STUK-B 194 / SEPTEMBER 2015

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Radiation practices

Annual report 2014

Riikka Pastila (ed.)

Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

STUK

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Abstract

1800 safety licences for the use of radiation were current at the end of 2014. On 1 September 2014, dental X-ray practices became subject to a safety licence and were practiced by 1600 responsible parties (parties running a radiation practice). The 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. The Radiation and Nuclear Safety Authority (STUK) conducted 757 inspections of licensed practices in 2014. 870 repair orders and recommendations were issued during the course of inspections. Radiation safety guides were also published and research was conducted in support of regulatory control.

The regulatory control of natural radiation (excluding cosmic radiation) was transferred to the Department of Environmental Radiation Surveillance at STUK on 1 June 2014. The reports on the regulatory control of natural radiation are reported in this publication.

A total of over 11 000 workers engaged in radiation work were subject to individual monitoring in 2014, and 73 585 dose entries were made in the Dose Register maintained by STUK.

In 2014, regulatory control of the use of non-ionising radiation (NIR) focused particularly on lasers, sunbeds, radio appliances and cosmetic applications producing non-ionising radiation. A total of 12 cases of sales or importation of dangerous laser devices were found in regulatory control. The number of show laser on-site inspections was seven. Municipal health protection authorities submitted the details of the inspections of 20 sunbed facilities to STUK for evaluation and decision. In addition to this, one sunbed facility was inspected on-site. In the market control of wireless communication devices, 10 devices were tested. In the market control of cosmetic applications, measurements were taken of three nail ovens used for curing nail enhancements.

In metrological activities, national metrological standards were maintained to the calibrations of the radiation meters for radiotherapy, radiation protection and X-ray imaging. STUK's metrological laboratory was found to be well within the acceptable variation of results in the measurement comparison. In external evaluations, the laboratory was found to comply with the requirements set for national metrological laboratories.

There were 138 abnormal events related to radiation use in 2014. 38 of the events dealt with the use of radiation in industry, research and education, 96 with the use of radiation in health care, one in veterinary medicine, and three with the use of non-ionising radiation.

Contents

Foreword

Eero Kettunen
Director
Department of Radiation Practices Regulation (STO)

The Department of Radiation Practices Regulation (STO) of the Radiation and Nuclear Safety Authority (STUK) functions as a regulatory authority on the use of ionising and non-ionising radiation, conducts research in support of regularoty control in the use of radiation, and maintains metrological standards for ionising radiation. Regulatory control involves safety licensing, approval and registration procedures, inspections of places where radiation is used, market control and monitoring of workers' radiation doses.

In 2014, the general state of radiation practice safety was good in Finland. STUK collects information on radiation practices and keeps a close eye on the signals on which the reaction to the safety situation is based, in order to maintain its desired level.

The European Council's new directive on the basic safety standards for protection against ionising radiation entered into force in early 2014. It must be implemented nationally within four years, and its regulations must be adopted in national legislation by 6 February 2018. The Finnish Radiation Act will be updated at the same time. The Ministry of Social Affairs and Health is responsible for monitoring compliance with the Radiation Act and steers the amendment of the Act. The updating of the Act commenced in 2014, and it will also involve STUK experts in the coming years.

The maintenance and updating of the ST radiation safety guides is an integral part of STUK's operations. Eight guides were published during the year under review. The ST guides will be renewed after a couple of years, in connection with the Act amendment. Until then, the guides will only be updated where absolutely necessary.

A total of more than 11 000 workers engaged in radiation work and were subject to individual monitoring in 2014. Of these workers, nearly 8000 were involved in the use of ionising radiation, while the rest consisted of nuclear power plant workers. In no case did the effective dose of a worker in 2014 exceed the annual dose limit or the five-year dose limit for workers.

The new Dose Register, which has been in development for several years, was put into use in January 2014. As a new service, the persons working as responsible medical practitioners, in approved dosimetry services, in airlines or in positions of responsibility in the use of radiation, were offered extranet access to the register, facilitating its use. By the end of 2014, the extranet service had been adopted by just under 300 users.

The number of abnormal events in health care X-ray practices reported to STUK continued to increase. However, no cases of dose limits being severely exceeded were recorded. STUK has been encouraging responsible parties to report abnormal events in its instructions, training courses and in connection to inspections. During the year, there were also a number of severe events in which equipment faults and human errors resulted in health care patients receiving significantly larger doses of radiation than intended.

During the year, responsible parties reported the loss of two registered radiation sources. One of the cases involved the theft of a measurement device containing a radiation source, as a result of which the incident was investigated by the police. In connection to this, STUK implemented a new guide concerning the security arrangements related to radiation sources. The regulatory control of activities covered by the guide will focus primarily on high-activity radiation sources.

In 2014, conventional dental X-ray practices that had previously been licence-exempt and only required appliances to be registered became practices that require a safety licence. The number of these practices is approximately 1600. The new regulation clarifies and harmonises control practices in this area.

STUK consolidated cooperation with the authorities responsible for monitoring the transport of other dangerous goods. A plan was prepared on the transport supervision of radiation sources, which will be further developed in collaboration with other authorities.

Discussion around the suspected health effects of mobile phones and other sources of electromagnetic radiation was active. STUK replied to hundreds of inquiries concerning the topic from citizens via telephone and email. The regulatory control of non-ionising radiation focused particularly on various consumer products based on the use of lasers and the control of the cosmetic applications of lasers. The increasingly open global sale of products across borders introduces challenges to safety control in this area.

The operation of STUK's national metrological laboratory was found to clearly meet the requirements set for it. The evaluation was conducted by MIKES Metrology. To ensure high quality, international measurement comparisons are regularly conducted at the laboratory. In 2014, the results of the comparisons were excellent.

STUK participated in a number of European research projects, which resulted in, for example, new recommendations by the European Commission on the use of radiation in health care. The EU project studying the radiation doses to the European population from the diagnostic use of radiation directed by STUK was completed. The report includes estimates of the number of X-ray and nuclear medicine examinations and procedures carried out in Europe and the resulting collective effective dose to the European population. Based on the study, the state of radiation use in the Finnish health care sector is good, as assessed based on patient doses. STUK aims to increase research collaboration with Finnish cooperation partners for the purpose of ensuring access to up-to-date information and the quality of expertise throughout the sector.

1 General

The expression “use of radiation” refers to the use and manufacture of and trade in radiation equipment and radioactive materials, and to associated activities such as possession, safekeeping, servicing, repair, installation, importing, exporting, storage, transportation, and the process of rendering radioactive waste harmless. The expression “radiation practices” refers to radiation use and also to any activity or circumstances in which human exposure to natural radiation causes or is liable to cause detriment to health.

The expression “radiation” refers to both ionising and non-ionising radiation.

The regulatory control of radiation use and other practices causing exposure to radiation in Finland is the responsibility of the Department of Radiation Practices Regulation (STO) at STUK, while regulatory control of exposure to natural radiation excluding cosmic radiation is the responsibility of the Department of Environmental Radiation Surveillance (VALO) at STUK.

1.1 Principal key figures

The principal key figures for the use of radiation and other practices causing exposure to radiation are shown in Figures 1–3.

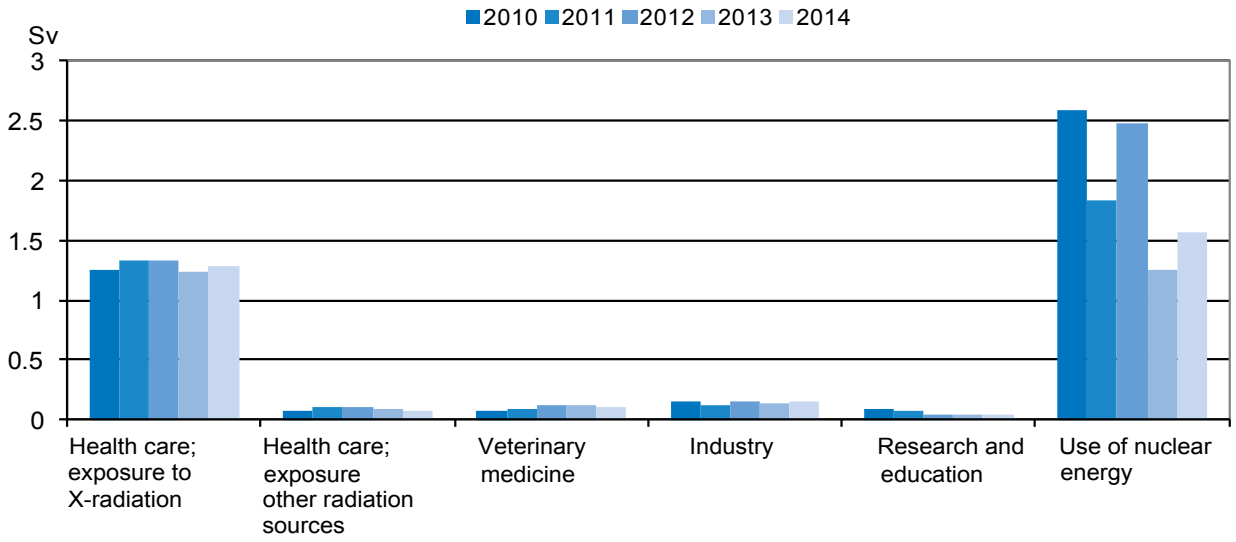

Figure 1. Combined doses ($H_p(10)$) of workers subject to individual monitoring by occupational category, 2010–2014. $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the use of X-rays in health care and veterinary practices, in which workers use personal protective shields and in which the dose is measured by a dosemeter on the exposed side of the shield. The effective dose is then obtained by dividing the $H_p(10)$ value by a factor between 10 and 60. Besides the workers specified in the graph, a small number of people subject to individual monitoring also work in the following sectors: manufacturing of radioactive materials, installation/servicing/technical test operation, trade/import/export and services pertaining to the use of radiation and radioactive materials (see Tables 9 and 10 in Appendix 1).

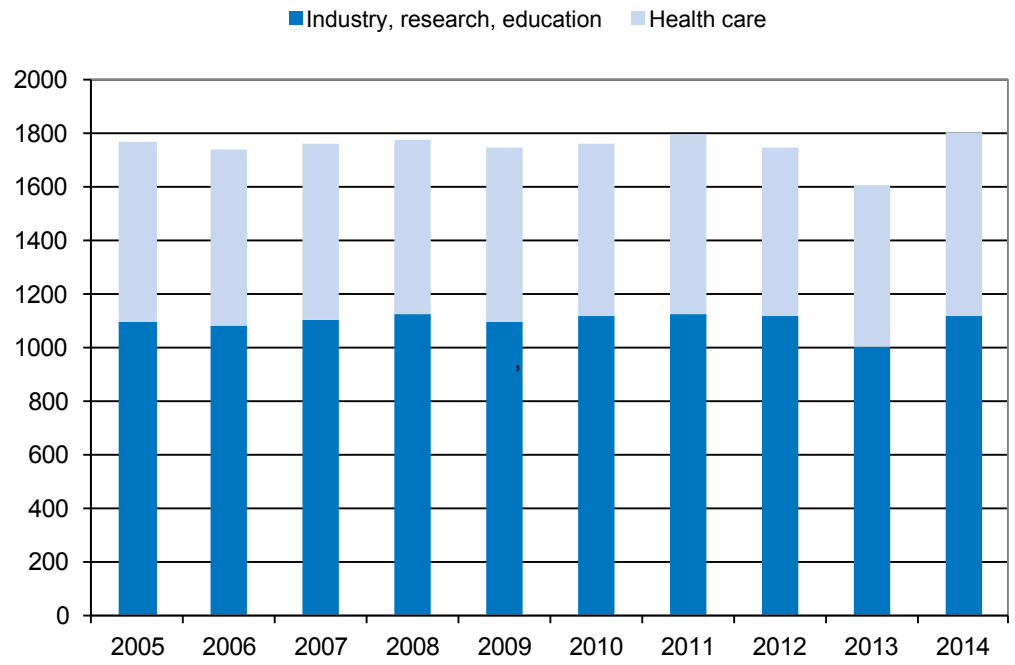

Figure 2. Current safety licences, 2005–2014.

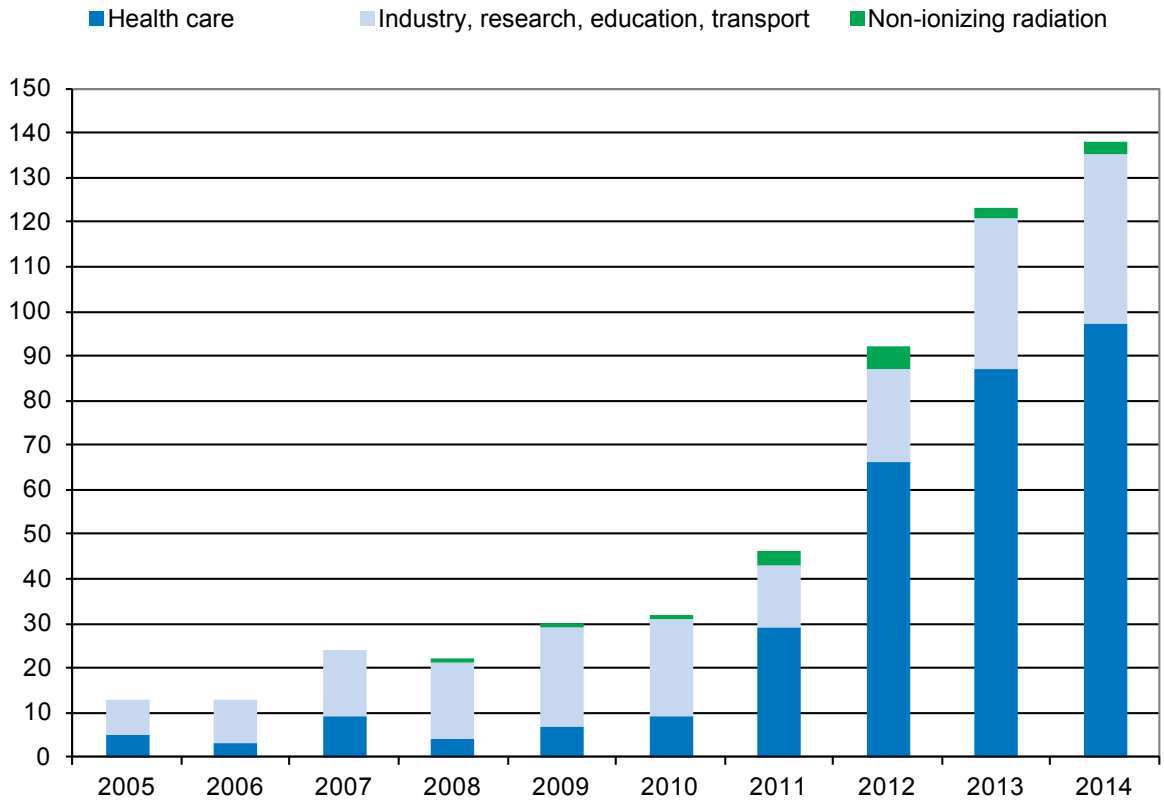

Figure 3. Abnormal events, 2005–2014.

2 Regulatory control of the use of ionizing radiation

2.1 Use of radiation in health care, dental care and veterinary practices

Safety licences

At the end of 2014, there were 682 current safety licences for the use of radiation in health care (see also Figure 2), of which 233 concerned veterinary practices. A total of 427 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.

In 2014, conventional dental X-ray practices that had previously been licence-exempt became practices that require a safety licence. Decision 5/3020/2014 "Change of conventional dental X-ray practices exempt from a safety licence to practices requiring a safety licence" entered into force on 1 September 2014, after which STUK began to issue safety licences to conventional dental X-ray practices. The number of these practices is approximately 1600. The majority of the licences were issued in late 2014. The rest of the safety licences for conventional dental X-ray practices are to be issued in early 2015.

The average time taken to process safety licence applications for X-ray practices in health care was 13.5 days. Roughly 7% of all licence applications were processed as urgent applications, meaning that the application was submitted to STUK only when it was time to take an appliance into use, and sometimes even after the appliance had already been taken into use.

Radiation appliances, sources and laboratories

Table 2 in Appendix 1 shows details of radiation appliances and sources, and of radionuclide laboratories used in health care and veterinary practices at the end of 2014.

X-ray practices, dental X-ray practices and veterinary practices

The consolidation of municipalities and combining of health care activities continued to cause a large number of licence amendments in regard to health care X-ray practices. The change of conventional dental X-ray practices exempt from a safety licence to practices requiring a safety licence also resulted in a great deal of work in 2014.

The renewed decision regarding the approval criteria for X-ray equipment in health care entered into force in 2014. The decision lays out approval criteria for radiography and fluoroscopy equipment, computed tomography equipment and bone densitometry equipment. The criteria do not apply to dental X-ray imaging equipment and radiotherapy equipment. In 2014 STUK also renewed the decision regarding reference levels for patient radiation exposure in the conventional X-ray examinations of adults. In addition to reference levels, the decision provides achievable dose levels for X-ray equipment with flat panel detectors. The dose levels between modern plate and flat panel imaging techniques are markedly different. The reference levels are based on measurements carried out by STUK at places of use and on actual patient dose data. The data is from 2010–2013. The reference levels will be supplemented in the second stage of the reference level reform, which involves the collection of patient dose data at places of use. The second stage is planned to define reference levels for dental CBCT examinations, among others.

The guide on the quality control of mammography equipment was completed, providing instructions on how to perform quality control tests on equipment and examples of suitable methods for performing these tests. The aim of the quality control of mammography

equipment is to ensure that the equipment remains in good condition. With the help of quality control, variations in operating condition, imaging quality or patient radiation exposure can often be detected and corrected before they occur in actual patient examinations.

A guide on the justification principles of X-ray examinations causing exposure to radiation was prepared in co-operation with an external work group. The guide is aimed at doctors who refer patients for examinations, and is set to be published in early 2015.

X-ray equipment suppliers reported the details of X-ray appliances installed or reinstalled in health care practices in 2013 to STUK. The survey revealed two X-ray appliances that had not been issued a safety licence before operations were commenced. In addition to this, 39 dental X-ray appliances that had not been reported to STUK were found in the survey.

A survey was conducted on responsible parties running screening mammography imaging practices for the purpose of collecting information on the extent of screening mammography practices and the qualifications and supplementary training of persons involved in screening mammography practices in 2013. The number of screening mammography examinations conducted in 2013 was approximately 370 000. The personnel involved in screening mammography practices were found to be qualified and regularly undergoing supplementary training. The survey revealed some discrepancies regarding the special qualifications of radiologists in screening mammography. The results of the survey were published in the report STUK-B 183 "Screening mammography practices in Finland in 2013".

The number of abnormal events reported continued to grow – in 2014, STUK received 56 reports related to X-ray practices in health care. The updated Guide ST 3.3 "X-ray examinations in health care", which entered into force in early 2015, aims to further specify the abnormal event reporting instructions.

In May, STUK held a conference on radiation safety and quality in X-ray diagnostics. The conference offered a comprehensive look at the current state of X-ray practices in health care from the perspective of the regulatory authority, as well as at quality control in places where radiation is used. In addition to this, STUK experts participated in several training events as lecturers and disseminated information on topical themes in professional magazines. In 2014, STUK sent out three newsletters aimed at health care professionals engaged in radiation practices.

In 2014, STUK also developed its official supervision practices related to X-ray practices in health care from a risk-based perspective. The most major change resulting from these development efforts is the supervisory survey regarding veterinary X-ray practices, which is set to be implemented in 2015. The aim of the survey is to chart out places where inspections could be substituted by surveys and on the other hand identify places of use where on-site inspections should be conducted based on the survey responses. Certain practices, such as those that conduct imaging of large animals, will continue to undergo on-site inspections. Similarly, on-site inspections will still be carried out at new premises of radiation use for the purpose of ensuring, among other things, the adequate radiation shielding of facilities. Other changes made to supervisory practices in 2014 included changing the inspection interval for demanding X-ray practices from the previous three years to five years, as well as establishing an inspection interval of eight years for panoramic tomography equipment used in conventional dental X-ray practices.

Nuclear medicine

Use of alpha emitters in radionuclide therapy

The use of alpha emitters in radionuclide therapy has commenced in Finland as well. Between 2012 and 2014, STUK granted permits to 17 nuclear medicine units for the use of ^{223}Ra. While at first ^{223}Ra was only used in research, clinical use commenced in early 2014 when a ^{223}Ra pharmaceutical (Xofigo) was granted a selling permit in Finland. The pharmaceutical in question, consisting of ^{223}Ra chloride, is used in the treatment of skeletal metastases of prostate cancer.

When using unsealed sources, safety considerations must be made not only for exposure caused by external radiation, but also for exposure to internal radiation resulting from the potential contamination of air, working surfaces or other

surfaces. When working with alpha emitters, exposure to external radiation is not a major issue. However, special attention should be paid to potential internal exposure. ^{223}Ra causes a dose equivalent to the annual limit for workers (20 mSv) when 200 kBq of it is ingested orally and 3 kBq is absorbed through the lungs. In order to minimise the possibility of internal exposure, working spaces etc. are kept clean. This should be ensured with regular contamination measurements using contamination meters suitable for measuring alpha radiation.

In 2014, STUK provided health care professionals engaged in radiation practices with training on how to conduct contamination measurements at a refresher course on radiopharmacy organised by the Finnish Society of Nuclear Medicine.

Radiotherapy

Radiotherapy CT simulations

In order to survey national simulation practices in radiotherapy, STUK collected data on imaging values and dose display values currently in use. The data was collected from CT simulations of four typical radiotherapy target areas: resected breasts, the prostate, the whole brain and the neck area. Data was received from all thirteen Finnish radiotherapy centres and from a total of 15 appliances.

The tube voltage used was typically 120 kV, but other values were also used. In diagnostic imaging, tube voltage can be used in the fine-tuning of patient dose optimisation, a practice which may in the future be used in CT simulations as well. However, the effect that tube voltage has on image values must be well understood so that dose distribution calculations can be conducted correctly.

Collimation is specific to each appliance and no data on the image thickness used in the final imaging stack was collected. Images were formed using both iterative and back projected reconstruction. The pitch used for imaging the entire brain and the head and neck area was below 1 apart from a few exceptions, but in scans of the breasts and the prostate the pitch used was typically over 1. Written sources recommend that a value of 1 or below be used in simulations in order to avoid certain imaging errors. As such, the necessity of using a pitch of over 1 in CT simulations should perhaps be further studied and discussed in the future.

The length of the imaging area is a key parameter as regards patient radiation exposure, and surprisingly large variations were observed between different hospitals. It would seem that instead of being adapted to each patient, imaging areas are anatomical areas chosen based on the object being imaged, remaining roughly consistent between individual patients. Variations in the length of the imaging were greater in the head and neck area owing to larger variation in the size of the target area.

Dose level is determined by the amount of available electricity and for example on the set image quality level (reference mAs and noise index). With some appliances, the dose level is chosen based primarily on the patient, while with others the dose level used remains constant or variation is very low. It would seem that with some appliances the image quality level is set so high that the maximum dose level would be used even with normal-sized patients. Dose modulation is also especially important as regards the consistency of image quality for example in the head and neck area, where patient thickness varies considerably.

The patient-specific results were used to calculate appliance and target specific averages. Major variance in dose levels was observed between individual appliances. Average dose levels were clearly higher than those used in diagnostic imaging. Based on the survey, the dose level used was not directly linked to, for example, the type of appliance, the chosen image thickness or pitch. Each radiotherapy target was simulated by at least one radiotherapy centre using a dose level corresponding to diagnostics and the image quality achieved at these levels was deemed adequate. Based on this we can conclude that there is room for optimisation in the dose levels and imaging values used in CT simulation.

Risk assessment in radiotherapy

The safety of radiotherapy is ensured in many ways, but it can be further improved through systematic risk assessment. All radiotherapy centres monitor abnormal events and investigate their causes. This is called *retrospective analysis*.

Abnormal events can also be used as the basis for evaluating the probability of future events and the events can be categorised based on their level of severity. This kind of predictive approach is called *proactive risk assessment*.

In 2014, the Radiation and Nuclear Safety Authority invited a working group to prepare a national guide on risk assessment in radiotherapy. In addition to STUK experts, the work involved radiotherapy specialist Leena Voutilainen (KYS); physicists Simo Hyödynmaa (TAYS), Mikko Tenhunen (HUS) and Juha Valve (KSKS); as well as radiographer Pirkko Annunen (TYKS).

The guide is intended to provide basic information on proactive risk assessment in radiotherapy. In this context risk refers to a radiation risk to the patient, meaning the risk of *an adverse error-event* to the patient resulting from radiation use. An adverse error-event means an event that results in either temporary or permanent unintended harm to the patient. For the purpose of this guide, radiation risk does not refer to the risk of *adverse effects*, meaning an adverse and unintended effect caused by a treatment method that occurs in connection to conventionally used treatment methods.

The guide introduces a recommended method for proactive risk assessment, the terminology and concepts related to the method as well as a brief summary of the recommended procedures for organising risk assessment at radiotherapy units. For the practical implementation of risk assessment, the guide's appendices include a detailed table with preliminary assessments of the risks of many typical adverse error-events in accordance with the recommended method. The idea is that with the help of the table, radiotherapy units can, by editing and supplementing it as necessary, assess the risks of the most probable adverse error-events in their unit. The events are categorised into adverse error-events related to the patient's care path, equipment and organisation.

The risk assessment involves considering the severity and probability of the events using the scales provided in the guide. The criticality of an event is calculated by multiplying its severity with its probability, resulting in its criticality index. Based on its criticality, the risk is either accepted, controlled or used as the basis for carrying out corrective measures.

The risk assessment described in the guide is meant for assessing the risks of external radiotherapy, but the method can also be applied to adverse error-events in other types of radiotherapy. The risk assessment of adverse error-events and the categorisation created as a result can also be utilised in recording and reporting on adverse error-events.

The radiotherapy risk assessment method will be showcased at a conference organised by STUK in June 2015 in Helsinki, where the guide will also be published.

Development of regulatory control in radiotherapy

In 2014, the resources reserved for developing the regulatory control of radiotherapy were primarily allocated to the joint European research project MetrExtRT. The project partners include leading European primary standards laboratories, including NPL (UK), ENEA (Italy) and PTB (Germany). STUK's contribution to the project is a study on the characteristics of radiochromic film (Gaf-Chromic EBT-3) and the preparation of the reading process best suited to film as well as the development of a method for verifying the calculations of dose planning systems using comparative measurements. The work has been carried out in collaboration with the university hospitals of Tampere and Helsinki.

The method development has required the development and manufacture of several phantoms, particularly ones suited to electron radiation, as well as the study of film characteristics using measurements and Monte Carlo calculations. The calibrations required for the study and the majority of the film irradiations were conducted in the national metrology laboratory, but the required high energy beam irradiations and dose planning were carried out in the radiotherapy unit of TAYS Central Hospital. In addition to STUK experts, the project involved a team of Italian physicists from ENEA.

Measurements were conducted to, for example, study the response of a new type of diamond indicator in electron and photon beams as well as the suitability of film for measuring dose distribution in combined photon and electron beams.

The results of the work have been showcased

in two international conferences as well as at the domestic radiotherapy physicists' conference. The aim is to produce new methods for measuring radiation and control measures for ensuring the continued high quality of radiotherapy.

2.2 Use of radiation in industry, research and education

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

Safety licences

There were 1115 current safety licences for the use of radiation in industry, research and education at the end of 2014 (see also Figure 2). A total of 409 licensing decisions (new licences or amendments to previous licenses) were issued during the year. The average time taken to process safety licence applications was 16 days. The numerical distribution of radiation practices referred to in these licences is shown in Table 3 of Appendix 1.

Radiation appliances, sources and laboratories

Figure 4 shows the number of appliances containing radioactive substances used in industry, research and education for the last ten years. The number has remained largely the same for a long time.

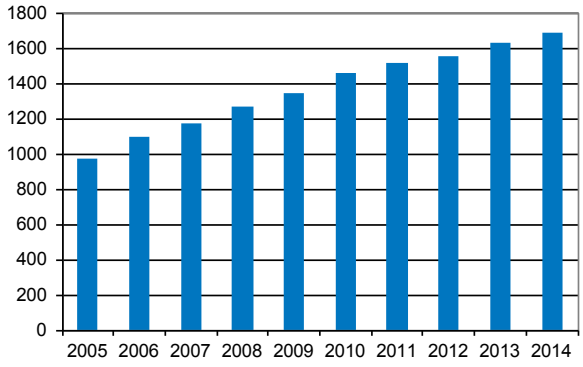

Figure 4. The number of appliances containing radioactive substances in 2005–2014.

Figure 5 shows the number of X-ray appliances in the last ten years. The number has almost doubled in ten years. Appliances containing radioactive substance have, to some extent, been replaced by X-ray appliances, in addition to which new scanning and analysis device applications have been introduced.

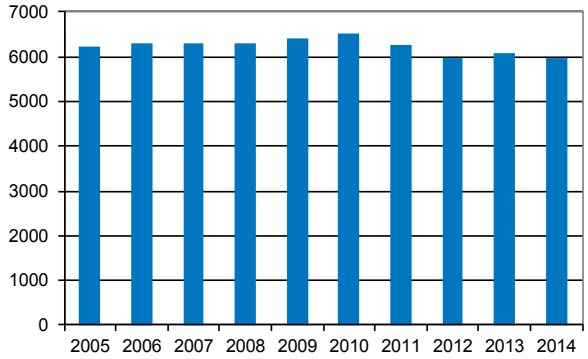

Figure 5. Number of X-ray appliances between 2005 and 2014.

Table 4 in Appendix 1 shows details of radiation appliances and sources, and of radionuclide laboratories used in industry, research and education at the end of 2014.

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

X-ray appliance survey

At the start of 2015, STUK requested notifications from all vendors of X-ray equipment operating in Finland (44 vendors) concerning appliances sold in 2014 and their custodians. These notifications revealed 12 responsible parties who did not have a licence for operating X-ray appliances. In addition to this, it was found that 26 licence holders had not notified STUK of their newly procured X-ray appliances. STUK issued the required orders to rectify the observed shortcomings and supervised the appropriate licensing of all aforementioned appliances.

2.3 Inspections of licensed radiation practices

Health care, dental care and veterinary practices

A total of 482 inspections were made of the use of radiation in health care and veterinary practices. Of these inspections, 233 were periodic inspections and 118 were initial inspections. In addition to these, 3 repeat inspections and 8 other inspections were made during the year. The number of veterinary X-ray practice inspections made was 46. These inspections resulted in 303 repair orders or recommendations issued to the responsible parties. A further 6 appliances were also found that did not have the required safety licence for their use. In addition to these, the inspections revealed 6 cases of inadequate radiation shielding in imaging rooms. Doses exceeding the reference level were measured during 15 inspections. During 2014 STUK updated the reference levels for conventional examinations, as a result of which the number of cases where doses exceeded reference levels was higher than in previous years.

There were approximately 1600 responsible parties engaged in dental X-ray practices in 2014. Patient radiation exposure due to dental X-ray imaging was measured in 400 intraoral X-ray appliances with testing equipment sent by mail. The average dose was 1.18 mGy. This dose corresponds to the dose administered on the surface of the cheek (Entrance Surface Dose, ESD) when imaging a tooth. The reference level of 2.5 mGy was exceeded in 13 imaging appliances. In addition to this, STUK conducted on-site inspections of 47 panoramic tomography appliances used in conventional dental X-ray practices. The majority of the deficiencies observed during these inspections had to do with quality control, the appliance itself, its accessories or the correctness of registration information. In addition to this, the inspections revealed 4 dental X-ray appliances that STUK had not been notified of for registration. Furthermore, doses exceeding reference levels were recorded on 9 panoramic tomography appliances.

After the inspections, radiation safety officers were sent a feedback survey asking for their opinion on the inspections. The majority of the respondents found the inspections to be useful and the issued repair orders to be justified. Some respondents wished that inspections could be booked further in advance. Respondents were satisfied with the contents and preparation speed of inspection reports.

Industry, research and education

In 2014, 206 inspections were conducted at sites where radiation is used for industrial, research and education purposes. These inspections resulted in 567 repair orders or recommendations. In accordance with the annual plan, periodic inspections are made every 2–8 years depending on the category and extent of operations. In addition to this, radiation practices pertaining to new safety licences are inspected before operations are commenced or within a year of issuing the licence. The date of the inspection is usually agreed upon in advance with the radiation safety officer. In 2014, one unannounced inspection of an industrial radiography practice was conducted.

After the inspections, radiation safety officers were sent a feedback survey asking for their opinion on the inspections. The majority of the respondents found the inspections to be useful and the issued repair orders to be justified. Respondents were also satisfied with the contents of inspections reports, but in some cases radiation safety officers reported that the inspection report did not arrive quickly enough following the inspection.

2.4 Importing, manufacture and exporting of radioactive substances

Details of deliveries of radioactive substances to and from Finland and of manufacturing of such substances in Finland in 2014 are shown in Tables 6 and 7 of Appendix 1. The figures in the tables are based on data gathered from radiation safety licensees engaged in trading, importing, exporting and manufacturing.

The tables do not include the following information:

- Radioactive substances procured by responsible parties for their own use from other countries within the European Union, and consigned from the said use to other European Union countries.
- Radioactive substances supplied to other countries via Finland.
- Smoke detectors and fire alarm system ion detectors containing americium (^{241}Am).

Approximately 106 000 of these were imported with a combined activity of about 3.5 GBq. Approximately 200 smoke detectors with a combined activity of approximately 2 MBq were exported from Finland.

- Lamps and fuses containing radioactive materials imported to Finland. Some of these appliances contain small quantities of tritium (^{3}H), krypton (^{85}Kr) or thorium (^{232}Th).
- Unsealed radioactive sources imported to Finland and exported from Finland. Based on activity, the most common unsealed sources imported were ^{99}Mo, ^{131}I, ^{123}I, ^{177}Lu, ^{201}Tl, ^{32}P, ^{153}Sm, ^{90}Y, ^{111}In, ^{125}I, ^{3}H and ^{35}S.

2.5 Radiation doses to workers

A total of over 11 000 workers engaged in radiation work were subject to individual monitoring in 2014. Including doses falling below the recording level, a little over 73 500 dose records were entered in the Dose Register maintained by STUK. This figure also includes the dose records of workers exposed to natural radiation (radon and cosmic radiation).

In no case did the effective dose of a worker in 2014 exceed the annual dose limit of 50 mSv or the five-year dose limit of 100 mSv. The combined doses ($H_p(10)$ values) to workers by occupational category sustained in the use of radiation were approximately 1.71 Sv and those sustained in the use of nuclear energy approximately 1.57 Sv. The total dose sustained in the use of radiation increased by slightly over 4% compared to the previous year. In the use of nuclear energy, the combined dose was nearly 26% higher than during the previous year. The total dose in the use of nuclear energy varies considerably each year, depending on the duration of annual operation at nuclear power plant and the duties performed in servicing work at these facilities.

The greatest ($H_p(10)$) value in health care was 28.8 mSv, recorded in the case of an interventional radiologist. This dose is equivalent to an effective dose of approximately 1 mSv. The highest effective dose recorded in health care from a source other than X-radiation was 3.2 mSv, recorded in the case of a radiographer working in a nuclear medicine department. The greatest $H_p(10)$ value in veterinary practice was 9.2 mSv, recorded in the case of a veterinarian performing X-ray examinations. This dose is equivalent to an effective dose of approximately 0.3 mSv. The highest effective dose in industry was 6.3 mSv, recorded in the case of an individual performing tracer element tests. The highest effective dose in research was 7.6 mSv, sustained by a researcher using several different radiation sources.

In some work tasks, such as in the handling of unsealed sources, workers are exposed to radiation unevenly. In such cases the dose sustained on the hands, for example, may be considerable even if the effective dose is relatively small. A separate annual dose limit of 500 mSv has been set for skin doses, and workers use a so-called finger dosemeter to monitor radiation dose to the hands. In no cases did the hand dose sustained by workers exceed the annual dose limit in 2014. The highest dose was 446 mSv, recorded in the case of a laboratorian working in health care. For most workers handling unsealed sources the skin dose sustained on the hands is less than 100 mSv.

The Dose Register also records the dose information of workers exposed to natural radiation during their work, even though such workers are not classified as radiation workers.

The radon exposure of workers was determined based on radon measurements and the monitoring of working hours at workplaces in which the radon concentration exceeded the action level. Some of these workplaces were conventional workplaces, while some were sites located underground or in tunnels. A total of 50 workers, whose doses were recorded in the Dose Register, were subject to radon exposure monitoring during 2014. The largest effective dose sustained by a worker as a result of radon exposure in 2014 was 17.1 mSv, recorded at a conventional workplace.

The number of workers subjected to individual monitoring due to radon exposure varies considerably from year to year due to variation in the amount of excavation and tunnelling work, in addition to which workplaces undergo repair work, the success of which has an effect on the amount of radon exposure.

The doses sustained by the employees of seven airlines were entered in STUK's Dose Register in 2014. In no case did the effective dose sustained by an employee exceed the limiting value of 6 mSv stipulated in Guide ST 12.4. The highest individual doses of cosmic radiation recorded were 4.5 mSv sustained by a pilot and 5.8 mSv sustained by

a cabin crew member. The cabin crew member who recorded the highest exposure had worked in two airlines where work resulted in radiation exposure during the year. The average annual dose sustained by pilots in 2014 was 2.3 mSv and the average annual dose of cabin crew members was 2.4 mSv. The average doses over the period from 2010 to 2014 are shown in Figure 6.

The total number of workers in flight crews decreased by 3.3% compared to the previous year, while the total dose decreased by 1.5%. The number of workers subject to individual monitoring of radiation exposure and their total doses are shown in Table 8 of Appendix 1.

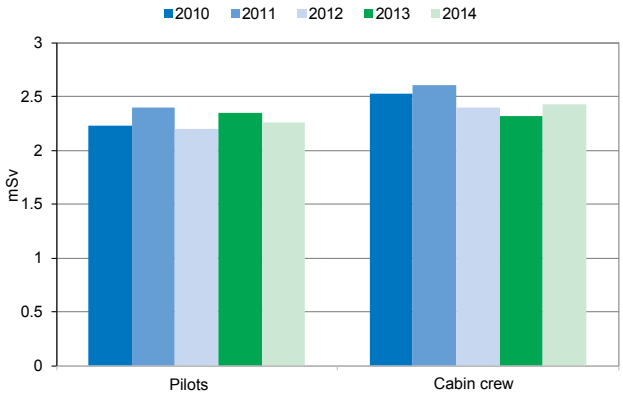

Figure 6. Average doses sustained by flight crews in 2010–2014.

Table 9 of Appendix 1 shows the number of radiation workers by occupational category subject to individual monitoring over the last five years. The combined doses to workers by occupational category are shown in Figure 1 (Item 1.1) and in Table 10 in Appendix 1. Table 11 in Appendix 1 shows the doses in 2014 to persons subject to high levels of exposure or of numerically large worker groups.

2.6 Approval decisions and verification of competence

Training organisations 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 organisations that arrange training and competence exams for radiation safety officers must apply to STUK for the right to arrange such exams.

In 2014, new approval decisions to arrange exams and organise training for radiation safety officers were issued to five training organisations. A total of 21 training organisations held valid approval decisions at the end of 2014. The approved training organisations are listed on STUK's website (www.stuk.fi).

Practitioners responsible for medical surveillance

STUK accredits the competence of practitioners responsible for medical surveillance of category A radiation workers. By the end of 2014, STUK had accredited a total of 430 doctors as practitioners responsible for medical surveillance, of whom 33 were accredited during 2014.

Parties engaged in aviation operations

In 2014, STUK found one new airline to be engaging in radiation practices based on the report submitted to STUK. The airline's radiation safety procedures were reviewed and found to comply with requirements.

Approval decisions of dosimetric services and methods of measurement

Two dosimetric services were approved for operating as dosimetric services conducting individual monitoring measurements on radiation workers. The approvals are valid for five years, after which they must be applied for again. In connection to this, the methods of measurement used by the dosimetric services were also approved. The currently approved methods are, depending on the dosimetric service, measurements based on the TL, OSL and DIS methods.

Approval decisions of radon measuring equipment

Four new approval decisions for radon measuring equipment were issued in 2014. A list of organisations with measuring methods that have been approved in accordance with the requirements of Guide ST 1.9 and that have consented to their names being published can be found on the STUK website It is a condition of such approval that the measuring instrument is properly calibrated.

2.7 Radioactive waste

STUK maintains a national storage facility for low level radioactive waste. The amounts of the most notable wastes held in the storage facility at the end of 2014 are shown in Table 12 of Appendix 1.

2.8 Abnormal events

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 in the location 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 reported.

A total of 135 abnormal events or observations of the use of ionising radiation were reported to STUK in 2014. Of these reports, 96 concerned the use of radiation in health care, one concerned the use of radiation in veterinary medicine and 38 concerned the use of radiation in industry or use of non-identifiable radiation sources. The numbers of abnormal events that occurred in Finland in 2004–2014 are shown in Figure 3 (Item 1.1), including abnormal events in the use of non-ionizing radiation, which are detailed in Item 4.4.

The abnormal events in the use of ionising radiation are presented below, grouped by incident type. More details are given of typical or significant events.

Abnormal events in health care

Imaging of a wrong patient or an insufficient referral

The wrong patient was imaged in 23 individual events. A typical reason for radiographing or examining the wrong patient was a deficient verification of identity by the radiographer or patient transporter, such as the social security number not being asked for when the patient was brought to be radiographed, or the verification was erroneous. In some cases, patient identification was hindered by communication problems, or two patients with the same or almost the same name were confused with each another. In many cases, a doctor recorded a referral for the wrong patient. The highest dose sustained due to the imaging of the wrong patient was estimated to be 6 mSv.

One SPECT-CT examination had to be retaken because of an erroneous referral, resulting in an additional dose of 4.9 mSv.

Example event:

An emergency room requested a head CT scan for a patient. Later a call was received from the hospital emergency room explaining that the referral had been made for the wrong patient. However, by then the CT scan had already been conducted. In other words, a request for a head CT scan meant for another patient was accidentally made for the wrong patient. The reason behind the incident was human error. The incorrect patient sustained an estimated effective dose of 1.5 mSv.

Abnormal events concerning radiopharmaceuticals

In four cases the injection given to a patient failed and in four cases the patient was given the wrong radiopharmaceutical or an incorrect activity of the correct radiopharmaceutical. In addition to these, two reports concerned abnormal events related to the transportation of radiopharmaceuticals.

Example event:

Two patients were given an excessively large dose of ^{123}I at a nuclear medicine department. According to the examination instructions, the activity that is supposed to be administered to the patient is 15–20 MBq. The nurse had access to a dosage table and a dosage record. A note accompanying the dosage table specifically states that the calibration time must be checked and that the table in question is only valid for the calibration made on the previous day. In the previous year, the aforementioned calibration time had been exceptional only once (calibrated on the same day). This time the calibration was again exceptional, which the nurse failed to notice. The exception would have also been evident from the note recorded in the dosage record. As a result, these two patients received 48 MBq instead of 20 MBq. The calculated thyroid dose increased by 26 mGy and the effective dose increased by 4 mGy.

Abnormal events in radiotherapy

Five abnormal events in radiotherapy were recorded, of which two concerned an equipment fault and one was a so-called near miss. In two cases treatment was incorrectly aligned and in one follow-up treatment the treatment order contained a mistake. The mistakes were noticed during the treatment period, as a result of which new plans could be made to compensate for the dose.

Example event:

A patient was receiving treatment to two targets at the same time, the thoracic spine and the iliac bone for 5 fractions of 5 Gy. Separate plans had been prepared for both targets, the isocentres of which had been marked on the patient's skin. During the fourth fraction, suspicions arose that the previous fractions might have been incorrectly aligned. It was found that fractions 2 and 3 made for the clavicle target had been administered to the isocentres of the thoracic spine plan on the same day as fractions 2 and 3 of the thoracic spine plan were administered. It had been assumed, most likely due to human error, that the transition between isocentres could be carried out automatically, as it sometimes is when targets are close to one another. In this case, however, the targets required separate alignments processes. The incorrectly aligned fields were reconstructed using a dose calculation system and a dose calculation was made for the administered treatment. The radiotherapy for the thoracic spine was discontinued after the fourth fraction and the treatment of the clavicle was continued. As a result, one treatment target received a larger dose than planned and the other underwent an unnecessarily long treatment break.

Appliance or system fault in X-ray or nuclear medicine examinations

The number of abnormal events recorded that resulted from an appliance or system fault was 29. In several cases, a patient's imaging had to be redone due to a malfunction in or breaking down of a CT or PET-CT appliance. In addition, faulty operation instructions and software errors caused aborted or faulty imaging. The highest additional exposure to a patient due to a device fault was approximately 40 mSv, in connection with a CT examination (example event 3).

Example event 1:

Two patients received an unnecessary ^{18}F-FDG radiopharmaceutical when a PET-CT scanner broke down. The scanner was supposed to be operational following repairs carried out on the previous day and the first patient of the day was successfully imaged. The extra doses sustained by the two patients were 7.6 mSv and 5.7 mSv.

Example event 2:

During a trauma-CT examination, the connection of the contrast medium injector failed and the contrast medium was spilled on the floor. At the request of the radiologist the contrast medium series was repeated. Usually examinations like this are conducted using the hospital's other CT scanner and the examination in question had rarely been conducted using this scanner. The estimated effective dose was approximately 33 mSv.

Example event 3:

During a CT scan (extensive CT scan of the body area) the examination technique was changed due to the patient's irregular heart rate. However, the scanner continued to image under ECG control the whole time. This caused an excessive dose to the patient. The estimated extra effective dose was approximately 40 mSv.

Exposure of a worker in health care use of radiation

There were eight cases of unintentional exposure of a worker or several individuals. In most cases, an X-ray examination was started before the nurse had time to leave the room or the irradiation was accidentally started too soon. In addition to this, there were a few cases of personnel entering the imaging room in the middle of an examination. In one case the clogged toilet of isolated patients receiving radioactive iodine treatment had to be unclogged. The exposures sustained by workers remained small.

Example event 1:

During an abdominal contrast medium CT scan the patient suffered nausea to the contrast medium just before the start of the imaging series. The appliance operator attempted to stop the imaging using the "stop" and "pause" buttons on the console

while the radiographer entered the imaging room. However, the imaging did not stop and the radiographer was exposed to scattered radiation for the duration of the imaging. The radiographer's effective dose was estimated to be 3.4 µSv. The imaging was adequate for diagnosing the patient, as a result of which the imaging did not need to be redone.

Example event 2:
During the gamma imaging of a small child's kidneys some of the contrast medium was splashed on the worker's hands. The worker was wearing protective gloves and there was a finger dose meter inside the gloves. The child had an iv cannula in the leg, which was attached to a three-way cock equipped with a filter. The cannula worked fine when tested with saline solution, but when injecting the radiopharmaceutical the injector was not immediately pushed deep enough (the filter always offers some resistance), as a result of which some of the radioactive substance was splashed on the worker's hands during injection. The imaging was successful and the medium was visible in the patient. The surroundings were immediately cleaned and the protective gloves and clothes were changed. No contamination was detected in contamination measurements of the surroundings and workers.

Other events caused by human errors

Other human errors were the cause of a total of 21 events. The largest extra exposure for a patient was approximately 30 mSv. In one abnormal event a foetus was exposed to radiation, but the exposure was very minor.

Example event 1:
An emergency room had requested an abdominal CT scan for a 4-year-old boy, but the scan had been accidentally conducted using a head CT protocol. However, the raw data from the examination was still usable for a diagnosis. The radiation exposure was over 20 times the exposure caused by an abdominal CT scan normally performed on a child this age. The effective dose was estimated at 25–30 mSv.

In addition to this, one abnormal event report concerned the malfunction of an appliance in veterinary X-ray examinations. In this case an inspection conducted by STUK revealed that the X-ray appliance's automatic exposure control unit was not working, as a result of which the appliance always expounded until the exposure timelimit. The fault was probably introduced when the appliance was transported half a year earlier, at which point the appliance had been inadequately installed. The fault had subjected people holding down animals, meaning the veterinary clinic's personnel and animal owners, to extra exposure equivalent to an estimated 2–3 times the normal exposure. Since the transport of the appliance, seven workers have exhibited mildly abnormal dosimeter readings.

Abnormal events in industry and research

Exposure of a worker in the industrial and research use of radiation

In 2014, the Radiation and Nuclear Safety Authority received a total of five reports of events in which a worker was exposed to radiation during the industrial use of radiation. In two of the events, workers were exposed to radiation emitted by a radiometric measuring appliance during maintenance because the radiation source's shutter had not been appropriately closed. In three of the cases exposure was caused by the handling of unsealed sources.

Example event:
A worker who was performing radiolabeling with ^{125}I noticed that her right hand had been contaminated with ^{125}I. No signs of thyroid contamination were found in more detailed radiation measurements. After this the responsible party contacted an occupational health care doctor, who recommended that the worker take an iodine tablet. The worker took an iodine tablet three days after the incident. Based on measurements conducted at STUK, the worker's effective dose was estimated at approximately 0.06 mSv and the thyroid gland's equivalent dose was approximately 1 mSv. The hand skin dose was estimated at approximately 26 mSv.

Industrial radiography

In 2014, the Radiation and Nuclear Safety Authority received one report of an abnormal event related to industrial radiography. A gamma

source used in imaging pipe systems (^{192}Ir, 680 GBq) was momentarily forgotten outside of the storage position during imaging preparations. The incident was not immediately noticed since the workers' radiation alarm signal could not be heard over the noise. After a moment one of the workers heard their radiation alarm signal, and the radiation source was retracted into the storage position before work was continued. Based on the measurement results of the workers' personal dosimeters it was determined that the workers were exposed to extra radiation doses no higher than 0.3 and 0.1 mSv. Other people were not exposed.

Radiation sources within recycled metal

In 2014, STUK received notifications of seven cases of radiation sources that had been identified in an incoming metal load by the radiation portal monitor of a metal recycling company or steel plant. Loads were found to include, for example, switches and metal chippings containing radium (^{226}Ra), an incineration grate contaminated with ^{137}Cs, and a ^{60}Co radiation source.

In two cases, an ^{241}Am radiation source was smelted at a steel plant. Due to the protective measures conducted, no radiation hazard was caused outside of the plant and workers were not exposed to radiation. The smelting of the americium source did not contaminate the metal that was being produced, because most of it exited as slag and combustion gas dust. The materials contaminated with ^{241}Am, a total of 1,057 tonnes, were later placed in the plant area in a manner approved by STUK.

In addition to radioactive material, two instances of empty radiation source packages with radiation warning labels still attached to them were found in scrap metal.

In one event the demolition work carried out a place where radiation was used that was undergoing renovation led to the discovery of six waste containers inside a concrete well which contained primarily ^{137}Cs, ^{60}Co and ^{3}H nuclides

Example event:

A scrap metal load set off radiation detectors at a scrapyard and the load was found to contain a belt conveyor scale. The belt conveyor scale contained a ^{60}Co radiation source, the activity of which was approximately 6 MBq at the time of discovery. The scrap metal load had arrived from Kiruna, Sweden in 1997–1998. The dose rate measured at the surface of the appliance was approximately 5 µSv/h. The appliance was delivered to Suomen Nukliditekniikka for final disposal.

Disappearance of radiation source

During an inspection, STUK discovered that a responsible party could not account for the whereabouts of two radiation sources. Later one of the radiation sources was found in Sweden (more detailed description below). In addition to this, one analyser containing a radioactive isotope (^{109}Cd, activity 25 MBq) was stolen from the responsible party's facilities. The radiation source's information was reported to the police investigating the theft, and recorded in the investigation report. The stolen source has so far not been found.

Example event:

During an inspection it was discovered that two measuring devices containing sealed sources (radiation sources ^{244}Cm, 1110 MBq and ^{241}Am, 2960 MBq) that had been in the possession of a responsible party had disappeared. The following investigation revealed that one of the devices, a basis weight gauge, had been delivered to Sweden for servicing in 2009 along with its radiation source and had never returned. The radiation source had been disposed of in Sweden. Despite the responsible party's search efforts, the ^{241}Am radiation source has not been found. The holder of the safety licence has set new regulations related to the use of radiation sources in order to prevent future disappearances.

Use of unsealed sources

Two abnormal events related to the use of unsealed sources were reported to STUK in 2014.

In one event 860 MBq ^{18}F was released into outdoor air from a laboratory. The amount corresponds to approximately 1% of the annual emission limit for operations. The emission was also detected with a spectrometer belonging to STUK's surveillance network, which was located near the laboratory at the time of the incident.

In the other event, during the use of calibration sources at a STUK measurement laboratory it was discovered that the lead shielding had been

contaminated on the inside with ^{137}Cs. Before the incident was revealed, the contamination had spread via STUK researchers' hands to surfaces and objects in the measurement laboratory. The event resulted in extensive decontamination procedures at the measurement laboratory.

Transportation of radioactive materials

Six abnormal events related to the transportation of radioactive materials were reported to STUK in 2014. In two of the events, transportation packages arriving in Finland were damaged, though the inner package remained intact. Three of the events concerned incorrect or insufficient markings on the packaging or consignment note. In one event a driver left a package at a loading dock without signing it off.

Example event:

A customer had received a shipment of radiation sources in the morning, which had been left at a loading dock without being signed off or informing the customer. The packages, which had been sent from France, contained four ^{57}Co reference sources, the activities of which ranged from 3.7 to 600 MBq. The driver who had delivered the sources had acted in violation of ADR regulations and the shipping company's own instructions. The customer company's personnel noticed the packages at the loading dock during the morning, and moved them inside. The shipping company investigated the inadequate handling and the company's transportation instructions were clarified.

Other abnormal events

STUK received reports of ten other abnormal events in 2014. Seven of these concerned the unauthorised possession or use of radiation sources. The rest concerned an excessively high dose rate outside of a radiation source warehouse and the contamination of a radiometric measurement device during the replacement of its radiation source.

Example event 1:

A responsible party sent a radiation device containing a sealed source to Germany for repairs without the required transfer form, and the package did not have the required markings. In addition to this, the device was not included in the safety licence of the party that was using it. The device was added to the licence as per STUK's order.

Example event 2:

As a result of an inspection, STUK was made aware that a responsible party had handed over a Troxler measurement device to another, unlicensed responsible party. The new holder of the measurement device was advised to apply for a safety licence as soon as possible. The company that had handed over the device was reminded of the obligation to make enquiries when handing over radiation sources. The matter was also brought up during the next inspection.

Example event 3:

Elevated dose rates were detected outside the facilities of a recognised installation. The company was ordered to immediately carry out measures in order to reduce the dose rate in the surrounding facilities. In addition to this, the company was asked to provide a report on the causes of the elevated dose rates. The elevated dose rates were found to be caused by the accumulation of an unusually high amount of radioactive waste in the warehouse. The company added more radiation shielding so that dose rates were reduced to an acceptable level.

3 Regulatory control of practices causing exposure to natural radiation

Regulatory control of practices causing exposure to natural radiation was transferred to the Department of Environmental Radiation Surveillance on 1 June 2014.

3.1 Radon at workplaces

Regulatory control of radon at workplaces was carried out in collaboration with the occupational health and safety units of regional state administrative agencies. A total of 35 inspections were conducted at 19 underground quarries and sites. Radon concentrations exceeded 400 Bq/m^3 at seven sites, which were ordered to reduce their radon concentrations. Three underground quarries were ordered to track working times, which was discontinued once radon concentrations were reduced. Radon concentrations at work sites were successfully reduced to below 400 Bq/m^3 at all seven work sites.

Radon inspections were conducted in six underground mines. Concentrations exceeding the action level were observed at one of these mines, though they were measured at a location where work was no longer being conducted.

In 2014, STUK's radon measurement cans were used to conduct measurements at workplaces other than mines or underground quarries, meaning so-called conventional workplaces, at 1398 measurement points. Of these measurements, 230 exceeded the action level of 400 Bq/m^3. During the year STUK prepared 165 inspection reports related to radon in indoor air at conventional workplaces. Of these, only the results of workplaces where radon concentrations exceeded the action level at one or more measurement points and workplaces those that had previously recorded concentrations exceeding the action level were recorded in the radon surveillance database. A total of 643 records were entered into the radon surveillance database. Based on measurement results, STUK issued orders for action as follows: corrective measures or reports on radon concentrations during working hours were ordered at 114 work areas and verification or repeat measurements to be carried out at another time of year were ordered at 33 work areas. In addition to this, 38 exhortations were sent to companies that had not reported repairs or measurements. Responsible parties carried out successful corrections of radon concentrations at 60 work areas.

Efforts to reduce radon concentrations or radon exposure were unsuccessful at three conventional workplaces and one workplace consisting of underground tunnels.

3.2 Other natural radiation from the ground

STUK monitors exposure caused by radioactive materials that occur naturally in water intended for human consumption, construction materials and other materials. The radioactivity of household water was monitored at 24 sites. A dose of 0.5 mSv was not exceeded at any of these sites. The number of monitoring measurements conducted concerning the radioactivity of construction material meant for building production was 116, leading to the preparation of a total of 21 inspection reports. According to the reports, no cases of dose limits being exceeded were recorded. The activity measurements of construction materials have increased as a result of the EU Construction Products Regulation, which entered into force on 1 July 2013. The Construction Products Regulation makes the CE marking obligatory, also in Finland, in all construction products that enter the market and fall within the scope of the harmonised product standard. The harmonised product standards are drafted by the European Committee for Standardization CEN.

STUK has been monitoring the radioactivity of the surroundings of the Talvivaara mine with regular samplings. The monitoring has revealed

elevated uranium concentrations of over 100 micrograms per litre mainly in the mine area's water systems, such as the opencast quarry and Salminen. Concentrations in the surface waters of water systems located outside of the mine area are so small that they do not pose any risk to people, animals or the environment as regards radiation protection. Such minor concentrations do not cause any adverse health effects in humans. Currently there are no restrictions related to radiation in place regarding natural products or foods harvested in the area. In addition to environmental control, STUK has been involved in the preparation of various statements related to mining operations.

4 Regulatory control of the use of non-ionizing radiation

4.1 General

The expression non-ionising radiation refers to ultraviolet radiation, visible light, infrared radiation, radio frequency radiation, and low frequency and static electric and magnetic fields. Coherent light, or laser radiation, is a special type of visible light. The use of non-ionising radiation requires a preliminary inspection only in certain special cases, such as in the use of high-powered laser equipment in public performances. In other respects, the Non-Ionising Radiation (NIR) Surveillance Unit of STUK conducts market control for devices and practices that expose the public to non-ionising radiation. Market control is targeted at the following practices:

- sunbed services
- consumer laser devices
- wireless communication devices and high-powered radio transmitters causing public exposure
- cosmetic treatment devices that utilise non-ionising radiation and their use in services.

In addition to regulatory control, STUK issues instructions on the application of the recommended values of low frequency electric and magnetic fields, stipulated by the Ministry of Social Affairs and Health Decree 294/2002, for example, for power lines, and approves the methods and instructions used in the inspection and regulatory control of the radio and radar devices used by the Finnish Defence Forces.

The work of the NIR Unit in regulatory control of the use of non-ionising radiation between 2005 and 2014 is shown in Tables 13–16 of Appendix 1. The number of dangerous laser devices on the market was high, as in the preceding years, which has increased the need for regulatory control of lasers. In 2014, STUK intervened in the sales or importing of a dangerous device 49 times. The number of statement and information requests to authorities concerning electromagnetic fields increased significantly compared to previous years. STUK has been requested to issue more statements on power line projects in particular.

In addition to carrying out regulatory control, STUK promotes the reduction of the harmful effects of UV radiation through active communication and participates as an expert in the discussion concerning the health effects of electromagnetic fields. Concerns related to mobile phone base stations and wireless networks in have been particularly apparent in the inquiries made by citizens and information requests submitted to STUK.

4.2 Regulatory control of UV radiation devices

The regulatory control of sunbed devices and establishments takes place in co-operation with municipal health protection authorities, based on the amendment of the Radiation Act that was taken into force on 1 July 2012. Health inspectors audit the facilities as part of the regulatory control of the Health Protection Act, and submit a report on their findings to STUK for decision-making. In addition to this, STUK carries out its own inspections where necessary.

The health protection authorities submitted the details of 20 inspections (Table 15 of Appendix 1). Deficiencies affecting safety were observed during eight of these inspections, while minor deficiencies were observed at five facilities. The most common deficiencies had to do with instruction manuals and timers. In addition to these, STUK conducted an inspection at one sunbed facility. Compliance with the repair requests issued based on inspections carried out by municipalities was actively monitored. The congestion that had built up related to this was successfully reduced.

4.3 Regulatory control of laser devices

The regulatory control of laser devices designed for private use is divided into importation control performed by customs, and market control of traditional and online sales. In addition to this, the use of high-powered laser equipment in public performances is subject to regulatory control.

In market and condition control, STUK intervened in the sale or use of 12 laser devices. Of these devices, ten were laser pointers, which all had deficiencies (relating, for example, to type examination certificates and markings) and one device was found to significantly exceed the highest permitted power defined for laser pointers, which is 1 mW. Repair requests were issued regarding the markings, and the excessively powerful laser was removed from the market. Two of the devices were effect lasers used in performances, which were investigated based on denunciations received from customers. One of these devices was found to comply with requirements, but its use was deemed to be subject to a STUK inspection. The other device was found non-compliant with the requirements. Furthermore, the device seller's catalogue included several devices that were being marketed without the appropriate warnings and instructions.

There were 41 requests sent to the huuto.net online sales forum and other Internet sales sites requesting the removal of sales advertisements because of excessively powerful laser pointers.

Finnish Customs solicited advice from STUK in 34 cases involving the importation of lasers from outside the European Union. In five of these cases, the laser devices were found to be dangerous and import was prevented. In seven cases the devices were found to have deficiencies requiring action from the importer.

A total of seven laser shows were inspected on site. In addition to this, 25 notifications were issued to STUK on the shows arranged by responsible parties using approved laser devices. In the inspections, the safety arrangements and the pointing of the laser beams were found to comply with the requirements in most cases. Table 13 of Appendix 1 contains a summary of the laser inspections.

4.4 Regulatory control of devices producing electromagnetic fields

In the market control of wireless communication devices, 10 products were tested, focusing on makes new to the Finnish market. The devices selected for testing consisted of phones and tablet computers, which were tested for the first time in 2014. In addition to these, tests were conducted on phone accessories that could have an impact on radiation characteristics. The highest measured average SAR value of 10-gram mass was 1.33 W/kg, which did not exceed the maximum value of 2 W/kg stipulated by Decree 294/2002 of the Ministry of Social Affairs and Health (Table 16 of Appendix 1).

Several preliminary investigations were carried out on the installations of wireless base stations, as requested by citizens and municipalities, for instance. No faulty installations were found.

4.5 Regulatory control of cosmetic NIR applications

The regulatory control of cosmetic NIR applications focused on problems related to regulations. The Ministry of Social Affairs and Health was asked to provide an interpretation of the Radiation Act regarding the regulatory control of cosmetic treatments. Based on this interpretation, responsible parties under the regulatory control of STUK who perform tattoo removals were instructed to apply for a permit from the Regional State Administrative Agency. The processing of two of these cases is still in progress. In the market control of cosmetic applications, measurements were made fo three UV nail dryers used for curing nail enhancements. The appliances did not pose any danger when used according to their instruction manuals.

4.6 Other tasks

The number of statement requests to STUK on power line projects and land use plans near power lines remained high. STUK issued a total of eight statements. In addition to this, a number of investigations were carried out concerning existing power lines located near dwellings, following requests by citizens. In 2014, STUK also conducted a comprehensive study on indoor distribution

substations, which cause magnetic fields in living spaces.

The number of statements issued on other matters related to non-ionising radiation was 13. The subjects of these statements included radars, laser devices and the health effects of electromagnetic fields.

The effectiveness of regulatory control was increased through active communication. STUK participated in a campaign on the safety of online shopping coordinated by Tukes and realised as a collaborative effort between several authorities, and published a bulletin on the dangers of lasers in cooperation with Trafi and the Finnish Pilots' Association.

4.7 Abnormal events

In 2014, STUK received three notifications of events caused by non-ionising radiation that required immediate attention.

In the first abnormal event STUK was notified of skin burns at a sunbed facility. However, an inspection of the sunbed in question revealed that it complied with requirements. The skin burns were presumably caused by user error.

The other two abnormal events had to do with the unauthorised use of high-powered lasers in restaurant facilities. In the first of these events, a night club located in Turku posed a significant risk of eye damage as a result of the beams being targeted directly at the audience. However, STUK was not made aware of any damage. In the second event, the device was directed in a way that the probability of the beams hitting the eyes was low.

The numbers of abnormal events between 2005 and 2014 are shown in Figure 3 (Item 1.1; see also Item 2.8 on abnormal events in the use of ionising radiation).

5 Regulation work

Radiation safety guides

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

The following radiation safety guides were published in 2014:

- ST 3.1 Dental X-ray examinations in health care
- ST 3.3 X-ray examinations in health care
- ST 6.2 Radioactive waste and emissions from the use of unsealed sources
- ST 7.1 Monitoring of radiation exposure
- ST 7.2 Application of maximum values for radiation exposure and principles for the calculation of radiation doses
- ST 7.3 Calculation of the dose caused by internal radiation
- ST 7.4 The dose register and data reporting
- ST 7.5 Medical surveillance of occupationally exposed workers.

Other regulation work

The new Directive 2013/59/EURATOM on basic safety standards on radiation protection was approved on 5 December 2013. It must be implemented in national legislation by 6 February 2018. The radiation legislation will be updated in connection with the implementation. Preparations for the legislative renewal have been made by drawing up an estimate of the updating needs, under the management of the Ministry of Social Affairs and Health and under the direction of a STUK expert working at the ministry as part of an exchanges of officials. The memo was completed in February 2014. The estimate underwent an extensive statement round and was published on the Ministry of Social Affairs and Health's website in summer 2014. The statements were compiled into a summary and the estimate was collaboratively updated based on the statements by STUK and the Ministry of Social Affairs and Health in November 2014.

Directive 2013/35/EU of the European Parliament and of the Council on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) must be implemented by July 2016. In Finland, the directive shall be implemented by a government decree, issued under the Occupational Safety and Health Act (738/2002) and drafted by the Ministry of Social Affairs and Health. STUK participated in the drafting of the decree as an expert at the request of the Ministry of Social Affairs and Health.

6 Research

The aim of research work conducted by STUK is to provide information on the occurrence and measuring of radiation, on its detrimental effects and how to combat them, and on the safe and optimal use of radiation sources and methods of using radiation. Research supports the regulatory and metrological activities of STUK and the maintenance of the preparedness to respond to emergencies.

Research into the uses of radiation also seeks to improve knowledge and expertise in this field and to ensure reliable radiation measurements. Most research into ionising 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 into non-ionising radiation focuses on the exposure determination methods needed in regulatory control and the development of regulation.

In 2014, the priorities of STUK's research themes were clarified as part of a national reorganisation of radiation safety research. In order to ensure a high level of domestic expertise, STUK has been preparing a national research action plan in collaboration with Finnish universities and research institutes. The action plan is set to published in 2015.

Research and development work was performed in the following projects:

EMRP European Metrology Research Programme

The metrology research programme MetrExtRT develops measuring methods for small and complex radiation fields in radiotherapy. STUK's focus within the project is on the verification of the plans of electron or electron-photon radiotherapies. In 2014, STUK finished a report on the characteristics of radiochromic film as part of the MetrExtRT project. The structure of the semi-anatomical phantom was improved and measurements on the dosimetry of electron radiation beams were conducted in collaboration with Italian partners and TAYS.

A metrology project launched in 2011 with the aim of developing radiation measurement methods for smelting works that process recycled metal was completed in 2014. During 2014, STUK participated in the analysis and reporting of the results of the measurement comparisons organised as part of the project. The project involved, among other things, the development of reference sources for testing the detection sensitivity of radiation measuring devices used in smelting works.

The Nordic co-operative project Evidence-based Quality Assurance in Digital Dental Imaging (EQD)

The project sought to develop curricula, teaching programmes and training material for web-based instruction, to support digital dental imaging and the quality assurance of dental imaging and viewing circumstances. The teaching programmes were aimed at the education of young people and adults who are radiation users, and for bachelor's and master's level university degree curricula. The results will be used in training in the Nordic countries and Estonia. The project was completed in 2014.

Determining the patient dose in mammography

The project evaluated the reliability of estimated doses based on standard phantoms and reflected on the possibility of determining reference levels for mammography based on actual patient exposure data. The results of the study will also be used in training.

Determining patient skin dose and staff dose in cardiac examinations

In collaboration with Finnish hospitals, STUK has been studying patient radiation exposure in cardiac examinations, including patient skin doses. In connection to this, the radiation exposure of workers closest to the radiation beam has also been mapped. The measurements are set to continue in 2015. The aim is to study the possibility of setting reference levels for patient radiation exposure corresponding to the complexity of the examination and to examine the radiation exposure of patients and workers as, for example, the function of the complexity of the examination and the patient's characteristics.

Personnel well-being in magnetic resonance imaging work

STUK and the Finnish Institute of Occupational Health took part in the research project "Henkilöstön työhyvinvointia edistävät toimintatavat magneettikuvaustyössä" ("Actions promoting staff well-being in magnetic resonance imaging"). The project involves investigating the exposure of workers to magnetic fields and drafting the safety guide for magnetic resonance imaging. The project was launched in January 2012 and it will be completed in November 2015.

Patients' exposure to radiation and reference levels in children's computed tomography examinations

The research on the computed tomography (CT) scans of children examined the dose data of around 3500 children, collected in co-operation with three hospitals in Sweden, three in Norway, one in Denmark, two in Estonia and one in Lithuania. The dose data was collected in accordance with the research indications, in the CT examinations of the children's lungs, abdomen, the whole body (both lungs and abdomen) and the head. The possibility to set international reference levels for the radiation dose on patients in children's CT scans was assessed on the basis of the results. The results were reported and used as the basis of the Finnish reference level proposition published in 2014. In late 2014, the trial use of the reference levels began in select hospitals, with the aim of enabling STUK to issue a decision regarding the reference levels in 2015. The results of the study were reported at the sector's international conferences and will be compiled in a separate publication.

Radiation doses to the European population from X-ray and nuclear medicine examinations

The aim of this project, funded by the European Commission (EC), was to investigate the collective effective dose to the European population from X-ray and nuclear medicine examinations. The final report of the project was completed in 2014. The report includes estimates of the number of X-ray and nuclear medicine examinations carried out in Europe and the resulting collective effective dose to the European population. The report also includes information on the number of examinations conducted and population doses in each country, as well as comparisons of population doses with previous values. In addition to this, the report provides information on the reference levels of X-ray and nuclear medicine examinations reported by other European countries. The radiation dose to the European population is approximately 1.1 mSv per capita, of which 5% is from nuclear medicine examinations. The largest share of the dose from X-ray examinations, approximately 52%, is caused by computed tomography examinations.

Assessing radiation risks and abnormal events in radiotherapy

STUK participated in the European Commission's ACCIRAD project, which involved the preparation of the Commission's recommendation on proactive risk assessment in radiotherapy. The recommendation also concerns the handling and reporting of a abnormal event in radiotherapy. For the purpose of proactive risk assessment in radiotherapy, STUK appointed a domestic working group, which will prepare a guide on the subject based on the European Commission's recommendation. The national guide supports uniform application of the recommendation at radiotherapy clinics in Finland. The guide will be published in 2015.

Other research activity

In 2014 STUK analysed methods for assessing radiation exposure dependent on patient size

and studied the calibration practices of the pencil-type ionisation chamber used in computed tomography dose measurements. In spring 2014, STUK conducted stopping power measurements on protons and ^{12}C ions in collaboration with the University of Jyväskylä. The measurements have to do with the dosimetry of cosmic radiation and radiotherapy.

7 International co-operation

Participation in the work of international organisations and commissions

Representatives of the Department of Radiation Practices Regulation are involved in several international organisations and commissions dealing with the regulatory control and the development of safety regulations and measuring methods in the use of ionising and non-ionising radiation, and in standardising activities in the field of radiation, e.g. IAEA, NACP, EURADOS, EURAMET, ESTRO, ESOREX, AAPM, IEC, ISO, CEN, CENELEC, ICNIRP, EAN, EUTERP, HERCA, EURATOM/Article 31 – Group of Experts, WHO, UNSCEAR).

The Department of Radiation Practices Regulation is involved in the European Commission's PiDRL project, in which the aim is to prepare a recommendation on radiation exposure reference levels for paediatric radiological examinations and procedures. The first draft of the recommendation was completed and it will be finalised for publication in 2015.

Participation in meetings of international working groups

In 2014, representatives of STUK took part in meetings with the following international organisations and working groups:

- EURAMET's (European Association of National Metrology Institutes) annual meeting of contact persons
- Meeting of the Nordic Dosimetry Group
- Meeting of the Nordic Diagnostics Group
- HERCA (Heads of the European Radiological Protection Competent Authorities) and its working groups
- Annual meeting of EURADOS (European Radiation Dosimetry Group) and its working groups
- NORGIR meeting (Nordic Working Group on Industrial Radiation)
- EACA meeting (European Association of Competent Authorities on the transport of radioactive material)
- Meeting of the main committee of ICNIRP (International Commission on Non-Ionising Radiation Protection)
- NACP Radiation Physics Committee
- Nordic Ozone Group (including UV questions)
- The Nordic radiation protection authorities' NIR seminar
- IEC TC 61 MT 16 meeting (sunbed standards)
- IAEA: Transport Safety Standards Committee
- IAEA: Radiation Safety Standards Committee.

8 Co-operation in Finland

Participation in the work of Finnish organisations and commissions

Representatives of STUK are involved in several Finnish organisations and commissions dealing with regulatory control of and research into the use of ionising and non-ionising radiation, and with standardising activities in the field of radiation, such as the Advisory Committee on Metrology, the Radiation Safety Conference Committee, the Education Committee of Medical Physicists, Eurolab-Finland, SESKO and the Finnish Advisory Committee for Clinical Audit appointed by the Ministry of Social Affairs and Health, the Screening Committee, SOTERKO and the Environmental Intolerance Network. STUK experts take part in several meetings in the field of radiation in Finland every year, giving presentations and lectures in them.

Participation in meetings of Finnish working groups

During 2014, representatives of STUK took part in meetings of the following Finnish organisations and working groups:

- The Screening Committee of the Ministry of Social Affairs and Health and the working group preparing the decree amendment working under it
- SESKO SK 61 committee (Safety of domestic electrical appliances)
- SESKO SK 106 committee (Electromagnetic fields)
- The Radiation Safety Committee of the Finnish Defence Forces (NIR matters)
- The Education Committee of Medical Physicists (radiation protection matters).

Finnish conferences arranged by STUK

STUK arranged the following conferences in 2014:

- The 31st Conference of radiotherapy physicists 5–6 June 2014 in Billnäs
- The 10th Conference on Radiation Safety in Industry 9–10 April 2014 in Jyväskylä.

Other co-operation in Finland

STUK's inspectors met with VALVIRA's inspectors and engaged in regulatory control co-operation.

STUK's X-ray, radiotherapy and nuclear medicine experts met with teachers from universities of applied sciences that train radiographers.

A STUK representative served as a member and secretary in the Finnish Advisory Committee for Clinical Audit (KLIARY) set up by the National Institute for Health and Welfare (THL) and funded by the Ministry of Social Affairs and Health (STM). KLIARY's recommendation 'Röntgentutkimusten syventävät auditoinnit' ('Advanced audits of X-ray examinations') was completed and published on the group's website on 1 January 2015.

9 Communication

During 2014, STUK received, via its website and by phone, a number of questions from members of the public, radiation users, the media, and other parties interested in radiation. Most of the questions were related to non-ionising radiation. Several interviews about current radiation topics were given to the media.

The harmful effects of UV radiation were actively communicated. STUK held its 12th annual UV press event on 15 April 2014. The event featured lecturers not only from STUK, but also from the Cancer Society of Finland, the Finnish Institute of Occupational Health and the Finnish Meteorological Institute. The topic of the event was protecting children. The bulletin published on the event gained a moderate amount of media visibility. Communication related to non-ionising radiation was refined through the improvement of the materials published on STUK's website.

Press releases and online news were written on the following topics:

- radiation exposure of nuclear power plant workers reduced
- melanoma growing more common in Finland
- radioactive materials found on the University of Turku campus did not pose any danger to employees or the environment
- radioactive concrete wells in the University of Turku construction area to be moved from the work site
- information brings more safety when shopping online
- darkness invites experimentation – laser pointers cause severely dangerous situations
- small amount of radioactive fluoride released into the air from a University of Helsinki laboratory.

In 2014, STUK published three newsletter aimed at health care professionals and two newsletters aimed at industry professionals engaged in radiation practices. The aim is to make the newsletter an integral part of communication.

10 Metrological activities

10.1 General

STUK serves as the national metrological laboratory for radiation dose quantities. STUK maintains national and other measurement 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 the European Association of National Metrology Institutes (EURAMET). STUK also participates in the international equivalence agreement (CIPM–MRA), the implementation of which is coordinated in Europe by EURAMET, and in the network of secondary standard dosimetry laboratories (SSDL), which is jointly coordinated by IAEA and WHO.

Metrological activities are the responsibility of STUK's Radiation Metrology Laboratory (the DOS Laboratory) for ionising radiation and the NIR Unit for non-ionising radiation. Metrology of ionising radiation activity quantities is the responsibility of the Department of Environmental Radiation Surveillance (VALO) at STUK.

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

Irradiation equipment and national metrological standards were maintained to the calibrations of the radiation meters for radiotherapy, radiation protection and X-ray imaging.

Meter and measurement comparisons

STUK took part in the measurement comparison for air kerma meters used in X-ray diagnostics organised by the IAEA. The measurements were conducted in early 2014. STUK's results deviated from the air kerma reference value by a maximum of 0.3%. Deviations from the reference value were significantly smaller than the measurement uncertainty.

11 Services

Calibration, testing and irradiation

The DOS Laboratory performed radiation meter calibrations and testing on request. 112 radiation meter calibration, inspection and testing certificates and 74 irradiation certificates were issued. The number of irradiated samples was 1281. Approximately 13% of the calibrations and approximately 12% of the irradiations were performed for STUK's own instruments and samples.

The NIR Unit performed a total of six radiation meter calibrations and tests and eight safety assessments and radiation measurements. The service work of the NIR Unit between 2005 and 2014 is shown in Table 14 of Appendix 1.

Other services

The PCXMC computer application designed for calculating patient doses in X-ray diagnostics was further developed, and 68 copies of it were sold.

APPENDIX 1

TABLES

Table 1. Radiation practices in the use of radiation in health care and veterinary practices at the end of 2014.

Use of radiation	Number of practices
X-ray practices	302
Veterinary X-ray practices	254
Challenging X-ray practices	90
C-arm practices	81
Small-scale X-ray practices	1095*)
X-ray practices outside X-ray departments	54
Screening with X-rays	54
Use of unsealed sources	27
Use of sealed sources	24
Radiotherapy	13

*) Conventional dental X-ray practice requires safety license starting from 1 September 2014. This change caused increase in number of small-scale X-ray practices compared to earlier years.

Table 2. Radiation sources and appliances and radionuclide laboratories in the use of radiation in health care and veterinary practices at the end of 2014.

Appliances/Sources/Laboratories	Number
X-ray diagnostic appliances (generators)*)	**1529**
fixed conventional X-ray appliances	503
portable fluoroscopy appliances	269
portable conventional X-ray appliances	190
mammography appliances, of which	168
• screening mammography	81
• tomosynthesis	3
fixed fluoroscopy appliances, of which	107
• angiography	44
• fluoroscopy	27
• cardioangiography	36
CT-appliances, of which	117
• SPECT-CT	30
• PET-CT	12
CBCT appliances (other than dental imaging)	10
O-arm appliances	4
dental X-ray appliances (other than conventional dental imaging), of which	157
• CBCT appliances	72
• panoramic scanners	54
• conventional dental X-ray appliances	31
bone mineral density measurement appliances	66
other appliances	4
Dental X-ray appliances (conventional dental X-ray practices)	**5819**
conventional dental X-ray appliances	5176
panoramic scanners	643

Radiotherapy appliances	**135**
accelerators	43
X-ray imaging appliances	40
afterloading appliances	7
manual afterloading appliances	3
X-ray therapy appliances	1
radiotherapy simulators	17
sealed sources (check sources)	24
Sealed sources	**257**
calibration and testing equipment	247
attenuation correction units	6
gamma irradiators	2
other sealed sources in health care	2
X-ray appliances in veterinary practices	**353**
conventional X-ray appliances	271
bone mineral density measurement appliances	3
fluoroscopy appliances	1
intra oral appliances	66
CT scanners, of which	10
• SPECT-CT	2
• PET-CT	1
other appliances	2
Radionuclide laboratories	**39**
B-type laboratories	24
C-type laboratories	15

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

Table 3. Radiation practices in the use of radiation in industry, research and education at the end of 2014.

Use of radiation	Number
Use of sealed sources	570
Use of X-ray appliances	531
Installation, test operations and services	174
Importing and exporting of radioactive materials or trading in them	116
Use of unsealed sources	96
Use of particle accelerators	15

Table 4. Radiation sources and appliances and radionuclide laboratories in the use of radiation in industry, research and education at the end of 2014.

Appliances/Sources/Laboratories	Number
Appliances containing radioactive materials	**5985**
level switches	1949
continuous level gauges	1086
density gauges	982
weight scales	617
basis weight meters	501
appliances or sources used for calibration, testing or education	319
moisture and density gauges	124
particle analyzers	72
fluorescense analyzers	57
radiography appliances	37
other appliances	241

X-ray appliances and accelerators	**1710**
X-ray screening appliances	681
diffraction and fluorescense analyzers	492
radiography appliances	369
basis weight meters	42
particle accelerators	23
other X-ray appliances	103
Radionuclide laboratories	**132**
A-type laboratories	6
B-type laboratories	25
C-type laboratories	98
activities outside laboratories (tracer element tests in industrial plants)	3

Table 5. Radionuclides most commonly used in sealed sources in industry, research and education at the end of 2014.

Radionuclide	Number of sources
Other than high-activity sealed sources	
Cs-137	3976
Co-60	993
Kr-85	317
Am-241 (gamma sources)	311
Am-241 (AmBe neutron sources)	111
Pm-147	105
Fe-55	101
Ni-63	72
Sr-90	69
High-activity sealed sources	
Cs-137	47
Co-60	27
Am-241 (gamma sources)	9
Ir-192	7
Sr-90	5
Am-241 (AmBe neutron sources	4

Table 6. Deliveries of sealed sources to and from Finland in 2014.

Radionuclide	Deliveries to Finland		Deliveries from Finland	
	Activity (GBq)	Number	Activity (GBq)	Number
Ir-192	58 814	19	6419	19
Kr-85	7581	63	1036	70
Pm-147	556	18	260	12
Se-75	444	2	402	2
Fe-55	164	38	131	29
Cs-137	162	75	< 1	2
Ni-63	37	98	26	71
I-125	31	*)	- **)	-
Gd-153	11	18	-	-
Cm-244	10	5	-	-
Co-57	8	47	-	-
Cs-129	6	5	-	-
Am-241 (gamma- and alpha sources)	3	15	3	426
Co-60	2	15	-	-
Sr-90	2	6	1	1
Cd-109	2	3	-	-
others total ***)	3	38	-	-
Total	**67 835**	**465**	**8 278**	**632**

*) The exact number of small sources of I-125 used in radiotherapy is not known.
**) The symbol "-" indicates no deliveries from Finland.
***) Nuclides: Am-241 (AmBe neutron sources), Po-210, Ge-68, Ba-133, Na-22 and Cf-252.

Table 7. Manufacturing of radioactive substances (unsealed sources) in Finland in 2014.

Radionuclide	Activity (GBq)
F-18	168 838
C-11	21 703
O-15	4250
Br-82	3239
others total*)	95
Total	**198 125**

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

Table 8. Number of air crew members subject to individual monitoring of radiation exposure and total dose of crew members (sum of effective doses) in 2010–2014.

Year	Number of workers		Total dose (Sv)	
	Pilots	Cabin crew	Pilots	Cabin crew
2010	1147	2281	2.56	5.75
2011	1208	2423	2.85	6.23
2012	1182	2419	2.60	5.80
2013	1184	2596	2.79	6.02
2014	1213	2441	2.74	5.93

Table 9. Number of workers subject to individual monitoring in 2010–2014.

Year	Number of workers in various sectors								
	Health care		Veterinary practices	Industry	Research and education	Manufacturing of radioactive materials	Others*)	Use of nuclear energy**)	Total***)
	Exposed to X-radiation	Exposed to other radiation sources							
2010	4467	989	491	1192	817	21	73	4151	12 062
2011	4320	1050	550	1209	742	22	79	3830	11 659
2012	3989	1083	582	1286	720	22	107	3676	11 341
2013	3953	1147	636	1329	727	20	125	3715	11 540
2014	3743	1243	653	1257	686	22	143	3621	11 197

*) 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 10. Total doses (sums of $H_p(10)$ values) of workers subject to individual monitoring in 2010–2014.

Year	Total dose in various sectors (Sv)								
	Health care		Veterinary practices*)	Industry	Research and education	Manufacturing of radioactive materials	Others**)	Use of nuclear energy***)	Total
	Exposed to X-radiation*)	Exposed to other radiation sources							
2010	1.25	0.08	0.08	0.15	0.09	0.004	0	2.59	4.25
2011	1.33	0.11	0.09	0.13	0.07	0.007	0.001	1.83	3.56
2012	1.33	0.10	0.12	0.16	0.05	0.007	0.001	2.47	4.23
2013	1.24	0.09	0.12	0.14	0.04	0.005	0.002	1.25	2.90
2014	1.29	0.08	0.11	0.16	0.04	0.019	0.007	1.57	3.28

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

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

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

Table 11. Data (H_p (10) values) on certain occupational groups in 2014.

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**)	207	0.65	3.5	3.1	24.1
Interventional radiologists**)	37	0.25	8.3	6.7	28.8
Radiologists**)	328	0.20	2.5	0.6	13.6
Consultant physicians**) ***)	295	0.06	1.5	0.2	12.8
Nurses**)	1118	0.05	0.5	0.1	4.5
Radiographers (X-rays)**)	1319	0.04	0.4	0.0	3.1
Radiographers (other than X-rays)	549	0.06	0.8	0.1	3.2
Veterinary nurses and assistants**)	399	0.07	0.8	0.2	4.1
Veterinary surgeons**)	246	0.04	1.6	0.2	9.2
Industrial material inspection technicians****)	488	0.10	0.3	0.2	4.0
Industrial tracer testing technicians	24	0.04	2.3	1.8	6.3
Nuclear power plant workers					
• mechanical duties and machine maintenance	701	0.50	1.4	0.7	7.1
• cleaning	218	0.19	1.7	0.9	7.7
• material inspection	224	0.17	1.1	0.8	9.1
• insulation work	75	0.13	3.3	1.7	9.2
• electrical and automation work	641	0.11	0.6	0.2	6.0
• radiation protection	82	0.10	1.7	1.2	6.2

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

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

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

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

Table 12. The principal radioactive waste in the national storage facility for low-level waste (31 December 2014).

Radionuclide	Actiivity (GBq) or mass
H-3	40 301
Cs-137	2950
Am-241	2752
Kr-85	1828
Pu-238	1536
Ra-226	236
Sr-90	224
Cm-244	154
Co-60	118
U-238 *)	1470 kg
*) Depleted uranium	

Table 13. The work of the NIR Unit in regulatory control of the use of non-ionizing radiation in 2005–2014.

Year	Regularoty inspections	Decisions	Statements	Co-operations with Finnish Customs in the import of lasers: cases (prohibited items)	Prohibitions of dangerous laser devices sold on the Internet	Total
2005	66	1	1			68
2006	48	1	7			56
2007	64	3	3			70
2008	67	5	6			78
2009	47	2	9	46 (39)	15	119
2010	55	3	9	96 (79)	31	194
2011	56	6	3	44 (27)	42	151
2012	53	0	15	21 (7)	43	132
2013	63	3	11	49 (17)	42	168
2014	53	2	23	34 (12)	41	153

Table 14. The service work of the NIR Unit in 2005–2014.

Year	Calibrations and tests	Safety assessments and radiation measurements	Total
2005	25	31	56
2006	17	7	24
2007	33	17	50
2008	46	24	70
2009	31	12	43
2010	36	13	49
2011	4	10	14
2012	8	16	24
2013	5	5	10
2014	6	8	14

Table 15. Inspections of sunbed facilities in 2005–2014. In addition to STUK's own inspections in 2012–2014, also health inspectors of municipalities inspected the sunbed facilities in 2012–2014 and submitted reports of their findings concerning radiation safety to STUK for decision-making. In brackets there is the number of STUK's decisions.

Year	Number of inspections
2005	36
2006	25
2007	31
2008	26
2009	19
2010	16
2011	7
2012	6 (16)
2013	3 (40)
2014	1 (20)

Table 16. SAR tests of mobile phones and other wireless devices in 2005–2014.

Year	Number of tests
2005	15
2006	15
2007	15
2008	10
2009	15
2010	10
2011	5
2012	15
2013	11
2014	10

APPENDIX 2

PUBLICATIONS IN 2014

The following publications completed in 2014:

International publications

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APPENDIX 3

ST GUIDES PUBLISHED BY STUK. SITUATION AS OF 30 APRIL 2015.

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ST 1.1 Safety in radiation practices, 23 May 2013
ST 1.3 Warning signs for radiation sources, 9 December 2013 (in Finnish)
ST 1.4 Radiation user's organization, 2 November 2011
ST 1.5 Exemption of radiation use from safety licensing, 12 September 2013
ST 1.6 Operational radiation safety, 10 December 2009
ST 1.7 Radiation protection training in health care, 10 December 2012
ST 1.8 Qualifications and radiation protection training of persons working in a radiation user's organization, 17 February 2012
ST 1.9 Radiation practices and radiation measurements, 17 March 2008
ST 1.10 Design of rooms for radiation sources, 14 July 2011
ST 1.11 Security arrangements of radiation sources, 9 December 2013

Radiation therapy

ST 2.1 Safety in radiotherapy, 18 April 2011

Diagnostic radiology

ST 3.1 Dental X-ray examinations in health care, 13 June 2014
ST 3.3 X-ray examinations in health care, 8 December 2014
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Industry, research, education and commerce

ST 5.1 Radiation safety of sealed sources and devices containing them, 7 November 2007
ST 5.2 Use of control and analytical X-ray apparatus, 26 September 2008
ST 5.3 Use of ionising radiation in the teaching of physics and chemistry, 4 May 2007
ST 5.4 Trade in radiation sources, 19 December 2008.
ST 5.6 Radiation safety in industrial radiography, 9 March 2012
ST 5.7 Shipments of radioactive waste and spent fuel, 6 June 2011
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 waste and emissions from the use of unsealed sources, 3 November 2014
ST 6.3 Radiation safety in nuclear medicine, 14 January 2013

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ST 7.1 Monitoring of radiation exposure, 14 August 2014
ST 7.2 Application of maximum values for radiation exposure and principles for the calculation of radiation doses, 8 August 2014
ST 7.3 Calculation of the dose caused by internal radiation, 13 June 2014
ST 7.4 The dose register and data reporting, 8 December 2014
ST 7.5 Medical surveillance of occupationally exposed workers, 13 June 2014

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

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ST 9.1 Radiation safety requirements and regulatory control of tanning appliances, 1 July 2013 (in Finnish)
ST 9.2 Radiation safety of pulsed radars, 2 September 2003 (in Finnish)
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Natural radiation

ST 12.1 Radiation safety in practices causing exposure to natural radiation, 2 February 2011
ST 12.2 The radioactivity of building materials and ash, 17 December 2010
ST 12.3 Radioactivity of household water, 9 August 1993
ST 12.4 Radiation safety in aviation, 1 November 2013

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