticed at the haulage company warehouse, where concern was expressed at the unclear package labelling.

The deficient labelling was due to a failure to furnish the user of the generator with adequate guidelines on returning used generators. The generator supplier has clarified the guidelines to avoid corresponding incidents in future. No abnormal exposure to radiation arose in the case.

Incident 8

Testing work was performed in a closed exposure room when commissioning new apparatus for X-ray radiography at an enterprise. The tester had discontinued the work while another worker moved the X-ray tube out of the shielded room to its normal place of storage. Two radiation meters sounded an alarm when the tester resumed work and restarted the apparatus, whereupon the tester immediately shut it down.

The active X-ray tube was partly unshielded for about five seconds following the restart. The tube radiation beam was directed away from the tester at this time. The responsible party reconstructed the situation, estimating the radiation dose sustained by the tester at no more than 20 µSv based on measurements of dose rate and exposure time. To avoid any recurrence of such incidents, the event was recorded in the responsible party's local abnormal incident system where it is visible to workers. Abnormal incidents are also discussed at enterprise staff training sessions.

Incident 9

A worker at a measurement and research service enterprise had to adjust the settings on an X-ray fluorescence appliance in order to use it for imaging unusual samples. This involved close contact with the appliance. The worker contacted STUK because he suspected a potential exposure to radiation when operating and adjusting the appliance.

STUK examined the appliance and its operation, and the person whose exposure was suspected was also interviewed to clarify the circumstances of this exposure. Based on measurements made during the inspection and on the time spent working, it was estimated that the worker could have sustained an effective dose of no more than 1 mSv. The radiation dose was also estimated using a dose calculation program developed for X-ray examinations, resulting in a high-end dose estimate of the same order of magnitude.

An estimate of 80 mGy (a confidence interval of 0–150 mGy with a 95% probability) for the absorbed whole-body dose was obtained by chromosomal analysis of a blood sample from the person concerned. No other explanation was found for highly divergent dose estimates than the statistical uncertainty of chromosomal analysis in this dose range.

It was also disclosed in the course of this incident that no safety licence had been issued for use of the appliance. Inadequacies were also found in the operating instructions. The responsible party applied for the appropriate safety licence for use of the appliance while also improving the operating

instructions and performing some minor technical modifications to the appliance that improved radiation safety.

Incidents 10 and 11

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

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

The contaminated slag and dust were initially stored in sealed containers. They were subsequently placed in a waste disposal area of the plant designed for this purpose.

Incident 12

A radiographer was performing industrial imaging using a 4 TBq ^{60}Co radiation source. After the imaging process, the source was accidentally not replaced in its container before the radiographer returned to its proximity, and the radiographer was exposed to radiation for a few minutes. The radiographer's dosemeter determined the dose at 55.7 mSv, which exceeds the prescribed annual dose limit of 50 mSv. Chromosomal analysis of a blood sample from the radiographer was also performed at STUK in order to verify that the radiographer had not sustained a significantly higher radiation dose than was shown by the dosemeter.

In addition to a dosemeter, workers engaged in industrial radiography should also have access to an alarm dosemeter that sounds an immediate alarm if the radiation level is high. Safety standards also require that the return of a radiation source to its container after imaging is always verified using a radiation meter. These safeguards failed in this case.

As a result of this incident, a decision was taken to improve the radiation alarming system at the imaging site by installing a fixed measurement and alarm device. The responsible party also reminded everyone engaged in imaging work of the radiation safety regulations governing this work.

The incident was classified at level 2 on the 7-level International Nuclear Event Scale (INES).

Such incidents are extremely rare in Finland. On only one previous occasion (in 1968) has such a large dose been sustained in the course of industrial radiography.

Incident 13

Two subcontractor employees worked in a factory near to a radiometric density gauge detector while the shutter of the device radiation source was in the open position. The density gauge had a ^{137}Cs radiation source of activity 1850 MBq. Owing to the narrow radiation beam, only the hands of workers near to the detector sustained any radiation dose. Based on radiation measurements and working time, the factory radiation safety officer estimated that the equivalent dose to the hands did not exceed 0.5 mSv for one worker and 0.1 mSv for the other.

One reason for the exposure was that warning signs on the radiation source had needed to be removed when performing previous repair work and had not been replaced thereafter. Inadequacies were also found in risk assessment for minor repair and maintenance work and in guidance provided to outside labour. Following the incident the radiation warning signs were fastened to permanent structures that are not removed during repair and maintenance. The guidelines and training were also revised to avoid any corresponding incidents in future.

Incident 14

Three workers at an industrial plant began cleaning a wood chip compartment in a debarking house in order to prepare it for welding work. Due to an oversight, however, the shutter in the housing of a radiation source (1.85 GBq ^{60}Co) in the compartment blockage detector was not closed. The workers were exposed to radiation for 20–30 minutes. They sustained doses of between 3 and 40 µSv, depending on the position of each worker in relation to the radiation source.

Incident 15

Some metal items bearing radiation hazard

warning signs were consigned to a scrap metal firm. No radiation was detected by the radiation measurement instruments at the firm, but the enterprise reported its measurements to STUK enclosing photographs of the items. The items were empty lead containers that had been used for storing indium sources (^{111}In) in 2005–2006. The half-life of ^{111}In is 2.8 days, and no radioactivity would have remained, even if the indium sources had contaminated the lead containers during storage. Inspectors from STUK nevertheless visited the enterprise to take measurements verifying that no other radioactive residues had remained in the lead containers.

Unnecessary signs indicating radiation and radioactivity should be removed from empty storage vessels and other goods sent for scrap. The party that scrapped the lead containers on this occasion had neglected to remove the warning signs.

Incident 16

An X-ray diffractometer used at a research institute had two exit paths for the radiation beam, one of which had been closed with a lead plate. Radiation meter readings taken by two workers nevertheless showed that radiation was coming from two points on the appliance. This was due to the fact that the lead plate covering the radiation aperture had been displaced for some reason. It is not known when this displacement occurred, and a dozen people may have used the appliance with the displaced lead plate.

The lead shield was moved back into the right place immediately on discovering the abnormality. The doses sustained by persons exposed did not exceed 10 µSv.

Incident 17

A radar component containing 74 MBq of radium (^{226}Ra) was found in a box next to an employee's workstation. Although there were no signs of radioactivity in the article, the details of the radiation source were determined on the basis of its type designation. The dose rate was about 10 µSv/h at the surface of the article, about 1.5 µSv/h at a range of 20 cm, and about 0.22 µSv/h at a range of 90 cm. Based on measurements and exposure time, it was estimated that a person had sustained an annual effective dose from the radioactive article not exceeding 0.14 mSv over the three years spent working at the said location. The equivalent dose to the feet in those years had been about 2 mSv.

The radiating radar component was moved away to a safe distance from the workstation with a view to consigning it as radioactive waste to Suomen Nukliditekniikka at a later date.

Radioactive substances have been used as ion sources in signal exchange switches and surge protectors of radar systems to enhance the features of these components. Radium was commonly used in the 1940s and 1950s, and other isotopes such as ^{60}Co, ^{85}Kr, ^{232}Th, ^{63}Ni, ^{147}Pm and ^{3}H were subsequently used for this purpose. The amounts of radioactive material in these radar components were generally fairly small, but more powerful gamma emitters such as ^{226}Ra may nevertheless be detected by radiation meters outside of the article concerned.

Incident 18

A level gauge with two radiation sources (each of 1.67 GBq ^{241}Am) disappeared at a technochemical plant. The device was not found after a search, neither was the time of loss determined.

Incident 19

Some items bearing radiation hazard warning labels were found in the stores at an industrial plant. An investigation determined that the items were radio transmitter tubes that had originally contained a 5.55 kBq ^{60}Co radiation isotope. The manufacturing labels indicated that the tubes had been made in the early 1980s. No readings exceeding the normal background dose rate were detected by measurements taken outside of the tubes, and the items could be disposed of as ordinary electronic scrap.

Incident 20

A cabinet containing worker accessories was located in an X-ray radiography imaging room intended for imaging welding joints at a workshop. A worker had entered the imaging room to access the cabinet and spent a moment in the vicinity of the X-ray equipment when the appliance was activated. Due to the brevity of exposure, the extraordinary radiation dose was nevertheless

minimal. Measurements and investigations conducted by the imaging enterprise indicated a dose of 29 µSv.

The reason for the incident was that the worker engaged in imaging failed to check that there was nobody in the imaging room before activating the X-ray appliance. The accessories cabinet was removed from the imaging room, after which persons other than the worker conducting imaging will no longer need to enter the imaging room. The workers were also reminded of the need to comply with the company's current instructions and to control access to the area during imaging.

Incident 21

A waste management firm notified STUK that it will collect two ^{60}Co sources and one ^{241}Am source from an industrial enterprise. The firm stated that it will use a type B package for transportation. This came as a surprise, as STUK was unaware that the firm had any type B packages. When inspectors from STUK went to inspect the transport container in question they discovered that it was not a type B package, but a storage container for a type B radiation source that cannot be used as a type B package in transportation of radioactive materials.

Incident 22

An X-ray fluorescence appliance used in elemental analysis of metals disappeared from an industrial plant. The appliance could not be found despite a search, and was then notified as stolen in a report of a criminal offence.

An investigation of the matter revealed that there had been shortcomings in the routines for storing and operating the appliance. The keys to the safe used for storing the appliance were readily available on top of a cabinet. The appliance had also been released for use by an individual with no operating licence for its use, and the Responsible Person had not appropriately registered the release and return of the appliance. These shortcomings were corrected after the device had been lost.

Incident 23

A radiopharmaceutical intended for sentinel lymph node examination was unnecessarily administered to a patient on the way to surgery. There were two patients on their way to surgery, and in neither case did the referral separately specify any nuclear medicine examination. The nurse went to fetch the radiopharmaceutical from the nuclear medicine unit where only one of the patients had been given a referral for nuclear medicine examination. It was assumed that a referral for the other patient would arrive later, as had often occurred, and the radiopharmaceutical was injected into both. It became apparent the next morning that only one of the patients was due for a nuclear medicine examination.

The incident was recorded as a quality anomaly at both the nuclear medicine unit and the radiology unit. It was discussed with the referring medical practitioners and the importance of clarity in referrals was stressed. The incident has been notified to the national Reporting System for Safety Incidents in Health Care Organizations (HaiPro). The patient was informed of the incident during the next visit to the general clinic.

Incident 24

Myocardial perfusion gamma imaging was performed on a patient with an attenuation correction, with a low dose CT scan of the patient performed before the gamma imaging proper. On commencing the gamma imaging it was observed that the EKG synchronization signal was not visible on the display terminal. Corrective measures were attempted but the problem could not be resolved. The examination had to be repeated in full after restarting the hardware. The low dose CT scan also then had to be repeated, causing the patient to sustain an additional dose of about 2 mSv. The incident was recorded as a quality anomaly and discussed in accordance with the unit quality assurance system. The incident has been reported to the National Supervisory Authority for Welfare and Health (Valvira) as a hazardous situation arising in the use of a medical device.

Incident 25

A hospital was accustomed to using urine from a patient who had received ^{131}I therapy for thyroid cancer to determine the ^{131}I peak point of a gamma camera. The patient received an ablation dose (2299 MBq) of ^{131}I on Friday morning and was asked to take a urine sample in a lead-shielded bottle on the evening of the same day. The aim was for the nuclear medicine department nurse to collect the sample on Monday of the following week

when attending to take the patient's discharge measurements. However, the patient notified the nurse on duty at the department late on Friday that the patient had submitted a urine sample. The nurse completed an examination request and sent the sample to the laboratory. The night shift nurse at the laboratory performed the required examinations on the sample and then put the sample bottle in a lead shield into the laboratory fume cupboard. This came to light on the following Monday when the nurse who had arrived to take the discharge measurements requested the urine sample bottle. The nurse notified the radiation safety officer and the urine bottle was found in the laboratory fume cupboard, from which it was forwarded to the nuclear medicine laboratory. The activity of the urine sample was measured on Tuesday morning and it was possible to use the result of this measurement to determine the activity in the bottle on Friday. The dose rate at a range of 30 cm from the urine bottle on Friday evening had been about 8 µSv/h. Each of the nurses had handled the bottle for much less than one hour, and so their associated radiation exposure had not exceeded 10 µSv.

Incident 26

The objective was to perform myocardial perfusion gamma imaging on a patient both under stress and at rest. The imaging under stress was performed successfully. For the purpose of imaging at rest, the patient was injected with a 750 MBq ^{99m}Tc labelled radiopharmaceutical. However, the gamma camera stopped during imaging, and efforts to restart it were unsuccessful. Imaging of the patient at rest had to be repeated at a later time with a radiopharmaceutical injection of activity 370 MBq, resulting in an extraordinary radiation dose of about 3 mSv.

Incident 27

A hospital patient received 4100 MBq of ^{131}I in therapy for thyroid cancer. The patient was transferred with an escort to an isolation room in the ward. According to regulations, the person who receives a patient on the ward must place a radiation hazard warning sign on the door of the isolation room. However, this did not occur. Two female hospital physicians on the ward entered the isolation room without knowing that this patient was undergoing radioiodine therapy. The physicians did not wear lead aprons. The physicians remained in the room for an estimated two minutes at a distance of about 1.5 metres from the patient and left immediately on learning that the patient was undergoing radioiodine therapy. The dose rate at a range of 1.5 metres from the patient had been about 200 µSv/h, so the said exposure for two minutes resulted in a radiation dose of no more than 10 µSv. Neither of the physicians was pregnant at the time.

Incident 28

Two hospital patients due for cardiovascular examinations were mistakenly injected with a radiopharmaceutical used for imaging sentinel lymph nodes. A third patient who was due for sentinel lymph node imaging instead received an intratumoural injection of a radiopharmaceutical used for cardiovascular studies. This incident was due to human error. When preparing the radiopharmaceuticals in a hot laboratory the ampoules were mistakenly placed in wrong lead shields and the patient doses were thereby taken from the wrong bottle. The error was noticed when beginning imaging of another cardiovascular patient. This patient and the other cardiovascular patient were given 500 mg of potassium perchlorate to reduce the radiation dose to the thyroid gland. The incidents were explained to the patients and new examination times were arranged for them. The incidents were also entered in the patients' medical records and discussed with the workers who had been involved in the case. The cardiovascular examination patients sustained an excessive effective dose of about 1.3 mSv. The radiopharmaceutical in the sentinel lymph node examination was locally injected into a tumour and the consequent effective dose from this is quite small. This dose was not estimated.

Incident 29

In adrenocortical gamma imaging the patient is imaged a few days after injecting a radiopharmaceutical both by static gamma imaging and by the SPECT/CT method, whereupon a low dose CT scan of the patient is made before gamma imaging. A patient underwent static gamma imaging, for which the patient's medical record was retrieved from the RIS appointment system. The

RIS data were not available on commencing the SPECT/CT examination, and so the patient data were entered into the imaging system manually. The low dose CT scan was performed normally. On commencing the gamma imaging, the software reported a conflict between the patient's name and identity number and prevented gamma imaging from proceeding. However, the software had not correspondingly prevented the low dose CT scan for this reason. The patient then had to undergo a new low dose CT scan, resulting in an extraordinary dose of 2 mSv. The reason for this was that the software distinguishes between uppercase and lowercase letters. This situation could have been avoided if the software had reported the problem before the CT scan. The incident was recorded as a quality anomaly and discussed in accordance with the nuclear medicine unit quality assurance system. The abnormal incident was reported to Valvira. Guidelines on correct spelling of names (case-sensitivity) were issued to the unit.

Incident 30

A hospital patient was mistakenly given an abdominal CT scan using a contrast medium when a conventional CT scan of the head was required instead. This was due to confusion between the medical records of two patients.

Incident 31

A ^{133}Ba source was used for testing the operation of an activity meter (a dose calibrator) used at a hospital. After measuring the test source the activity meter settings were changed to ^{99m}Tc settings, but owing to a malfunction in the meter the energy window was not in fact changed correctly. The outcome of this was that the activity of a radiopharmaceutical (^{99m}Tc phosphonate) administered to two patients for skeletal imaging was measured with the wrong energy window. The patients were males aged 69 and 79 years. One of them sustained a radiation dose of 17.8 mSv and the other sustained a radiation dose of 17.2 mSv. Excessive activity was observed on the basis of the skeletal images of these patients. The average dose sustained by a patient undergoing skeletal gamma imaging is 3.7 mSv. These patients sustained a dose that was about five times greater than normal. STUK also requested that a report of the incident be sent to Valvira.

3 Regulatory control of practices causing exposure to natural radiation

3.1 Radon at workplaces

During 2010 STUK received 416 radon measurement notifications concerning either a radon concentration exceeding the action level of 400 Bq/m^3 measured in a work area, or further investigations of previously reported excessive levels. 139 inspection reports were sent to enterprises on the basis of these measurements. The reports required reductions in radon concentrations or an investigation of radon concentration during working hours in 122 work areas, and a measurement at another time of year in order to determine an annual average in 32 work areas. Radon concentrations were successfully reduced in 26 work areas during the year. STUK discontinued regulatory control in 15 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 177 work areas for other reasons (e.g. short working periods or discontinued use of premises). 348 work areas at 140 workplaces were subject to regulatory control by STUK during the year.

Statutory radon inspections were conducted at four underground mines, at all of which the average radon concentration fell below the action level.

Inspections were conducted at 13 underground quarries. Radon exposure limitation orders were issued for four of these quarries, while radon concentrations were successfully brought below the action level through corrective measures at three quarries.

Radon exposure of workers was monitored by regular radon measurements and monitoring of working hours at six conventional workplaces and two quarries where the radon concentration exceeded the action level. A total of 70 workers were subject to radon exposure monitoring during 2010.

No new approval decisions for radon measuring equipment were issued in 2010. A list of organizations with measuring methods 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.

STUK began regular radon inspections of underground quarries in 1992, when amendments to the Radiation Act and the Radiation Decree included a new requirement to determine radiation exposure in work causing exposure to natural radiation, and a duty to notify STUK of any underground excavation work lasting for longer than two months. Figure 7 shows the number of inspections performed underground between 1992 and 2010. There was a clear increase in the number of inspections in 2004. This is explained by an increase in underground construction work and also by the fact that STUK reminded excavator enterprises to submit notifications in the said year. It has also been necessary to make several inspections at some underground quarries when action levels have been exceeded.

In 2002 STUK investigated the radiation exposure sustained by miners in Finland due to radon over the period from 1972 to 2001. This study was extended in 2010 to include the years from 2002 to 2009. Radon measurements taken in 2008–2009 indicate that the average radon concentration in underground mines was 110 Bq/m^3. This concentration has remained more or less constant over the last decade. Figure 8 shows the average annual radiation doses (mSv) of miners in Finnish mines between 1972 and 2009.

3.2 Other natural radiation from the ground

STUK monitors radiation exposure caused by radioactive substances that occur naturally in water intended for human consumption, construction materials and other materials. Eleven inspection reports on the radioactivity of construction materials were prepared during 2010. These reports imposed restrictions on the use of materials where necessary. An order was issued to one waterworks requiring more precise measurements of water intended for human consumption. An analysis of the findings indicated that the concentrations of radioactive substances in the water did not exceed the maximum values. A statement was also issued on the final disposal of materials containing naturally occurring radioactive substances.

3.3 Cosmic radiation

The doses sustained by employees of six airlines were entered in the Dose Register of STUK in 2010. 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 4.6 mSv sustained by a pilot and 5.3 mSv sustained by a cabin crew member. The average annual dose sustained by pilots in 2010 was 2.2 mSv and the average annual dose of cabin crew members was 2.5 mSv. The average doses over the period 2006–2010 are shown in Figure 9.

The total number of workers in flight crews fell by about 6% compared to the preceding year, with only a slight decrease in the number of flying hours. The total radiation dose nevertheless fell by 5% compared to the preceding year. The number of workers subject to individual monitoring of radiation exposure and their total dose are shown in Table 16 of Appendix 1.

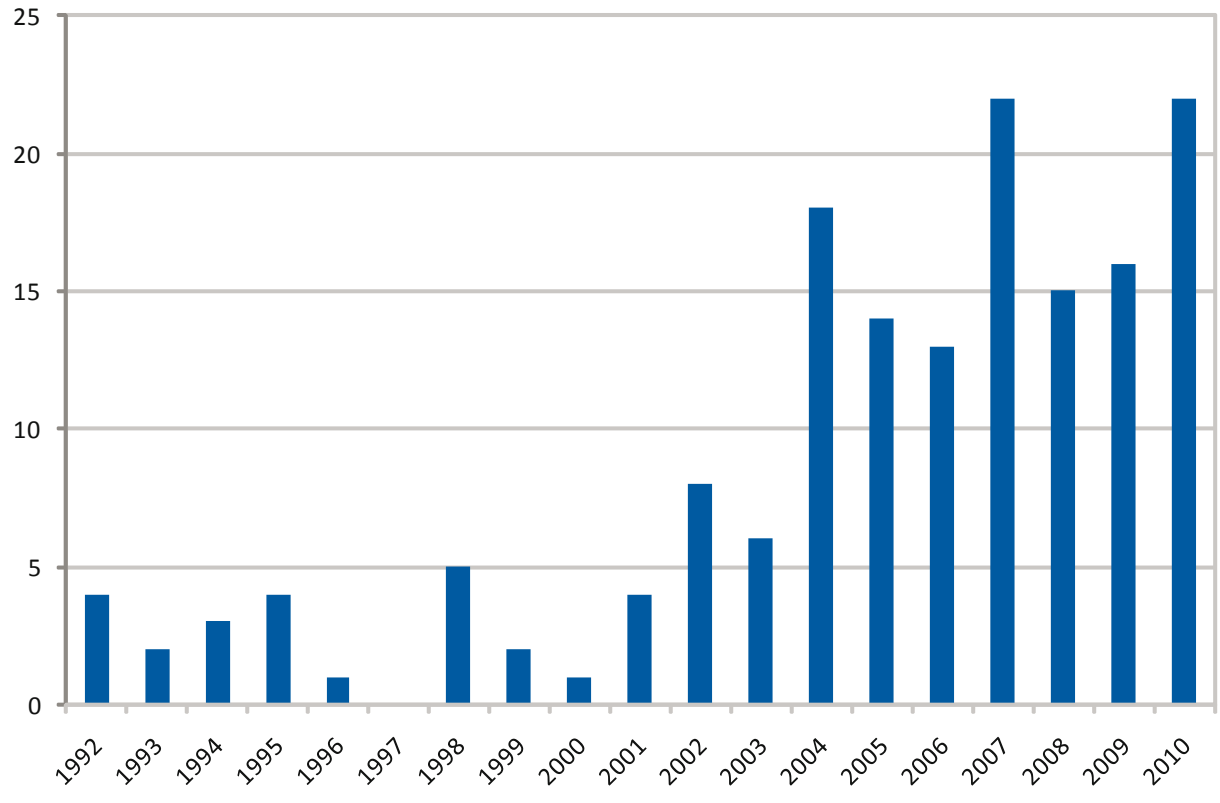

Figure 7. Radon inspections at underground quarries, 1992–2010.

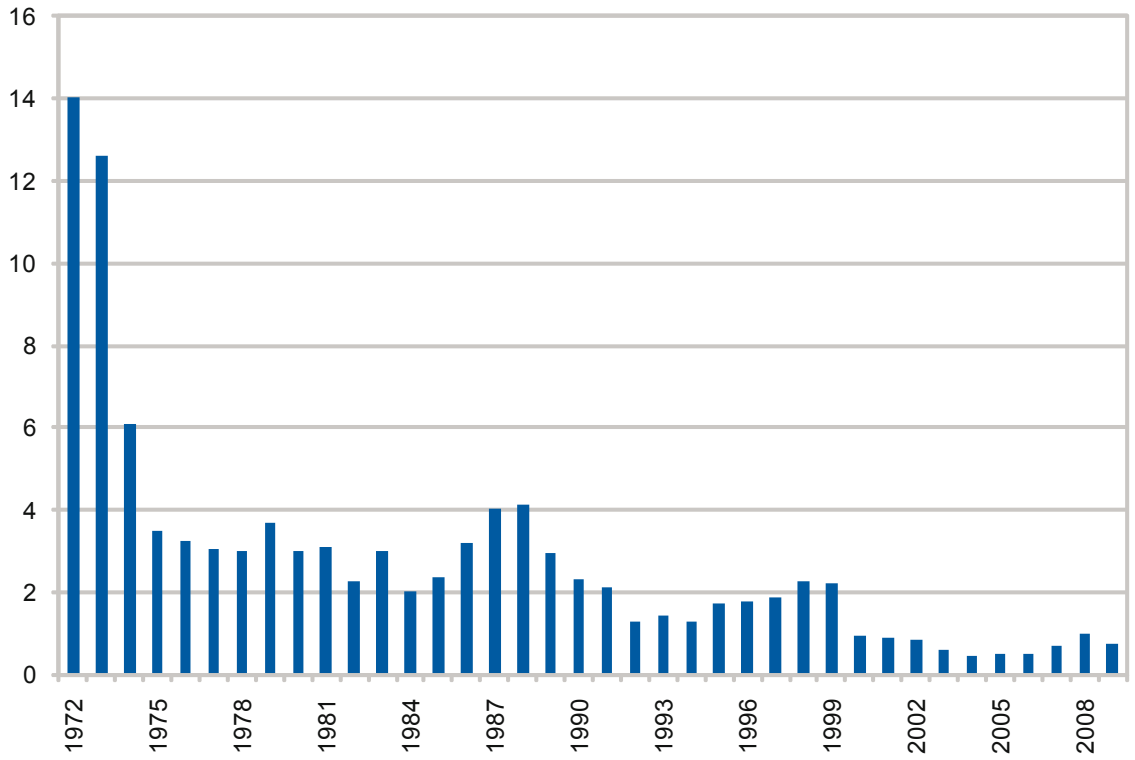

Figure 8. Average annual radiation doses (mSv) of miners in Finnish mines, 1972–2009.

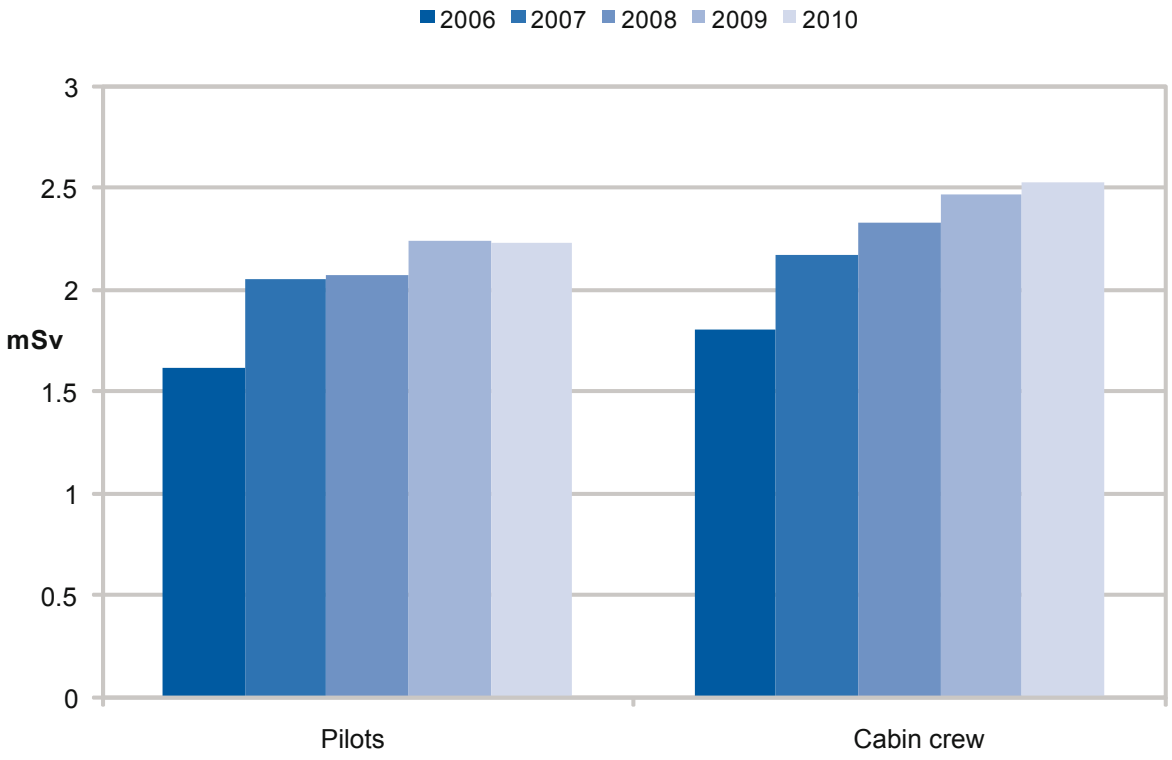

Figure 9. Average doses of air crews, 2006–2010.

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. The use of high power laser equipment at public performances has increased due to advances in laser technology (semiconductor lasers) and falling prices.
- Annual inspections have been made of a few public broadcasting stations and radar stations.

The work of the NIR Unit in regulatory control of the use of non-ionizing radiation between 2001 and 2010 is shown in Table 17 of Appendix 1. Numerous (about one hundred) requests for clarification and enquiries concerning importation of laser devices submitted by the Customs in an official capacity and by importers (including private individuals) have increased the need for regulatory control of lasers.

4.2 Optical radiation

Regulatory control of sunbed equipment

A total of 42 sunbed appliances were inspected in the course of 16 inspections conducted at sunbed establishments (see Table 18 in Appendix 1). 8 of these establishments were entirely self-service units, 4 were in fitness rooms and 4 were in hairdressing businesses. Only one establishment passed the inspection on all counts. No appliances exceeded the maximum value of 0.3 W/m^2 prescribed in the Decree of the Ministry of Social Affairs and Health on the Limitation of Public Exposure to Non-ionizing Radiation (294/2002, hereinafter referred to as the STM Decree). There was no mention at 10 establishments (60%) of the regulation limiting annual use of sunbed appliances (about 20 tanning sessions) and the 18-year age limit recommendation stipulated in the STM Decree. 6 appliances (14%) had non-compliant timers allowing an excessively long starting time. The operating instructions for 17 appliances (40%) correspondingly recommended excessively long starting times. There were also non-compliant cosmetic advertisements in the vicinity of 12 appliances (29%).

A proposal to amend the Radiation Act (592/1991) was drafted for the Ministry of Social Affairs and Health that would prohibit sunbed businesses from exposing persons under 18 years of age to sunbed radiation. This amendment to the Radiation Act will also require a change in the STM Decree.

In line with the proposal, the Ministry prepared draft legislation that was circulated for comments at the end of the year. If the proposal reaches the statute book, then the current recommendation in the STM Decree will become a legal prohibition (section 11). The draft legislation also requires sunbed operators to check the age of their

customers and to ensure that operating staff instruct customers in using sunbed appliances. In practice this will put an end to many self-service sunbed operations. Regulatory control of sunbeds will also be increased by increasing the supervision of sunbed establishments performed by public health inspectors under the Health Protection Act (763/1994).

The prohibition of sunbed use by persons under 18 years of age is supported by a decision of the International Agency for Research on Cancer (IARC) in summer 2009 to assign sunbed UV radiation to its highest cancer risk category 1A. There have been indications of increased use of artificial tanning in recent years, particularly by girls under 18 years of age. Unsupervised, coin or smartcard-operated sunbeds have also become more common in recent years. It is impossible to supervise compliance with user age limits or to provide personal guidance in sunbed operation at these establishments.

Regulatory control of laser devices

On-site inspections were conducted at 8 laser show installations. These inspections found that physical protection and the orientation of laser beams largely complied with requirements. Information received by STUK suggested that two shows had failed to comply with orders issued at the inspection by directing laser beams at part of the audience. STUK was also notified of five unauthorized laser shows where laser beams had been directed at the audience. Reports of these shows were requested. In one case it was necessary to enforce the reporting obligation by imposing a threat of a fine on the show presenter.

At the request of the National Bureau of Investigation, STUK measured the power and assessed the safety of two laser pointers that had been used in the way hazardous to eyes. The power of these pointers was about 50 times greater than the 1 mW power level permitted for laser pointers. STUK also measured two toy laser guns that were included in the Christmas toy project of the Safety Technology Authority (Tukes). The more powerful of these toys was 12 times more powerful than the permitted maximum of 0.39 mW for laser toys. Tukes ordered the removal of both toy laser guns from sale.

3 requests were made to investigate online sales of laser pointers, leading the sellers to withdraw non-compliant devices from sale. 31 requests to remove advertisements from the huuto.net online sales forum were also sent because of excessively powerful laser pointers.

The Customs submitted about one hundred requests for advice concerning the admission to Finland of lasers from outside of the European Economic Area. Most of these requests concerned battery-operated laser pointers. Import permits were refused to nearly all laser pointers, either due to a lack of type inspection certificate or to excessive radiation power. The highest powers of the laser pointers 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 110 mobile phones to date (see Table 19 of Appendix 1). A total of 10 GSM and UMTS type mobile phones were tested in 2010. The highest measured SAR value was 0.94 W/kg. This did not exceed the maximum value of 2 W/kg prescribed in the STM Decree.

Other regulatory control

Regulatory control was extended to include pads for recharging mobile phone batteries. The phone is placed on the pad and its battery is then wirelessly recharged by a low-frequency magnetic field generated by the pad. The radiation safety of two such recharging devices was assessed by measuring the magnetic fields that they generate. The exposure caused by these devices was clearly smaller than the maximum values for magnetic fields imposed under the STM Decree.

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). Through police and media reports, STUK learned of 6 cases in 2010 in which a laser pointer had caused a hazard to the eyes.

A separate safety assessment of one incident (see below) was conducted at the request of the National Bureau of Investigation.

Figure 3 (in item 1.1) shows abnormal incident numbers between 2000 and 2010.

Incident 1

A case arose in the Åland Islands where a group of men shone a green laser pointer at a police vehicle. STUK measured the power of the device at 57 mW. Even momentary exposure to the beam of a laser of power exceeding 5 mW can cause retinal damage. Although the laser beam did shine into the eyes police officers, the incident did not cause any permanent injury to the officers concerned. Subsequent to this incident the Åland Islands police department was advised of the hazards of laser radiation and of current Finnish legislation on lasers.

5 Regulation work

ST Guides

To achieve the level of safety that complies with the Radiation Act, STUK publishes Radiation Safety Guides (ST Guides) for responsible parties that use radiation or that engage in practices causing exposure to natural radiation. These Finnish language guides are also translated into Swedish and English.

The following Guide was published in 2010:

- ST 12.2 The radioactivity of building materials and ash.

An extranet service for comments on ST guides was introduced on the STUK website, enabling external commentators to submit their views on the guides to STUK. This service also enables the public to review ongoing work and submit comments on upcoming ST Guides.

Other regulation work

STUK was involved in work to revise the law on transportation of hazardous materials by submitting comments on draft legislation in this field. STUK also participated in the work of a Ministry of Transport and Communications committee preparing this legislative reform.

A proposal to amend the Radiation Act by introducing a ban on the use of sunbeds by persons under 18 years of age was prepared for the Ministry of Social Affairs and Health (see 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 also supports regulatory activities pertaining to radiation and maintains the preparedness to respond to radiological and nuclear emergencies. Research into uses of radiation seeks to improve knowledge and expertise in this field and to ensure reliable radiation measurements.

6.1 Ionizing radiation

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

IAEA code of dosimetry practice in X-ray diagnostics

An International Atomic Energy Agency (IAEA) research project to test a code of diagnostic dosimetry practice that began in 2006 was successfully completed as planned. The project facilitates the assessment of patient dose determination methods used for X-ray diagnostics in Finland and improves the reliability of dose determinations. The IAEA is preparing a project publication internally.

European Metrology Research Programme (EMRP)

Two co-financed European metrology research projects launched in 2008 developed and tested new regulatory control methods for radiotherapy that will improve regulatory control of the accuracy of internal radiotherapy and new therapeutic techniques of external radiotherapy (e.g. intensity-modulated radiotherapy in the treatment of prostate cancer). A water phantom for the pelvic region was developed at STUK for demanding dosimetry of small and intensity-modulated fields. The phantom uses GafChromic film dosimetry, for which STUK also developed a reading instrument. A method of verifying measurements based on Monte Carlo calculation was developed enabling simulation of the dose distribution produced by a radiotherapy accelerator. The simulated data verify the fitness of the measurement method. The project findings were reported at a meeting of the European Society for Therapeutic Radiology and Oncology (ESTRO) in September and at an international dosimetry conference of the IAEA in November. Both EMRP projects will continue in 2011.

6.2 Non-ionizing radiation

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

The WIRECOM project

As part of the WIRECOM project, the University of Turku (TY) and the Finnish Institute of Occupational Health (TTL) exposed human test subjects to mobile phone radiation and studied the effects of this exposure by various methods (including PET imaging, monitoring of temperature and blood flow measurements using near-infrared spectroscopy). The irradiation device for test subject exposure was made at STUK and used at two studies conducted at TY and one study conducted at TTL. The accurate exposure level of the test subjects in these three studies was determined by computation using the FDTD method.

The EMRP-NIR project

The role of STUK in the EMRP-NIR project (see also item 6.1) 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 taking comparison measurements together with a British project partner, the National Physical Laboratory (NPL).

The STUK SAR-TEM chamber was sent for surfacing at the end of 2009, as the interfaces of various metals on the internal surface of the chamber caused electrolysis in tissue-equivalent fluids made by the NPL, changing the colour and electrical properties of the fluid. The surfacing took longer than expected, and the chamber was only returned to STUK at the end of April 2010. Following the surfacing, the chamber seams had to be further sealed. It was only possible to commence the recalibrations at frequencies of 30, 150 and 300 MHz at the end of summer 2010. The calibration result at a frequency of 300 MHz differed by nearly 20% from the result obtained in 2009, which had been substantial affected by the change in properties of the fluid. There were no significant discrepancies at other frequencies. The NPL SAR measurement probe used in the comparison was returned to the NPL in October. The NPL has not yet had time to perform its own recalibration, and so the technical report and scientific article will be completed in 2011.

The calibration instruments for limb current measuring devices developed at STUK and the NPL were compared by calibrating the STUK limb current transformer using both instruments at frequencies of 10–110 MHz. The comparison indicated that the discrepancies between currents in the calibrated instruments were no greater than 3% at frequencies of 10–90 MHz.

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.

When a person moves in the vicinity of a magnetic imaging device, the powerful static magnetic field induces strong internal electric fields in the human body that can cause dizziness and other effects. A scientific article on limiting motion induction fields was completed and approved for publication in the journal Health Physics. The study formed the basis for commencing work at the International Commission on Non-Ionizing Radiation Protection (ICNIRP) to prepare guideline values limiting motion induction fields.

Work to prepare an application to the Finnish Work Environment Fund to study the safety in magnetic imaging work began in association with TTL, the magnetic imaging unit of Tampere University Hospital (TAYS) and the National Supervisory Authority for Welfare and Health (Valvira). The research is expected to:

- test new motion induction field guideline values experimentally and develop exposure determination methods that are compatible with these values,
- determine the exposure of patients and workers to magnetic fields, and
- prepare general safety instructions for magnetic imaging work.

ICNIRP published new guideline values limiting exposure to low-frequency electric and magnetic fields. The recommendations govern such aspects as household electrical appliances and cables, power lines, transformer substations, magnetic resonance imaging equipment, electronic article surveillance gates, and electric induction heating and welding equipment used in industry.

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.

Microwave Dosimetry in Biological Exposure Studies and in Practical Safety Evaluations

This doctoral dissertation analyzed the exposure systems used in studies of mobile phone safety and the reliability of the measurement methods used for determining exposure.

7 International co-operation

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

Participation in meetings of international working groups

During 2010 representatives of STUK took part in meetings of the following international organizations and working groups:

- X-ray diagnostics working group of the Nordic radiation use regulatory authorities
- A meeting of the European Study on Occupational Radiation Exposure (ESOREX)
- A meeting of the European Radiation Dosimetry Group (EURADOS)
- Working groups of the Heads of the European Radiological Protection Competent Authorities (HERCA)
- Main Committee meetings of the ICNIRP (3 meetings)
- Nordic UV and ozone working group (NOG)
- Nordic laser and light pulse device working group
- A meeting of the TC 106X committee of the European Committee for Electrotechnical Standardization (CENELEC).

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).

The International Radiation Protection Association (IRPA) held its third European Congress in Helsinki between 14 and 18 June 2010. Representatives of STO attended several sessions of the Congress as Chairman or Vice-Chairman and gave presentations at the event.

Other international co-operation

Together with the World Health Organization (WHO), STUK arranged a Specialist Workshop entitled Towards safer and more effective use of radiation in paediatric healthcare.

The Directors-General of the Nordic radiation safety authorities (excluding Denmark) sent a letter to the European Commission expressing their concern at the widespread abuse of battery-operated laser pointers. The Directors-General urged the Commission to prepare a Directive banning all laser pointers of power exceeding 1 mW from public use and restricting imports of laser pointers to the territory of the EU Member States.

Meetings of the Main Committee of the ICNIRP prepared new guideline values for low-frequency electric and magnetic fields that were published in the journal Health Physics. One meeting gave preliminary consideration to a draft prepared at STUK on limiting electric fields induced in persons moving in a static magnetic field.

A proposal for the official position of Finland on a revised draft of occupational health and safety Directive concerning electric and magnetic fields was prepared in association with the Finnish Institute of Occupational Health for submission to the Department for Occupational Safety and Health of the Ministry of Social Affairs and Health. It was proposed that all limiting values for low-frequency fields should be set in accordance with the new guideline values of the ICNIRP, and should not be confused with the limiting values proposed by the occupational health and safety authorities of Germany.

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 2010:

- Radiation Safety Conference, 28–29 October 2010, Tampere, in association with the Radiological Society of Finland,
- Conference on radiation detection and preparation for radiation accidents with stakeholders in the metal and engineering sector, 2 December 2010, Helsinki,
- Two meetings of the SESKO SK 106 committee (Exposure to electromagnetic fields),
- Conference of radiotherapy physicists, 10–11 June 2010, Pirkkala.

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).

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.

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, and representatives took part in discussion events together with NGOs concerned at the hazards of electromagnetic fields. These events were arranged by the Summer University of Häme, the newspaper Aamulehti, the Kone Oy Foundation and the Ministry of Social Affairs and Health.

Queries came from members of the public through the website every day and telephone calls were received on a very wide range of radiation concerns. These contacts concerning the safety of non-ionizing radiation were dealt with on a public service basis. The burden on qualified experts from client enquiries was alleviated by improving the website with particular attention paid to frequently asked questions, and by transferring some of the service to STUK information officers.

For the last eight years in a row, STUK has been involved in organizing a UV press event in association with the Finnish Meteorological Institute and the Cancer Society of Finland. The messages of the event in 2010 were that Finnish people are keen on a suntanned appearance; only half of UV radiation in open spaces comes from the sun; young people will be banned from using sunbeds due to the risk of cancer; and the incidence of skin cancer is still increasing.

A guest contribution article on the prohibition of sunbed use by people under 18 years of age was prepared for Finland's largest circulation daily newspaper Helsingin Sanomat.

Press releases were prepared on the following subjects:

- High-altitude long-haul flights increase the radiation doses of flight crews
- Radon and UV radiation are also among the most important sources of harmful exposures in our surroundings
- Finnish people are keen to appear suntanned
- Academic thesis: Poorly designed testing arrangements impair microwave radiation risk assessments
- Findings of major international mobile phone research published
- Mobile phone use does not appear to increase the risk of brain tumours
- X-ray imaging of children less common
- Worker exposed to radiation in Kotka
- 70 000 people in Finland invited to take part in research into the health impacts of mobile phone use
- Radiation safety authorities propose ban on powerful laser pointers
- New recommendations issued on low-frequency electric and magnetic fields.

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 Metrlogy 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 new ^{60}Co appliance was procured for the DOS Laboratory. Installation and commissioning measurements were commenced for the device, and a corresponding old appliance was removed from the laboratory.

The final two of six gamma sources ordered in 2009 for radiation meter calibration and testing in radiation protection were taken into use. The other four sources were already commissioned in 2009.

The dosemeter calibration procedure for radiotherapy accelerator electron beams was modified by changing from meter calibrations in hospitals to laboratory calibrations.

Meter and measurement comparisons

In 2010 the DOS Laboratory took part in the annual TLD comparison measurement of the absorbed dose of ^{60}Co gamma 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 -0.8%. This result is well within the IAEA acceptable variation of results.

In 2005–2008 the laboratory participated in a comparison of ^{60}Co calibrations of radiotherapy dosemeters organized by the EURAMET. The findings of this comparison were published in 2010. The deviations from the reference value in the laboratory calibration results calculated as an average of calibration results for various chamber types were -0.2% for air kerma and -0.3% for the dose absorbed to water.

Figure 10 shows the deviations in the measurement results of STUK from the reference value in IAEA/WHO measurement comparisons over the period from 2000 to 2010.

External assessments

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

10.3 Non-ionizing radiation

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

The serviceability of temperature measurements was improved when calibrating SAR probes.

Linking temperature measurements to the DASY4 system was not worthwhile, as a decision was taken to update the system to a new DASY52 system in the near future.

A newer 9.4 GHz pulse radar transmitter was installed in place of the old pulse radar transmitter used for checking the operation of pulsed radar microwave radiation meters. Transmitter function was tested in an anechoic chamber at the NIR radio laboratory by checking the operation of a pulse power density meter developed at STUK and used by Millog Oy. Operating instructions were prepared for the transmitter.

Meter and measurement comparisons

STUK calibrated some broadband erythema-weighted UV radiometers (SL 501 meters) used by the Finnish Meteorological Institute for local monitoring of solar UV radiation levels. Following this calibration, one of the meters at the Jokioinen observatory and research station showed readings that were 20% lower than the station's fixed Brewer spectroradiometer. An investigation of the reasons for this discrepancy began immediately in the summer and this work is still pending.

A measurement probe used in SAR testing of mobile phones was sent to its Swiss manufacturer (Schmid & Partner Engineering AG – SPEAG) for calibration at frequencies of 300, 450, 900, 1810, 1950 and 2450 MHz. Following this calibration, a comparison calibration was performed using STUK apparatus at frequencies of 300, 450 and 2450 MHz. This in-house calibration differed by no more than 30% from the manufacturer's calibration.

The findings of an electric field intensity measurement comparison project completed in 2008 were finalized (EURAMET project 819: Comparison of electrical field strength measurements above 1 GHz). The comparison involved calibrating a miniature electric field measurement probe (dipole, length 6.5 mm and thickness 1.2 mm) in air at ten measurement laboratories for frequencies of 1–2.5 GHz. The calibrations at STUK were performed in rectangular waveguides. The deviation between the results at STUK and the average for the laboratories did not exceed 2%, which is clearly smaller than the estimated calibration uncertainty of 5.3% (k=2) for a smaller waveguide and 4.7% (k=2) for a larger waveguide. The individual deviations from the average were much greater at other laboratories.

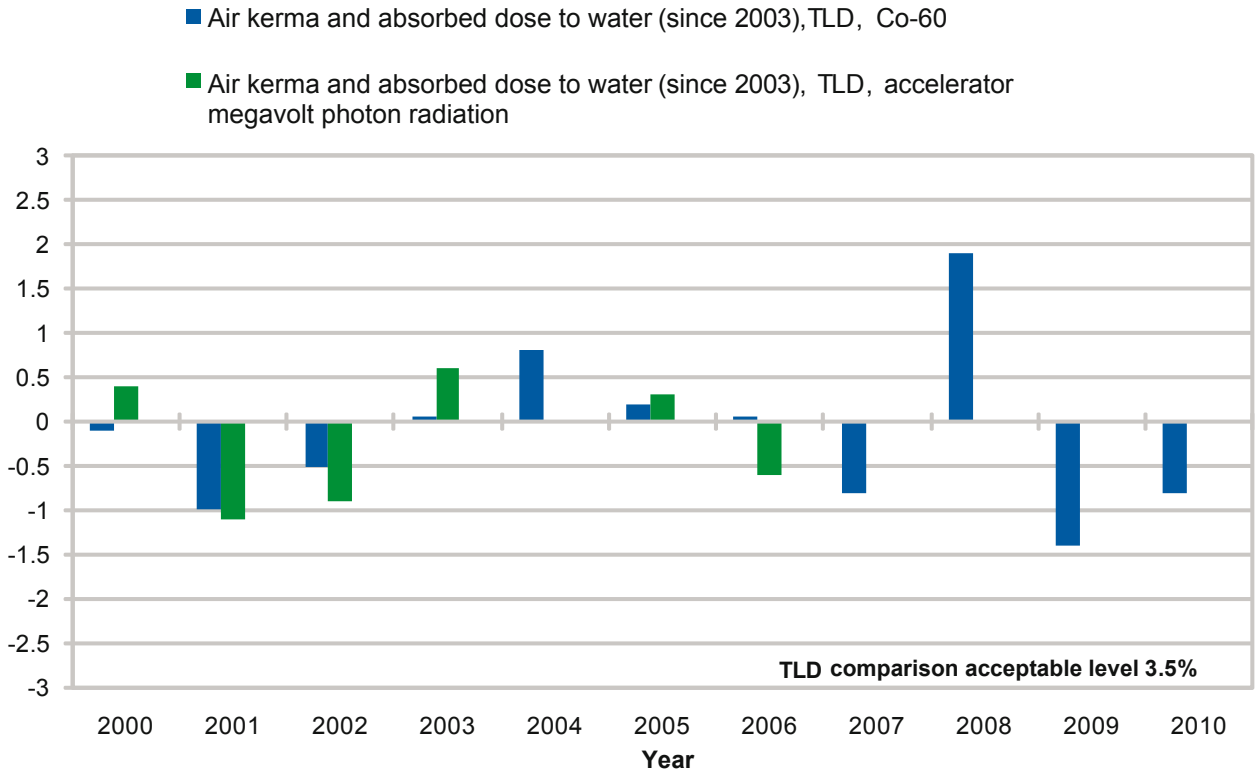

Figure 10. Deviations (%) in measurement results of STUK from the reference value in IAEA/WHO measurement comparisons, 2000–2010.

11 Services

11.1 Ionizing radiation

Calibration, testing and irradiation

The DOS Laboratory performed radiation meter calibrations and testing on request. 98 radiation meter calibration, inspection and testing certificates and 17 irradiation certificates were issued. About 20% of the calibrations and about 60% of the irradiations were performed for STUK´s own instruments and samples.

Other services

STUK concluded an agreement with the European Commission to co-ordinate a two-year project entitled Study on European Population Doses from Medical Exposure (Dose Datamed 2). The project will collect 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 data will be collected using the RP 154 guidelines published by the Commission and recommendations for improving these guidelines will be made on the basis of the experiences so gained. For the purpose of data gathering, a database will be established that may subsequently be updated with new data. The aim is to obtain comparable information from each country in order to assess the dose sustained by Europeans and thereby improve awareness in each country of the exposure caused by radiological examinations.

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

STUK arranged the following event as a training service in 2010:

- Training conference on radiation safety and quality in X-ray diagnostics, Kuopio, 25–26 March 2010.

11.2 Non-ionizing radiation

Calibration, testing and irradiation

The NIR Unit performed a total of 36 radiation meter calibrations and tests and 13 safety assessments and radiation measurements. The service work of the NIR Unit between 2001 and 2010 is shown in Table 17 of Appendix 1.

APPENDIX 1 TABLES

Table 1. Radiation practices in the use of radiation in health care and veterinary medicine at the end of 2010.

Use of radiation	Number of practices
Conventional dental X-ray practices	1789
X-ray practices	316
Veterinary X-ray practices	226
Extensive X-ray practices	97
C-arm practices	86
Minor X-ray practices	84
X-ray practices outside X-ray departments	64
Screenings with X-rays	50
Use of unsealed sources	39
Use of sealed sources	26
Radiotherapy	14

Table 2. Radiation sources and appliances and radionuclide laboratories in the use of radiation in health care and veterinary practices at the end of 2010.

Appliances/sources/laboratories	Number
X-ray diagnostic appliances (generators)[*)]	**1532**
fixed conventional X-ray appliances	509
portable fluoroscopy appliances	217
portable conventional X-ray appliances	215
mammography appliances, of which	163
• screening mammography	74
fixed fluoroscopy appliances	127
• angiography	55
• fluoroscopy	45
• cardioangiography	27
CT scanners, of which	113
• SPET-TT	22
• PET-TT	7
dental X-ray appliances (licensed)	71
• CBCT appliances	33
• panoramic scanners	23
• conventional dental X-ray appliances	14
• cephalostats	1
bone mineral density measurement appliances	71
other X-ray appliances	4
Dental X-ray appliances (notifiable)	**5556**
conventional dental X-ray appliances	4877
panoramic scanners	679
Radiotherapy appliances	**124**
accelerators	40
X-ray imaging appliances	22
afterloading appliances	6
manual afterloading appliances	5
X-ray therapy appliances	1
radiotherapy simulators	19
sealed sources (check sources)	30
BNCT therapy unit	1

Sealed sources	**204**
calibration and testing equipment	177
attenuation correction units	17
gamma irradiators	5
other sealed sources in health care	5
X-ray appliances in veterinary	**284**
conventional X-ray appliances	239
dental X-ray appliances	29
CT scanners, of which	5
• SPET-TT	2
• PET-TT	1
other appliances	11
Radionuclide laboratories	**50**
B-type laboratories	22
C-type laboratories	28

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

Table 3. Reference levels and average activities (2009) in nuclear medice examinations.

Examination	**Radiopharma-ceutical in examination**	**STUK reference level (MBq)**	**Average activity in examination (range) (MBq)**
Bone imaging	^{99m}Tc-MDP	700	640 (500–800)
Inflammation	^{99m}Tc leucocytes	300	269 (200–600)
Lung perfusion	^{99m}Tc-MAA	150	139 (50–185)
Lung ventilation	^{99m}Tc-aerosol (Technegas)	40	33 (15–50)
Renal imaging	^{99m}Tc-MAG3	150	111 (70–150)
Renal imaging	^{99m}Tc-DTPA	300	299 (100-370)
Cardiac blood pool (equilibrium)	^{99m}Tc-RBC	750	746 (550–890)
Thyroid metastases (after ablation)	^{131}I-NaI	200	243 (74–370)
Parathyroid imaging	^{99m}Tc-MIBI	800	749 (710–800)
Tumour imaging, PET	^{18}F-FDG	370	360 (284–370)

Table 4. Radiation practices in the use of radiation in industry, research and education at the end of 2010.

Use of radiation	Number of practices
Use of sealed sources	602
Use of X-ray appliances	443
Importing and exporting of radioactive materials or trading in them	126
Installation, test operations and servicing	123
Use of unsealed sources	122
Use of particle accelerators	16

Table 5. Radiation sources and appliances and radionuclide laboratories in the use of radiation in industry, research and education at the end of 2010.

Appliances/sources/laboratories	Number
Appliances containing radioactive materials	**6532**
level switches	2251
continuous level gauges	1140
density gauges	1036
basis weight meters	659
weight scales	599
appliances or sources used for calibration, testing or education	209
moisture and density gauges	127
fluorescense analyzers	87
radiography appliances	24
other appliances	400
X-ray appliances and accelerators	**1453**
X-ray screening appliances	515
radiography appliances	399
diffraction and fluorescence analyzers	363
basis weight meters	46
particle accelerators	22
other X-ray appliances	108
Radionuclide laboratories	**165**
A-type laboratories	4
B-type laboratories	30
C-type laboratories	128
activities outside laboratories (tracer element tests in industrial plants)	3

Table 6. Radionuclides most commonly used in sealed sources in industry, research and education at the end of 2010.

Radionuclide	Number of sources
Other than high-activity sealed sources	
Cs-137	4599
Co-60	1445
Kr-85	439
Am-241 (gamma sources)	401
Pm-147	174
Am-241 (AmBe neutron sources)	168
Fe-55	127
Ni-63	75
Ra-226	74
Sr-90	66
High-activity sealed sources	
Co-60	106
Cs-137	57
Ir-192	15
Am-241 (gamma sources)	8
Sr-90	5
Am-241 (AmBe neutron sources)	5

Table 7. Inspections of licensed practices in 2010 (itemized by type of inspection).

Type of inspection	Number of inspections	
	Industry, research and education	Health care and veterinary practices
Initial inspection	0	42
Periodic inspection	197	134
Repeat inspection	2	3
Other inspection or measurement	4	2
Total	**203**	**181**

Table 8. Inspections of licensed practices in 2010 (itemized by type of practice).

Type of practice	Number of inspections
Use of radiation in health care and veterinary practices[*)]	
X-ray diagnostics	81
radiotherapy	42
veterinary X-ray diagnostics	47
nuclear medicine	15
other uses of radiation	0
Use of radiation in industry, research and education[*)]	
industry	140
research and/or education	48
trading in radioactive materials	11
installation and/or servicing	10
other uses of radiation	14
Total	**408**

*) The total number of these inspections is larger than in Table 7, because in some cases one inspection concerned two types of practice.

Table 9. Deliveries of sealed sources to and from Finland in 2010.

Radionuclide	**Deliveries to Finland**		**Deliveries from Finland**	
	Activity (GBq)	**Number**	**Activity (GBq)**	**Number**
Ir-192	869 057	20	1174	18
Co-60	37 083	3	3	1
H-3	4130	1551	3478	1175
Se-75	2220	2	< 1	1
Cs-137	1865	41	8944	13
Kr-85	1593	103	1003	68
Pm-147	500	10	114	23
Fe-55	258	54	122	26
I-125	108	*)	-**)	-
Ni-63	38	104	1	1
Gd-153	34	17	-	-
Sr-90	13	9	2	4
Am-241 (gamma and alpha sources)	7	40	5	800
Co-57	7	31	< 1	2
Am-241 (AmBe neutron sources)	4	3	-	-
others total ***)	4	21	1	195
Total	**916 921**	**2009**	**14 847**	**2327**

*) 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: Cd-109, Eu-152, Ge-68, Po-210.
Deliveries from Finland, nuclides: C-14, Cd-109, Cm-244, Eu-152..

Table 10. Deliveries of unsealed sources to and from Finland in 2010.

Radionuclide	**Activity (GBq)**	
	Deliveries to Finland	**Deliveries from Finland**
Mo-99	35 388	5119
I-131	9168	1690
Tl-201	6079	-*)
I-123	1187	41
Lu-177	828	478
In-111	448	-
Sm-153	365	-
P-32	207	46
Y-90	77	-
H-3	51	1
I-125	42	4
S-35	19	-
Cr-51	5	-
Ge-68	3	-
F-18	-	2794
others total **)	6	< 1
Yhteensä	**53 873**	**10 173**

*) The symbol "-" indicates no deliveries to or from Finland.
**) Deliveries to Finland, nuclides: Ba-133, C-14, Ce-141, Co-57, Co-60, Eu-152, Fe-55, Ga-67, I-129, Na-22, Nb-95, P-33, Po-208, Rb-86, Re-186, Se-75, Sr-85, Sr-89.
Deliveries from Finland, nuclides: C-14, I-129.

Table 11. Manufacturing of radioactive materials (unsealed sources) in Finland in 2010.

Radionuclide	**Activity (GBq)**
F-18	140 808
O-15	22 200
C-11	10 559
Br-82	2989
others total*)	200
Total	**176 756**

*) Nuclides, such as: Au-198, Cu-64, La-140, Na-24, Pt-191.

Taulukko 12. Number of workers subject to individual monitoring in 2006–2010.

Year	**Number of workers in various sectors in the use of radiation and nuclear energy**								
	Health care		**Veterinary practices**	**Industry**	**Research and education**	**Manufacturing of radiaoactive materials**	**Others*)**	**Use of nuclear energy**)**	**Total***)**
	Exposed to X-radiation	**Exposed to other radiation sources**							
2006	4779	936	363	1281	948			3862	12 039
2007	4767	961	368	1275	927			3257	11 441
2008	4872	984	392	1293	884			3444	11 550
2009	4440	992	458	1232	810	15	49	3704	11 571
2010	4467	989	491	1192	817	21	73	4151	12 062

*) 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 13. Total doses (sums of Hp(10) values) of workers subject to individual monitoring in 2006–2010.

Year	**Total dose (Sv) in various sectors in the use of radiation and nuclear energy**								
	Health care		**Veterinary practices*)**	**Industry**	**Research and education**	**Manufacturing of radiaoactive materials**	**Others**)**	**Use of nuclear energy***)**	**Total**
	Exposed to X-radiation*)	**Exposed to other radiation sources**							
2006	1.43	0.14	0.08	0.24	0.08			4.11	6.08
2007	1.37	0.15	0.11	0.26	0.08			2.16	4.13
2008	1.51	0.12	0.11	0,22	0.09			2.76	4.69
2009	1.27	0.09	0.08	0.15	0.06	0.01	0	2.37	4.04
2010	1.25	0.08	0,08	0.15	0.09	0.004	0	2.59	4.25

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

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

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

Table 14. Data ($H_p(10)$ values) on certain occupational groups in 2010.

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**)	206	0.58	3.4	2.8	21.3
Radiologists**)	476	0.23	2.4	0.5	13.7
Interventional radiologists**)	41	0.22	6.2	5.3	25.5
Consultant physicians **) ***)	306	0.07	1.7	0.2	12.8
Nurses**)	1199	0.05	0.4	0.0	3.5
Radiographers (X-rays)**)	1897	0.04	0.4	0.0	3.1
Radiographers (other than X-rays)	440	0.04	0.9	0.1	3.9
Veterinary nurses and assistants**)	268	0.05	1.2	0.2	9.9
Veterinary surgeons**)	137	0.02	1.1	0.1	6.1
Industrial material inspection technicians****)	460	0.1	0.9	0.2	55.7
Other radiation work	557	0.05	1.9	0.1	22.2
Researchers	621	0.04	1.4	0.1	10.2
Industrial tracer testing technicians	25	0.04	2.7	1.6	7.6
Nuclear power plant workers					
• mechanical duties and machine maintenance	945	0.71	1.2	0.8	12.7
• cleaning	268	0.36	2.5	1.4	13.9
• insulation work	75	0.32	5.7	4.3	15.8
• material inspections	245	0.30	1.7	1.2	15.3
• electrical and automation work	721	0.22	0.9	0.3	8.6
• radiation protection	90	0.16	2.1	1.8	7.2
• stand building and hauling	170	0.08	1.3	0.5	5.2

*) The recording level is 0.1 mSv per month or 0.3 mSv per quarter.

**) Hp(10) values are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the dose sustained by these worker groups. Workers engaged in the use of radiation (X-rays) in health care and in veterinary 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 Hp(10) value by a factor between 10 and 60.

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

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

Table 15. The principal low-level radioactive waste in the national storage facility (December 2010).

Radionuclide	Activity (GBq) or mass
H-3	12 681
Cs-137	2411
Kr-85	1669
Am-241	1664
Pu-238	1559
Sr-90	235
Ra-226	232
Co-60	121
Cm-244	93
U-238	1270 kg

Table 16. Number of air crew members subject to individual monitoring of radiation exposure and total dose of crew members (sum of effective doses) in 2006–2010.

Year	Number of workers		Total dose (Sv)	
	Pilots	Cabin crew	Pilots	Cabin crew
2006	1072	2412	1.73	4.35
2007	1125	2583	2.30	5.61
2008	1206	2562	2.45	5.93
2009	1195	2460	2.68	6.07
2010	1147	2281	2.56	5.75

Table 17. Work of the NIR unit in 2001–2010.

Year	Regulatory inspections	Decisions	Statements	Calibrations and tests	Safety assessments and radiation measurements	Total
2001	23	2	16	27	9	77
2002	36	1	4	31	13	85
2003	49	0	3	23	11	86
2004	55	3	1	30	12	101
2005	66	1	1	25	31	124
2006	48	1	7	17	7	80
2007	64	3	3	33	17	120
2008	67	5	6	46	24	148
2009	47 (108*))	2	9	31	12	101 (162*))
2010	55 (182**))	3	9	36	13	116 (243**))

*) 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).

Table 18. Inspections of sunbed facilities in 2000–2010.

Year	Number of inspections
2000	14
2001	17
2002	36
2003	31
2004	30
2005	36
2006	25
2007	31
2008	26
2009	19
2010	16

Table 19. Mobile phone SAR-tests in 2003–2010.

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

APPENDIX 2

PUBLICATIONS IN 2010

The following publications completed in 2010 were authored by one or more employees of STO or the NIR Unit.

International publications

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Standards, Applications and Quality Assurance in Medical Radiation Dosimetry (IDOS), 9–12 November 2010, Vienna, Austria. pp. 331–332.

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Markkanen M. Natural radiation environment and NORM. In: Abstracts – Third European IRPA Congress, 14–18 June 2010, Helsinki, Finland. Helsinki: Nordic Society for Radiation Protection; 2010. p. 299.

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Regulatory control reports

Rantanen Erkki (toim.). Säteilyn käyttö ja muu säteilylle altistava toiminta. Vuosiraportti 2009. (Use of radiation and other practices involving exposure to radiation. Annual report 2009). STUK-B 116. Helsinki: STUK; 2010.

Rantanen Erkki (ed.). Radiation practices. Annual report 2009. STUK-B 122. Helsinki: STUK; 2010.

Tenkanen-Rautakoski Petra. Radiologisten tutkimusten ja toimenpiteiden määrät vuonna 2008 (Radiological examinations and interventions in 2008). STUK-B 121. Helsinki: STUK; 2010.

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Finnish language

Rakennusmateriaalien ja tuhkan radioaktiivisuus. Ohje ST 12.2 (Radioactivity in building materials and ash. Guide ST 12.2). STUK (17 Dec. 2010).

Swedish language

Strålsäkerhet på arbetsplatsen. Direktiv ST 1.6 (Operational radiation safety. Guide ST 1.6). STUK (10 Dec. 2009).

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English language (translations)

Operational Radiation Safety. Guide ST 1.6. STUK (10 Dec. 2009).

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APPENDIX 3

ST GUIDES PUBLISHED BY STUK. SITUATION AS OF 31 DECEMBER 2010.

General Guides

ST 1.1 Safety Fundamentals in Radiation Practices, 23 May 2005
ST 1.3 Warning Signs for Radiation Sources, 16 May 2006
ST 1.4 Radiation User's Organization, 16 April 2004
ST 1.5 Exemption of the Use of Radiation from the Safety Licence and Reporting Obligation, 1 July 1999
ST 1.6 Operational Radiation Safety, 10 December 2009
ST 1.7 Radiation Protection Training in Health Care, 17 February 2003
ST 1.8 Qualifications of Persons Working in Radiation User's Organization and Radiation Protection Training Required for Competence, 16 April 2004
ST 1.9 Radiation Practices and Radiation Measurements, 17 March 2008

Radiation Therapy

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

Diagnostic Radiology

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

Industry, Research, Education and Commerce

ST 5.1 Radiation Safety of Sealed Sources and Devices Containing Them, 7 November 2007
ST 5.2 Use of Control and Analytical X-ray apparatus, 26 September 2008
ST 5.3 Use of Ionising Radiation in the Teaching of Physics and Chemistry, 4 May 2007
ST 5.4 Trade in Radiation Sources, 19 December 2008.
ST 5.6 Radiation Safety in Industrial Radiography, 17 February 1999
ST 5.8 Installation, Repair and Servicing of Radiation Appliances, 4 October 2007

Unsealed Sources and Radioactive Wastes

ST 6.1 Radiation safety when using unsealed sources, 17 March 2008
ST 6.2 Radioactive Wastes and Discharges, 1 July 1999
ST 6.3 Use of Radiation in Nuclear Medicine, 18 March 2003

Radiation Doses and Health Surveillance

ST 7.1 Monitoring of Radiation Exposure, 2 August 2007
ST 7.2 Application of Maximum Values for Radiation Exposure and Principles for the Calculation of Radiation Doses, 9 August 2007
ST 7.3 Calculation of the Dose Caused by Internal Radiation, 23 September 2007
ST 7.4 The Dose Register and Data Reporting, 9 September 2008.
ST 7.5 Medical Surveillance of Occupationally Exposed Workers, 4 May 2007

Non-Ionizing Radiation

ST 9.1 Radiation Safety Requirements and Regulatory Control of Tanning Appliances 1 December 2003 (in Finnish)
ST 9.2 Radiation Safety of Pulsed Radars, 2 September 2003 (in Finnish)
ST 9.3 Radiation Safety during Work on Masts at FM and TV Stations, 2 September 2003 (in Finnish)
ST 9.4 Radiation Safety of High Power Display Lasers, 28 February 2007 (in Finnish)

Natural Radiation

ST 12.1 Radiation Safety in Practices Causing Exposure to Natural Radiation, 6 April 2000
ST 12.2 The Radioactivity of Building Materials and Ash, 17 December 2010
ST 12.3 Radioactivity of Household Water, 9 August 1993
ST 12.4 Radiation safety in aviation, 20 June 2005