STUK-B 178 / SEPTEMBER 2014

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# Radiation practices

## Annual report 2013

Riikka Pastila (ed.)

Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

STUK

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## Annual report 2013

Riikka Pastila (ed.)

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**STRÅLSÄKERHETSCENTRALEN**
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# Abstract

1994 safety licences for the use of radiation were current at the end of 2013. 1632 responsible parties (parties running a radiation practice) were engaged in notifiable licence-exempt dental X-ray activities. 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 494 inspections of licensed practices in 2013. 718 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.

Regulatory control of natural radiation focused on radon at workplaces and exposure of aircrews to cosmic radiation. 190 workplaces, including a total of 390 work areas, were subject to radon monitoring in 2013. A total of 3780 cockpit and cabin crew members were monitored for exposure to cosmic radiation.

A total of nearly 11 600 workers engaged in radiation work were subject to individual monitoring in 2013, and about 145 000 dose entries were made in the Dose Register maintained by STUK.

In 2013, regulatory control of the use of non-ionizing radiation (NIR) focused particularly on lasers, sunbeds, radio appliances and cosmetic applications producing non-ionizing radiation. A total of 57 cases of sales or importation of dangerous laser devices were found in regulatory control. The number of show laser on-site inspections was nine. Three sunbed facilities were inspected. In addition, the municipal health protection authorities submitted the details of the inspections of 40 sunbed facilities to STUK for evaluation and decision. In the market control of wireless communication devices, 11 device types were tested, of which nine were mobile phones and two wireless modems. The regulatory control of cosmetic NIR applications intervened in the practices of cosmetic and tattoo removal service providers ten times.

In metrological activities, the demand for irradiation and calibration services increased notably compared to previous years. 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.

There were 123 abnormal incidents related to radiation use in 2013. Thirty-four of the cases dealt with the use of radiation in industry, research and education, 87 with the use of radiation in health care and veterinary medicine, and two with non-ionizing radiation. One of the incidents had severe consequences, as an employee of a company producing radiopharmaceuticals was exposed to iodine-131. The incident was rated as a level 2 incident with significant safety impact within the INES classification scale.

# Contents

# Management 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 ionizing and non-ionizing radiation, conducts research in support of regulation into the medical use of radiation, and maintains metrological standards for ionizing radiation. Regulatory control involves safety licensing, approval and registration procedures, inspections of places where radiation is used, and monitoring of worker radiation doses.

The decision was made to rename the department from the beginning of 2013 so that the new name better describes the regulatory entity; the English translation was kept the same as before. At the same time, the Non-Ionizing Radiation (NIR) Surveillance Unit became part of the department.

The general state of safety in the radiation practice is 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.

STUK participated actively in the discussions concerning the EU directive on the protection against the dangers arising from exposure to ionizing radiation in the European Council's Atomic Questions Group. The directive was approved by the Council in December 2013, and it was enacted at the beginning of 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 implementation of the directive will lead to amendments to the Rescue Act and the Nuclear Energy Act, among others. The Ministry of Social Affairs and Health is responsible for monitoring compliance with the Radiation Act and it steers the amendment of the Act. The updating of the Act commenced in 2013, 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 7800 workers involved in the use of ionizing radiation were subject to individual monitoring in 2013. This figure excludes nuclear power plant workers. The number of people subject to dose monitoring has increased in industries and in the field of veterinary practices in recent years. In no case did the effective dose of a worker in 2013 exceed the annual dose limit or the five-year dose limit for workers. In one individual case, the equivalent dose to a worker's hands exceeded the annual limit for workers.

Work to revise the individual dose monitoring registers continued during the year under review. The workload of STUK's experts has been higher than anticipated due to errors and deficiencies that arose in testing. The development of the register continued during the year under review and the new Dose Register was completed by the end of 2013.

STUK received more notifications on abnormal incidents compared to previous years. People have become more familiar with the requirements, and a safety culture that stresses open reporting of incidents has

gained popularity. One of the abnormal incidents related to industrial use was classified as a level 2 incident within the INES scale, meaning that its impacts on safety were significant. In the incident, the skin of a worker's hand was exposed to a local dose of 25–30 Sv, which is around fifty times the permitted annual dose of skin exposure. STUK filed one request for investigation of a missing radiation source to the police. The reason for filing the request was the neglect involved with the case.

The regulatory control of radiotherapy appliances by STUK is up-to-date and the control measures are constantly being developed. In 2013, the new control measures helped prevent the entry into service of a radiation beam that produced an erroneous treatment dose, which also prevented the cumulative effects on future patients. The mistake could not have been detected with the old control measures.

Computed tomography (CT) scans have become increasingly common in nuclear medicine hybride imaging. The use of CT scans in nuclear medicine could double medical exposure during nuclear medicine examinations, unless appropriate justification assessment and optimization are carried out. The instructions were developed by preparing a guide for the use of CT in nuclear medicine with external experts.

STUK continued to monitor the radioactivity that had spread to the environment after a water system damage, as well as the water system management at the Talvivaara mine in 2013. The environmental damage highlighted the importance of co-operation between authorities. To enhance co-operation, the Ministry of the Environment set up a group of authorities to discuss environmental safety. The group assessed the tasks, measures and means of co-operation to prevent environmental damage. STUK was an active participant in the group. As a result of the environmental damage, the mine was made subject to stress tests, the purpose of which was to analyse the mine's response to exceptional situations. STUK was involved in planning the tests and analysing the results. The stress tests revealed that the most significant challenges concerning stress tolerance at the mine were related to the overall water management.

The discussion was active around the suspected health effects of mobile phones and other sources of electromagnetic radiation. STUK replied to hundreds of inquiries concerning the topic from citizens, sent by telephone and email. The Nordic radiation protection authorities released a joint statement in 2013, concluding that there is no scientific evidence for adverse health effects, but that it is important to continue to monitor the research results due to current uncertainties.

The European Metrology Research Programme developed measurement methods for small and complex radiation fields in radiotherapy, along with observation and identification methods of radioactive materials in the treatment of recycled metal.

The operation of STUK's national metrological laboratory was found to meet the requirements set for it. The operations were assessed by the Swedish radiation protection authority SSM. To ensure high quality, international measurement comparisons are regularly conducted at the laboratory. In 2013, the results of the comparisons were excellent.

# 1 General

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

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

Regulatory control of safety in radiation use and in other practices causing exposure to radiation in Finland is the responsibility of the Department of Radiation Practices Regulation (STO) 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.

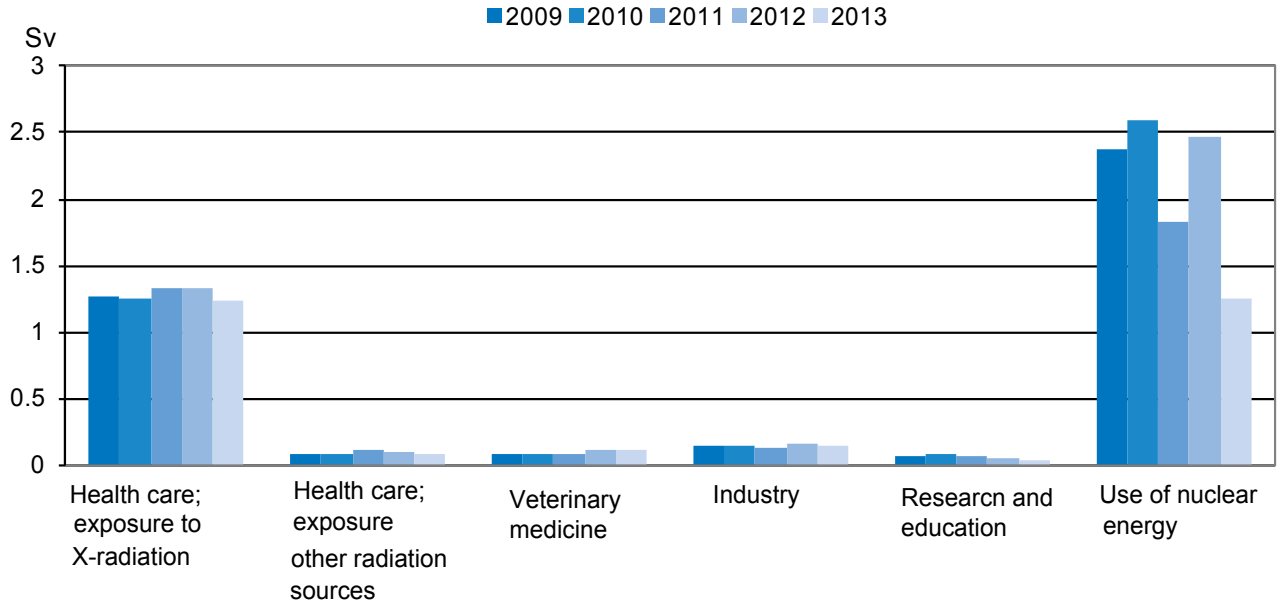


**Figure 1.** Combined doses ($H_p(10)$) of workers subject to individual monitoring by occupational category, 2009–2013. $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. One exception to this is the use of X-rays in health care and veterinary practices, in 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).

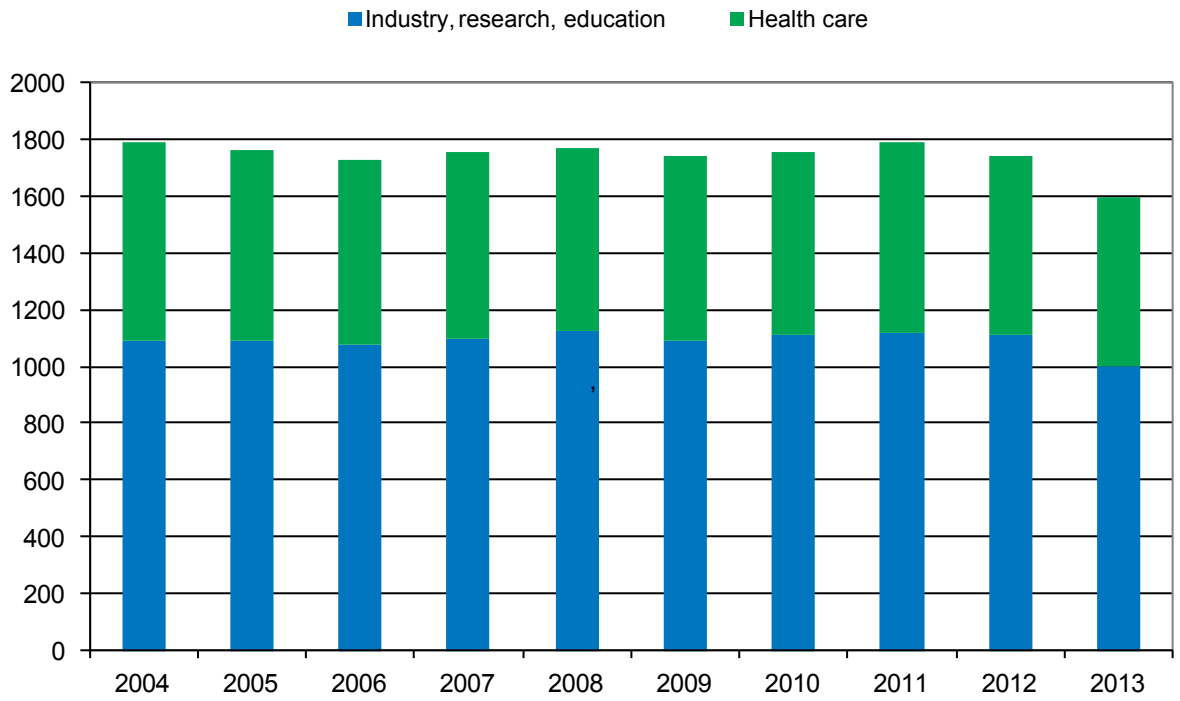


**Figure 2.** Current safety licences, 2004–2013.

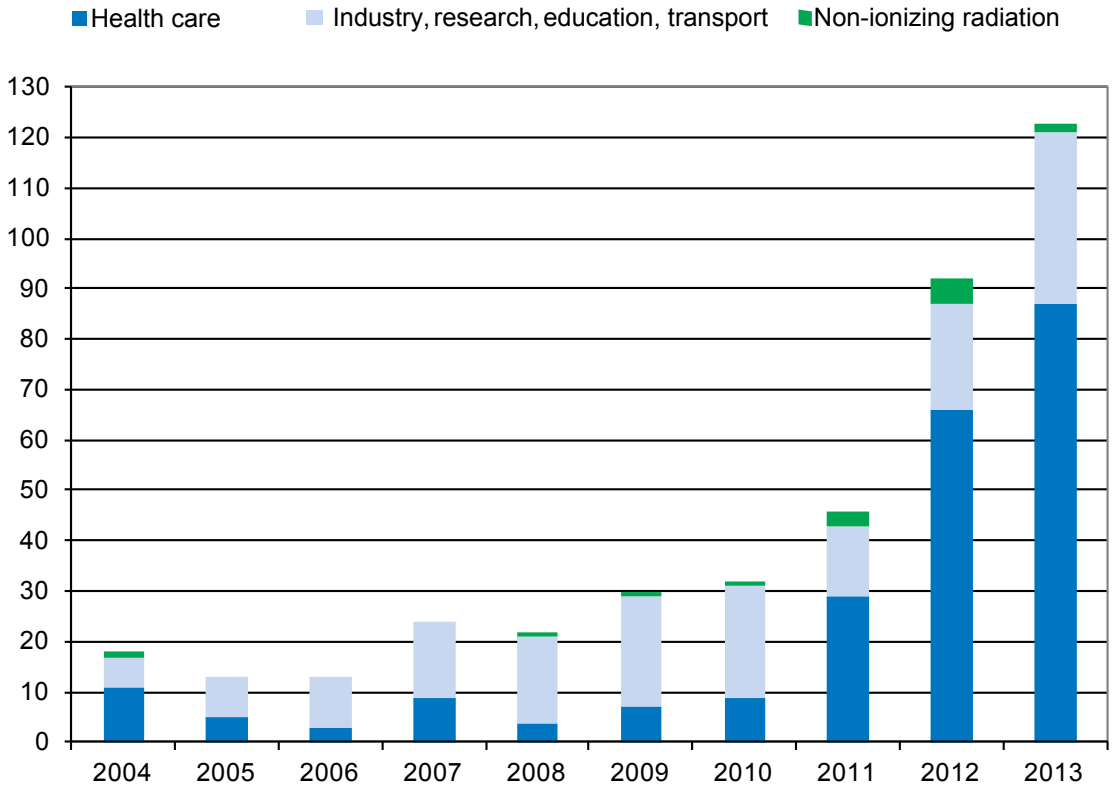


**Figure 3.** Abnormal incidents, 2004–2013.

# 2 Regulatory control of the use of ionizing radiation

## 2.1 Use of radiation in health care and veterinary practices

### Safety licences

At the end of 2013, there were 672 current safety licences for the use of radiation in health care (see also Figure 2), of which 218 concerned veterinary practices. A total of 443 licensing decisions (new licences or amendments to previous licenses) were issued during the year. The numerical distribution of radiation practices referred to in these licences is shown in Table 1 of Appendix 1. There was a seven per cent growth in the total number of safety licences in health care compared to the previous year.

The average time taken to process safety licence applications for X-ray practices in health care was 16.5 days. Roughly 9% 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. Furthermore, several applications were 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 2013.

In the last ten years, the greatest change has concerned the use of computed tomography (CT) appliances in nuclear medicine and radiotherapy. The amount of regular CT appliances decreased from 73 to 66, as seven appliances were changed to cone beam computed tomography (CBCT) appliances, but the total number of CT appliances increased, currently being 118. In 2013, 41% of the CT appliances were SPECT or PET-CT appliances or CT simulators used in radiotherapy, whereas in 2003 there were no nuclear medicine hybride imaging equipments and only three radiotherapy CT simulators (Figure 4).

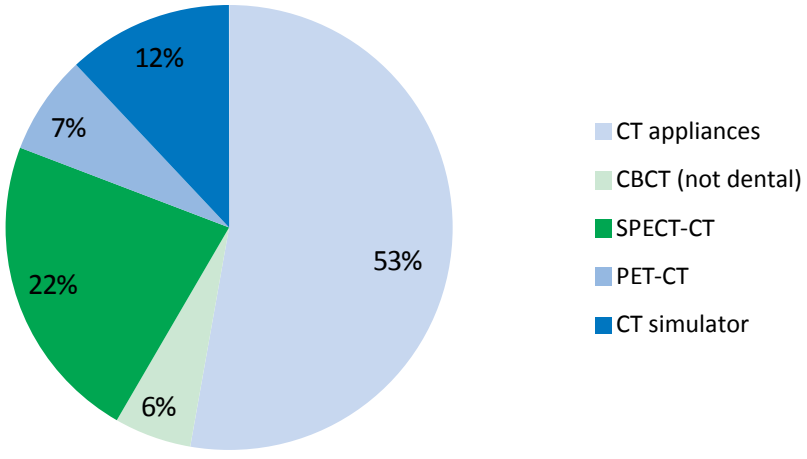


**Figure 4.** There were 118 CT appliances in use in 2013 including conventional CT appliances, nuclear medicine hybride imaging appliances and radiotherapy CT simulators.

## X-ray practices

A balance has been reached in the regulatory control of X-ray practices in health care, after a retirement and training cycle of inspectors that has taken place in recent years. The number of deficiencies found in the structural radiation protection of X-ray rooms during initial inspections has decreased notably. Municipal mergers and the combining of health care activities have caused a higher than normal amount of handling of licence amendments and registration changes for dental X-ray work. The survey that was conducted in 2012 on the radiation user organizations and staff competence was one of the elements that supported the updates to the organizations of radiation users. Measurement methods were developed for the novel types of CBCT appliances used for scanning arms and legs, in order to harmonize the regulatory control of the devices.

The number of radiological examinations and interventions was recorded in 2012 and the report on the examination numbers, including magnetic imaging, was completed in early summer 2013. The total number of X-ray examinations is on the decrease, which is mainly due to the strong decline in the amount of conventional X-ray examinations. The increase in the number of CT examinations seems to be slowing down. The number of magnetic resonance imaging examinations continues to grow rapidly. The radiation risk assessment of the most common examinations and interventions and those with the greatest exposure potential was postponed to 2014.

New reference levels were set for patient radiation exposure in CT examinations of adults. The reference levels have been divided into generic reference levels concerning a specific imaging area, and other levels based on imaging indications and specific examination types.

Preparations were made to renew the acceptability requirements for X-ray equipment used in health care in 2013. A draft of the new acceptability requirements were submitted for external reviews at the start of 2014, and the decision came into effect on 1 June 2014.

In 2013, preparations were made for STUK's decision to change conventional dental X-ray practices exempt from a safety licence to practices requiring a safety licence. The responsible parties were heard concerning the change, and the preparations continued with an external statement round in early 2014.

A guide in STUK's series "Advice from STUK" 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 to examinations, and its writing process will continue in 2014.

A guide in STUK's series "Advice from STUK" on the quality control of mammography appliances was prepared, containing instructions on quality assurance tests and appropriate testing methods, in accordance with the Guide ST 3.8 on Radiation safety in mammography examinations. The guide was published in May 2014.

The X-ray device suppliers reported the X-ray devices installed or reinstalled in health care practices in 2012. The survey revealed one X-ray device that had not been issued a safety licence before the operations were started. In addition, 31 dental X-ray appliances that had not been reported to STUK were found in the survey.

Veterinary X-ray imaging has increased in recent years. At the beginning of the 2000s, there were 200 veterinary X-ray devices in Finland, whereas the current number is 280. The majority of veterinary imaging is carried out with digital imaging equipment. A survey was conducted among veterinary X-ray practices, analysing the amount of veterinary X-ray examinations, the maintenance of the X-ray appliances and quality control. In addition, the survey helped to identify the persons conducting veterinary X-ray imaging and to reveal the status of their individual monitoring. Based on the survey, there is room for improvement in quality assurance practices.

A student at Metropolia University of Applied Sciences wrote an academic thesis on non-medical X-ray examinations causing exposure to radiation conducted in Finland in 2012, in co-operation with the Radiation and Nuclear Safety Authority. The thesis is the first survey on the subject in Finland. Its aim is to analyse the state of non-medical X-ray examinations, and to produce information that can be used for regulatory control and guiding the examinations. The survey revealed that hundreds of people undergo non-medical X-ray examinations in Finland each year. According to the recently competed thesis, the non-medical

examinations causing exposure to radiation mainly comprise tuberculosis screenings and bone density scans. The thesis concluded that all the non-medical examinations carried out by the Finnish authorities are lawful and justified. However, there are deficiencies and room for improvement in the statistics and monitoring of the examinations. The thesis serves as a starting point for STUK, allowing us to develop the monitoring and control of non-medical examinations that exploit radiation.

The number of abnormal incidents reported continued to grow – during 2013, STUK received 60 reports related to X-ray practices in health care. The aim of updating of the Guide ST 3.3 "X-ray examinations in health care" was to further specify the abnormal incident reporting instructions. In addition, an electric form was added on the STUK webpage, allowing practitioners to submit the abnormal incident report.

A conference of medical X-ray technology experts was organized in September. The themes of the conference included the maintenance of X-ray devices, radiation measurements, CBCT imaging and CT imaging. In addition, STUK experts participated in several training events as lecturers and disseminated information on topical themes in professional magazines. The first newsletter aimed at health care professionals engaged in radiation practices was sent out in 2013. The aim is to make the newsletter an integral communication channel.

## Nuclear medicine

In 2013, STUK conducted a survey on nuclear medicine examinations and radionuclide therapy in Finland during 2012. A questionnaire was sent to all hospitals that carried out nuclear medicine examinations and/or therapy in 2012. The results of the survey were published in the report STUK-B 169.

The total number of nuclear medicine examinations conducted in 2012 was 40 907, 1674 of which were examinations of children and 868 of which were scientific examinations. The number of nuclear medicine treatments was 1854. The number of nuclear medicine examinations decreased by 5% and the number of nuclear medicine treatments increased by 6% compared to 2009. The number of nuclear medicine examinations per 1000 citizens was 7.5 and the number of nuclear medicine treatments was 0.03. PET examinations and using CT in nuclear medicine examinations are on the increase within nuclear imaging. The number of PET examinations increased by 47% and the use of CT 48% compared to 2009. Figure 5 shows the numbers of nuclear medicine examinations from 1975 to 2012. Figure 6 shows the numbers of PET examinations from 2003 to 2012.

In 2012, the collective effective dose due to nuclear medicine examinations was 183.0 manSv, of which 150.3 manSv was caused by the use of radiopharmaceuticals and 32.7 manSv by CT. The average per capita effective dose was 0.034 mSv, of which 0.028 mSv were due to radiopharmaceuticals and 0.006 mSv to CT. The average effective dose due to use of radiopharmaceuticals was 3.8 mSv per each nuclear medicine examination. CT scanning used in SPECT-CT and PET-CT examinations increased the dose by an average of 3.8 mSv. Doses due to nuclear medicine examinations are calculated on the basis of examinations on adults.

There was a total of 58 devices used for nuclear imaging in 2012, 12 of which were PET, PET-CT or PET-MRI cameras and 46 were SPECT, SPECT-CT or gamma cameras. The development of the quantities and age divisions of SPECT and gamma cameras and SPECT-CT devices between 2000 and 2012 is shown in Figure 7. There were 67 activity meters at the nuclear units, and their average age was 11 years.

A total of 10 436 bone mineral density measurements were carried out in nine nuclear medicine units in 2012. Six nuclear medicine units reported groups engaged in bone mineral density measurements. In four of the units, examinations were carried out by a radiographer or another health care professional, in one unit they were carried out by only radiographers and in one unit, the examinations were performed by other health care professionals.

Average activities of radiopharmaceuticals given to patients in nuclear medicine examinations reported by hospitals are used for determining the reference levels of nuclear medicine examinations.

The draft of the nuclear medicine CT guide was completed together with hospital experts. The draft attracted positive feedback at the Radiation Safety and Quality in Nuclear Medicine conference in autumn 2013. The guide emphasises CT optimisation that is based on image quality, The guide will be completed in 2014.

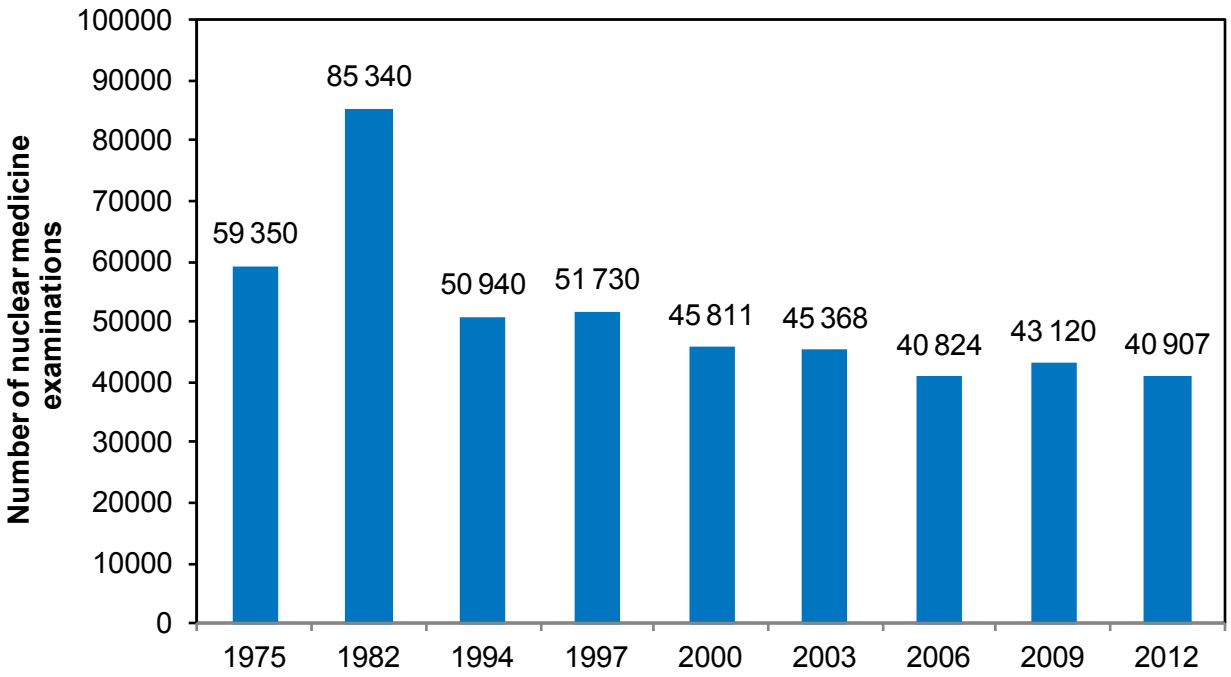


**Figure 5.** Number of nuclear medicine examinations in 1975, 1982, 1994, 1997, 2000, 2003, 2006, 2009 and 2012.

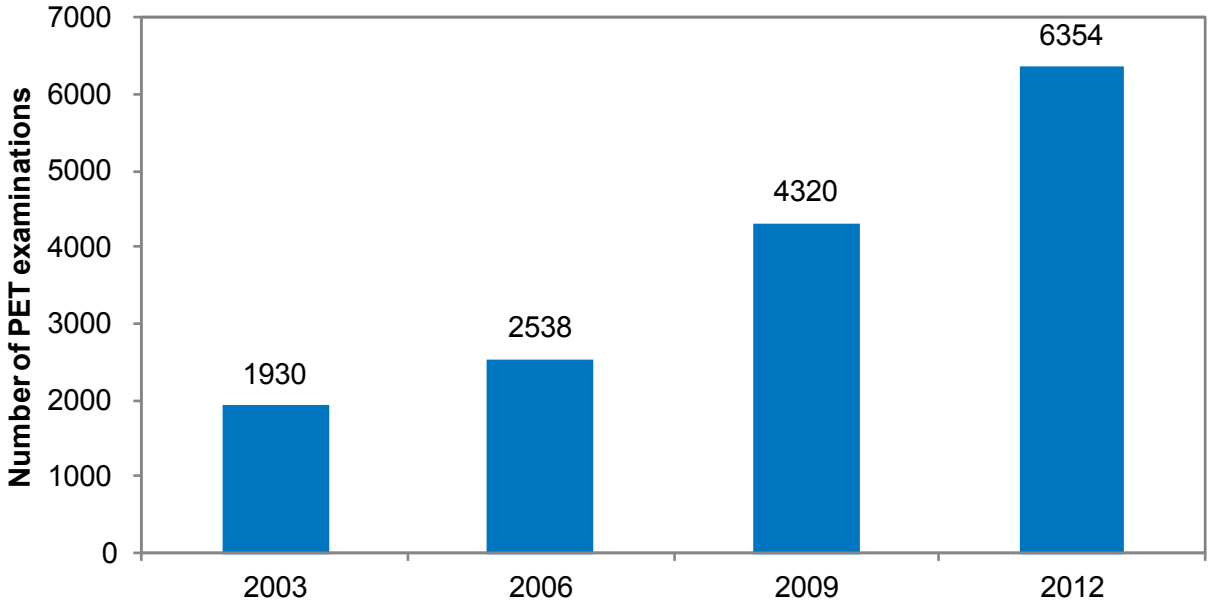


**Figure 6.** Number of PET examinations in 2003, 2006, 2009 and 2012.

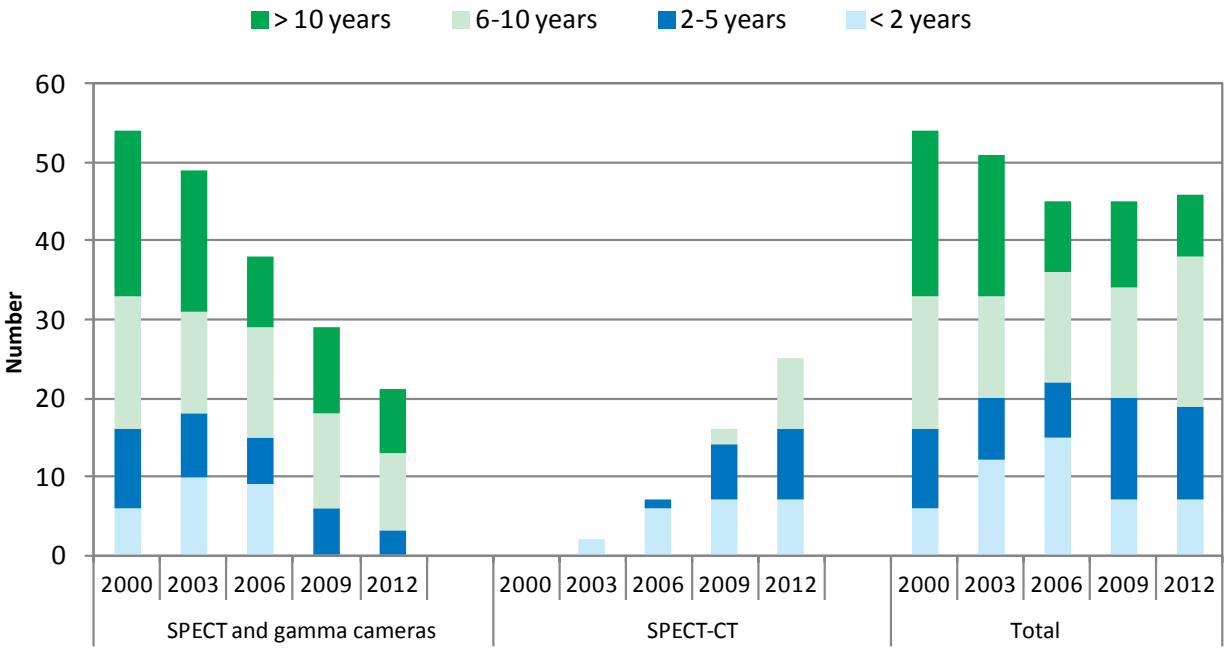


**Figure 7.** The development of the quantities and age divisions of SPECT and gamma cameras and SPECT-CT devices in 2000, 2003, 2006, 2009 and 2012.

### Radiotherapy

The comparison measurements between STUK and hospitals revealed the treatment dose accuracy to be on a good level: the average deviation in photon beams was 0.1% (average divergence 0.5%) and in electron beams 0.1% (average divergence 0.7%). No excessively large doses that would risk treatment safety were found in the comparative measurements.

For the first time, the EMRP phantom developed by STUK was systematically used in the regulatory control of radiotherapy. The phantom allows the doses produced by novel treatment techniques to be controlled by comparing them with the planned doses via the dose calculation system. Doses that clearly exceeded the planned amount by 6–10% were discovered in the regulatory control, in the initial inspection of two so-called flattening filter free fields. The hospital was ordered to renew the dose plan configuration of these radiation beams. A dose comparison of this kind would not have been possible with the old control measures. The method has received international attention and it has been introduced to the Nordic authorities and our European metrology partners.

The decision to prepare the method of abnormal incident prevention and risk assessment in radiotherapy required by the new basic safety standard on radiation protection (EU BSS) as a national co-operation was made at the conference of radiotherapy physicists in summer 2013. The working group will start its operations in 2014, after the completion of the European guide (ACCIRAD). STUK coordinates the preparation of both the European and the Finnish guide.

## 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 substances, and the transport of radioactive materials.

### Safety licences

There were 1104 current safety licences for the use of radiation in industry, research and education at the end of 2013 (see also Figure 2). 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 8 shows the amount of appliances containing radioactive substances used in industry, research and education for the last ten years. The amount has remained largely the same for a long time.

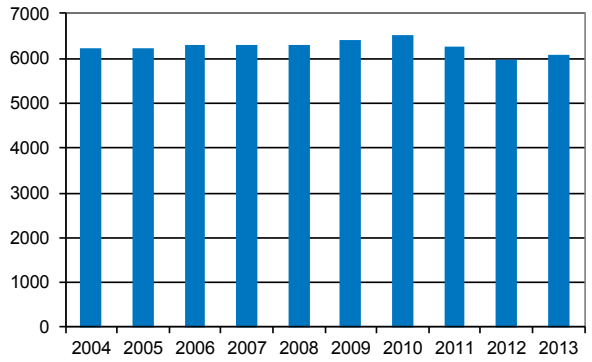


**Figure 8.** The number of appliances containing radioactive substances in 2004–2013.

Figure 9 shows the number of X-ray appliances in the last ten years. The number has almost doubled in ten years. Devices containing radioactive substance have, to some extent, been replaced by X-ray devices, in addition to which there are new scanning and analysis device applications.

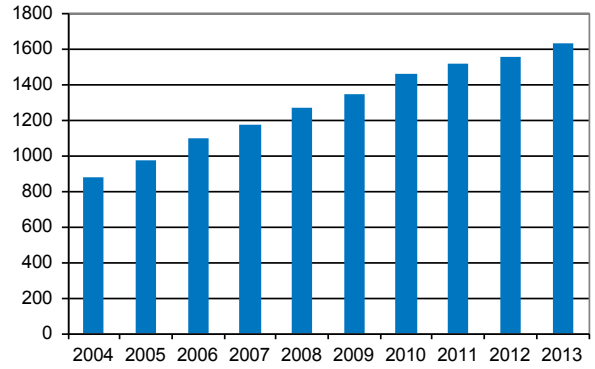


**Figure 9.** Number of X-ray appliances between 2004 and 2013.

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 2013.

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

## Inspections

Inspections were targeted, in accordance with the annual plan, to holders of safety licences. The aim has been to inspect the functions of new safety licences within a year from the granting of the licence. After the inspections, an electronic feedback questionnaire was sent out, which was used to gather the opinions of the radiation safety officers responsible for the safe use of radiation. In the opinion of many of the respondents, inspections helped to improve their operations, and it was felt that the repair orders were justified. However, the respondents felt they would have benefitted from having more information on the scope and content of the inspections beforehand.

## X-ray appliance survey

STUK requested an annual notification from all known vendors of X-ray appliances (48 vendors) concerning appliances sold and their custodians. These notifications disclosed eight responsible parties who had failed to apply for a licence on taking one or more X-ray appliances into use. It was also discovered that 12 licensees had acquired one or more new X-ray appliances without notifying this to STUK. STUK issued the required orders to rectify the observed shortcomings and supervised the appropriate licensing of all appliances.

## Regulatory control of transport

STUK participates in the regulatory control of the transport of radioactive materials. As part of the regulatory control, STUK submitted a survey to safety licence holders concerning the number of road transports of radioactive material in 2013.

The aim of the survey was to update the estimate of the number of packages containing radioactive material shipped in Finland. The Ministry of Transport and Communications conducts a survey on the transportation amounts of other dangerous goods; the latest survey is from 2013.

The survey was submitted to 291 safety licence holders, 248 of whom completed the survey. 120 of the respondents indicated that they ship packages containing radioactive material. Based on the survey, around 23 000 packages containing radioactive material are shipped in Finland each

year. Some of the transports involve shipping the same package several times. 10 900 of the packages are basic packages and 11 400 are type A packages. The number of LSA and SCO substances and type B packages shipped each year is slightly below 100. Most of the transports are related to health care.

The number of shipping companies, grouped by their roles, is shown in Table 1. A small share of the respondents' roles were corrected at STUK on the basis of the safety licence details.

**Table 1.** Role of the shipping companies in radiation use.

| Role of the responsible party | Number |
|---|---|
| Sale of radiation sources | 29 |
| Industry | 10 |
| Health care | 23 |
| Research | 19 |
| Responsible party shipping the radiation sources specified in its safety licence | 36 |
| Other | 3 |
| Total number of shipping companies | 120 |

Table 2 displays the responsible parties involved in shipping by package types. Some companies reported several package classes.

**Table 2.** Shipping responsible parties by package type.

| Item/package type | Number of shipping companies |
|---|---|
| Companies shipping basic packages | 53 |
| Companies shipping LSA/SCO substances*) | 5 |
| Companies shipping type A packages | 62 |
| Companies shipping type B packages | 4 |

*) LSA and SCO substances have been grouped together because of their small quantities. Furthermore, they are typically transported in IP packages.

The parties involved in the transportation of radioactive material must name one or more safety advisors, who perform their tasks under the surveillance of the responsible party. The nominated safety advisor is not needed, for example, if the transportation of dangerous goods takes place irregularly within the national borders and the operations do not cause more than minor risks to people, the environment or property. In the transportation of radioactive materials, minor risk refers to transports falling below the exemption value.

The safety advisor should be used at least by those companies that regularly ship packages of at least type A. Sixty-two of the respondents reported shipping type A packages. Twenty-eight of these reported using a safety advisor.

The respondents were asked to specify the number of packages by item and package type in the survey. STUK's estimate on the number of packages shipped during the year, based on the survey answers, is shown in Table 3. The numbers have been rounded to the closest hundred.

**Table 3.** The numbers of shipped packages by UN number.

| Substance classes | Estimate of annual numbers |
|---|---|
| Basic packages | 10 900 |
| LSA and SCO substances | 100 |
| Type A packages | 11 400 |
| Type B packages | 150*) |
| Total | 22 600**) |

*) Rounded up from 130.
**) Rounded from 22 550.

Based on the survey, the company that ships the most basic packages is an importer of smoke detectors. Not all smoke detector importers completed the survey. Some 142 180 smoke detectors were imported to Finland in 2011, which means the actual number of basic packages is larger.

In addition, the survey contained questions on the average transport distance and transport index (TI). Based on this data, it is possible to make a rough estimate on the radiation doses caused by the transport, because TI value correlates with external dose rate and transport distance with exposure time. A conservative estimate drawn from the survey answers is that the collective dose resulting from the transport is, at most, tens of millimanSv. The dose per package would be around 1–2 micromanSv. It was not possible to estimate the doses to individuals engaged in the shipments.

## 2.3 Inspections of licensed radiation practices

A total of 322 inspections were made of the use of radiation in health care and veterinary practices. These inspections resulted in 156 repair orders or

recommendations issued to the responsible parties. A further seven appliances were also found that did not have the required safety licence for their use.

Some 172 inspections were made of the use of radiation in industry, research and education. These inspections resulted in 562 repair orders or recommendations.

The numbers of inspections by inspection type are shown in Table 6 of Appendix 1.

## 2.4 Inspections of notifiable dental X-ray practices

There were 1632 responsible parties engaged in licence-exempt dental X-ray practices. Patient radiation exposure due to dental X-ray imaging was measured, in 920 appliances, with testing equipment sent by mail. The average dose was 1.4 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 5 mGy was exceeded in two imaging appliances.

Of all notifiable dental X-ray appliances, 44 were inspected. The number of repair orders issued was 35 and the number of repair recommendations was one. In addition, inspections disclosed ten dental X-ray appliances that had not been duly notified to STUK for registration. Doses exceeding the reference level were measured in three panoramic tomography appliances.

## 2.5 Importing, manufacture and exporting of radioactive materials

Details of deliveries of radioactive substances to and from Finland and of manufacturing of such materials in Finland in 2013 are shown in Tables 7–8 of Appendix 1. The figures in the tables are based on data gathered from radiation safety licensees engaged in trading, importing, manufacturing and exporting.

The 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 135 000 of these were imported with a combined activity of about 4.5 GBq. Around 300 smoke detectors with a combined activity of 5 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. The most common unsealed sources were $^{99}$Mo, $^{131}$I, $^{123}$I, $^{177}$Lu, $^{153}$Sm, $^{201}$Tl, $^{32}$P, $^{90}$Y, $^{111}$In, $^{125}$I and $^{18}$F.

## 2.6 Radiation doses to workers

A total of nearly 11 600 workers engaged in radiation work were subject to individual monitoring in 2013. Including doses falling below the recording level, about 145 000 dose records were entered in the Dose Register maintained by STUK (this figure also includes the dose records of workers exposed to natural radiation, see Chapter 3).

In no case did the effective dose of a worker in 2013 exceed the annual dose limit of 50 mSv or the five-year dose limit of 100 mSv. In one individual case, the equivalent dose to a worker's hands exceeded the annual limit of 500 mSv. The incident was rated as a level 2 incident with significant safety impacts within the INES classification scale (see Item 2.10 on abnormal incidents)

The combined doses ($H_p(10)$ values) to workers by occupational category sustained in the use of radiation were nearly 1.6 Sv and those sustained in the use of nuclear energy nearly 1.3 Sv. The total dose sustained in the use of radiation decreased by more than 6% compared to the previous year. In the use of nuclear energy, the combined dose was nearly 50% lower than during the previous year. The total dose in the use of nuclear energy varies considerably each year, depending on the duration of annual nuclear power plant servicing and the duties performed in servicing work at these facilities.

The greatest ($H_p(10)$) value in health care was 45.1 mSv, recorded in the case of an interventional radiologist. This corresponds to an effective dose of 0.8–4.5 mSv. The highest effective dose in health care from a source other than X-radiation was 3.0 mSv, recorded in the case of a research worker

using unsealed sources. The greatest $H_p(10)$ value in veterinary practice was 9.7 mSv, recorded in the case of a veterinarian performing X-ray examinations. This corresponds to an effective dose of 0.2–1.0 mSv. The highest effective dose in industry was 6.6 mSv, recorded in the case of an individual performing tracer tests. The highest effective dose in research was 4.8 mSv, sustained by a laboratory worker using unsealed sources.

The highest dose to the hands was 30 mSv, recorded in the case of an individual working in the industry field and using unsealed sources. The dose was due to an abnormal incident.

Table 9 of Appendix 1 shows the number of 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 2013 to persons subject to high levels of exposure or of numerically large worker groups.

## 2.7 Approval decisions and verification of competence

### Training organizations providing radiation protection training for radiation safety officers

In Guide ST 1.8, STUK has stipulated the minimum qualifications of the radiation safety officers who are responsible for the safe use of radiation. Training organizations that arrange training and competence exams for radiation safety officers must apply to STUK for the right to arrange such exams.

In 2013, no new approvals were given to arrange exams and organize training for radiation safety officers. A total of 23 training organizations held valid approval decisions at the end of 2013.

A list of the approved training organizations has been published on the STUK website (http://www.stuk.fi/proinfo/koulutus/sateilysuojelu/fi_FI/koulutusorganisaatiot_1/ (in Finnish only).

### Responsible medical practitioners

STUK accredits the competence of medical practitioners responsible for medical surveillance of category A workers. There were 386 STUK-accredited responsible medical practitioners in Finland at the end of 2013, of whom 28 were accredited during the year under review.

## 2.8 Radioactive waste

STUK maintains a national storage facility for low level radioactive waste. The amount of waste held in the storage facility at the end of 2013 is shown in Table 12 of Appendix 1.

## 2.9 International assessment of the regulatory control of the use of ionizing radiation

The international IRRS working group (Integrated Regulatory Review Service) evaluated STUK's regulatory activities in the autumn of 2012. The evaluation also included the assessment of the regulatory control in the use of ionizing radiation, and the representatives of the Department of the Radiation Practices Regulation (STO) participated in many of the assessment modules.

The suggestions and recommendations given in the assessment led to the following actions:

- a description of authoritative co-operation and joint regulatory control interest was drafted
- procedures for approving STUK's own use of radiation were created
- the radon dose data of workers was included in annual reporting
- requirements on patient safety and the handling of safety defiencies were added to the updated ST guide on X-ray examinations in health care
- STUK's internal procedures were complemented with specific inspection criteria for other than periodic inspections.

## 2.10 Abnormal incidents

Under section 17 of the Radiation Decree (1512/1991), STUK must be notified of any abnormal incident involving the use of radiation that is substantially detrimental to safety 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 121 abnormal incidents or observations of the use of ionising radiation were

reported to STUK in 2013. Some 87 of these notifications concerned the use of radiation in health care and 34 involved other radiation use or non-identifiable sources (see also Item 4.4 for abnormal incidents in the use of non-ionizing radiation). Figure 3 (in Item 1.1) shows abnormal incident numbers between 2003 and 2013.

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

## Abnormal incidents in health care

### Imaging of a wrong patient or an insufficient referral

The wrong patient was imaged in 23 individual incidents. 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 imaged, 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 one another. In many cases, the doctor recorded a referral for the wrong patient. The highest dose due to the imaging of the wrong patient was estimated to be 10 mSv.

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

***Example incident:***

One case involved a doctor at a health centre department referring the wrong patient for a conventional X-ray of the hip bone. The doctor noticed the mistake and cancelled the referral the day before the examination. However, the information did not reach the X-ray department on time, and they performed the imaging. The radiation dose to the patient was estimated to be 2 mSv.

### Abnormal incidents concerning radiopharmaceuticals

There were five abnormal incidents related to radiopharmaceuticals and its dosage. The wrong radiopharmaceutical was given to two patients. The highest additional dose was estimated to be 4 mSv or below. The injection of radiopharmaceutical failed in the case of three patients. The highest additional dose resulting from these incidents was 6.5 mSv.

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

26 incidents caused by an appliance or system fault were recorded. 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 imagings. Additional exposure to a patient due to a device fault was 21 mSv at its highest, in connection with a PET-CT examination.

***Example incident 1:***

A cancer patient was imaged at the nuclear medicine department once every few months. The first two imagings were aborted because of a device failure after the imaging was nearly completed, and there was an error in the PET collection on the third occasion, resulting in the need to redo the CT, as well. The older incidents were only discovered during the final imaging. The total extra dose for the patient due to the three CT examinations was 21 mSv.

***Example incident 2:***

A radiographer scanned a native series of the adrenal gland in a CT examination. When checking the images, the radiologist noticed some of the cuts were missing from the image. The imaging was redone, but some of the cuts remained invisible. Another device was used for the imaging of the contrast medium series. Half an hour later, all cuts from the first imaging became visible, which meant the second imaging had been unnecessary. The effective dose for the patient was estimated to be 8.5 mSv.

## Exposure of a worker in health care X-ray practices

There were six cases of unintentional exposure of a worker or several individuals. In most cases, the X-ray examination had been started before the nurse had time to leave the room. In addition, there were a few cases of personnel entering the

imaging room in the middle of the examination. The highest dose for a worker was 0.14 mSv, the typical dose falling clearly below the figure.

***Example incident:***
Four hospital cleaners were exposed during the cleaning of an angiography room. During the cleaning of a coronary angiography room, the castor of a sterile table had slid on the pedal, which activated the scanning. The exposed persons were 1.5–2.5 metres away from the X-ray tube. After hearing the alarm, they left the room within five seconds. The highest individual dose was estimated to fall below 10 µSv.

### Other incidents caused by human errors

Other human errors were the cause of a total of 33 incidents. The highest exposure for a patient was estimated to be 32 mSv. Three cases of abnormal incidents involved unintentional exposure of a foetus. The greatest individual exposure of a foetus was 8 mSv. In radiotherapy, the sources of an eye applicator were lost during the preparation stage, resulting in an exposure of 1 mSv to an external party.

***Example incident 1:***
A trauma CT examination was performed on the head and body of a weak patient, urgently and in a rushed situation. The examination was done, by accident, with the wrong device settings, without contrast medium, and it had to be redone with the contrast medium. The additional exposure to the patient due to the extra CT body scan was estimated to be 32 mSv.

***Example incident 2:***
In one case, a 40-year-old woman suffering from abdominal pains arrived for an abdominal CT examination with a referral from a surgeon at a hospital emergency room. In the imaging room, the patient was asked whether she could be pregnant, to which the patient replied that she uses contraceptive pills and that her period had started the day before. A contrast medium CT scan was performed on the patient's abdomen, and the images revealed there was a nearly full-term foetus in the uterus (the estimated age of the foetus was 37 weeks). The effective dose on the foetus was approximately 8 mSv.

## Abnormal incidents in industry and research

### Exposure of a worker in the industrial use of radiation

In four cases, a worker was exposed to the radiation of a radiometric measuring device in connection with maintenance work, when the shutter of the radiation source had not been appropriately closed. In all four cases, the workers were employed by an external subcontractor. The reasons for the incidents included missing instructions or failure to follow the instructions. Because of short exposure times, the extra radiation doses to workers remained below 0.1 mSv in all cases.

***Example incident:***
An incident where a worker entered a tank to collect an object they had dropped without shutting down the radiation source inside the tank is an example of bad safety culture. The manhole of the tank was labelled with warning signs and instructions to shut down the radiation source. The worker had also received safety training in reference to radiation sources. Despite the training, the worker failed to follow the instructions.

### Industrial radiography

There were two abnormal incidents related to industrial radiography, each of them involving a gamma camera ($^{192}$Ir).

***Example incident 1:***
The radiation source could not be retracted into the exposure container, because the projection sheath of the source had been bent during imaging. The source could be returned to its container after one of the radiographers straightened the projection sheath by hand. The extra dose for the worker could not be estimated, because the personal dosimeter was not submitted for evaluation immediately. It is unlikely that the dose due to the incident was over 1 mSv. The incident involved disregard of the imaging company's instructions. The imaging device was checked and no faults were found in it.

***Example incident 2:***
The radiation source did not coil up completely inside the exposure conteiner at the end of the imaging. The radiographer failed to notice the situation, because the radiation alarm signal could

not be heard over the noise. The other radiographer heard the signal, noticed the increased reading in the radiation meter and warned the worker approaching the exposure container. The source was fully coiled up inside the container The additional dose for the radiographer who approached the container was estimated to be 0.5–0.7 mSv.

### Radiation sources within recycled metal

STUK received a notification of six 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 in 2013. Exit signs containing tritium and radium, fire detectors containing radium, a $^{137}$Cs radiation source and an unidentified shielded radiation source (presumably $^{90}$Sr) were discovered in the loads. In addition, three incidents were reported to STUK of the accumulation of natural radioactive materials on the surface of metal items activating the radiation portal monitor.

In one case, a $^{241}$Am radiation source was smelted at the steel plant. No radioactive material escaped outside the factory and no workers were 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 contaminated materials will be reposited in the factory site later, with STUK's approval.

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.

***Example incident:***

A radiation source activated the radiation portal monitor of a steel plant in November 2013. Based on the measurements taken by the plant's own analysts and the STUK inspector present at the site, the source was identified as $^{137}$Cs. The load was transported back to the metal recycling company that found a partly flattened pipe section within the load, containing a sealed $^{137}$Cs source. The activity of the radiation source was estimated to be 1.5 GBq. The radiation source was placed in a lead-lined container and later transported to a radioactive waste treatment facility. The additional doses to people involved in the operation were minor (< 10 µSv). The person transporting the metal load was not exposed to an extra radiation dose.

There were no labels or protective structures in the pipe section. Its origin and function remain unclear. STUK will attempt to identify the original owner of the radiation source if the manufacturing number is shown on the sealed source contained within the pipe. The flattened pipe will be opened inside a hot cell at the VTT Technical Research Centre of Finland. According to the information from the recycling company, the radiation source may have been used by a Finnish service provider.

### Damaged radiation sources

There were two incidents in 2013 where the radiation shield of a radiometric measurement device was damaged during use. Furthermore, in one incident, the radiation source shield fell to the floor in transit and was damaged. Several long, rod-like shields were being transported at the same time, and one of them was released during lifting.

In addition, there was one incident where the lead shield of an X-ray device was found to have been moved and caused a minor increase of the dose rate outside the device.

***Example incident:***

A steel plant casting ladle was punctured, causing melted steel to spill on the shields of two radiation sources. The $^{137}$Cs radiation sources were used in the level gauges and their activities were 12.5 GBq at the time of the incident. The lead inside the shields was partly melted. Part of the melted lead had spilled from one of the shields. Steel mass had to be removed around the sources by flame-cutting, and efforts were made to close the shutters of the sources. However, the shutters were stuck, and extra shields had to be installed on the radiation sources before their transportation to the importer and, eventually, to the device manufacturer. The dose resulting from the detachment and processing of the sources that was sustained by two plant workers was about 10 µSv.

STUK performed contamination measurements at the steel plant, in the vicinity of the radiation sources. The aim of the measurements was to verify that the radiation source capsules had stayed intact.

### Disappearance of radiation source

Three disappearances of radiation sources were reported to STUK. The missing sources were a wood density measuring device ($^{241}$Am, 11 100 MBq), an elemental analyser ($^{241}$Am, 370 MBq) and a silo level gauge ($^{137}$Cs, 370 MBq). In each case, the disappearance was caused by deficiencies in the bookkeeping and inventory checks of the licensee. The disappeared radiation sources were not found, despite efforts.

***Example incident:***

While amending a safety licence, it was discovered that a density measuring device that had been in the possession of a responsible party had disappeared. The device contained an 11 100 GBq, $^{241}$Am radiation source. Investigations into the incident revealed several examples of neglect related to the disappearance. In addition to deficiencies in bookkeeping and inventories, no one had been appointed to replace the retired radiation safety officer, and no responsible persons had been nominated for the use of radiation sources. The missing device or the americium source contained within it have not yet been found. STUK filed a request for investigation by the police, suspecting a number of violations of the regulations of the Radiation Act and the Radiation Decree.

### Use of unsealed sources

Five abnormal incidents related to the use of unsealed sources were reported to STUK in 2013. The incidents concerned the exceeding of the emission limit to sewer, the contamination of a draft cupboard, the sending of contaminated pipettes to the manufacturer for calibration and two cases of worker exposure during the manufacture of radiopahrmaceuticals.

***Example incident:***

A worker of a radiopharmaceutical company was contaminated with radioactive iodine ($^{131}$I). The worker's hand came into contact with radioactive iodine through a hole in the protective glove. The contamination was discovered during regular measurements as the worker was leaving the production facilities. Based on the measurements taken at the site and the STUK facilities, the original activity of the skin contamination was estimated to be 12 MBq, and the resulting skin dose 30 Sv, with the contaminated skin area being 10 cm$^2$. The dose on skin exceeds annual the dose limit of 500 mSv. A dose of this magnitude might cause local skin damage within weeks of the exposure. However, no damage has yet been found on the worker's hand. The estimated dose to the thyroid gland was 430 mSv, which is not large enough to cause malfunction of the thyroid gland. The effective dose sustained in the thyroid gland exposure was 16.8 mSv, which falls below the annual dose limit of 20 mSv of workers engaged in radiation practices.

The incident was rated as a level 2 incident within the International Nuclear Event Scale (INES), which means its impacts on safety were significant. The incident was reported to the INES databank maintained by the IAEA. Because of the incident, a risk analysis was performed on the work procedures of the company, and extra training was provided to personnel. Protective gloves were exchanged for a thicker variety, and their material was changed. In addition, a decision was made to acquire new equipment for the manufacture of $^{131}$I capsules.

### Transportation of radioactive materials

Two abnormal incidents related to the transportation of radioactive materials were notified to STUK. In one of the incidents, a transportation package arriving in Finland was damaged at the airport during unloading. However, the radiation sources and their shields stayed intact. The representative of the importer receiving the sources repaired the damaged package.

***Example incident:***

A level gauge ($^{137}$Cs, 55 MBq) that had been withdrawn from use was ordered to be transported as freight in a coach, against the regulations set for the transport of dangerous goods (VAK regulations). The wrong transport method was caused by the mistakes of both the sender and the transportation company. Because of the low level of activity of the radiation source, the dose rate was low outside the package, and the transportation did not cause major exposure for the person handling the package or the coach passengers.

### Other abnormal incidents

A company was planning to analyse wooden raw material at a forest industry plant with an X-ray radiography device. However, the company did not possess the necessary safety licence. Contrary to the requirements, no radiation meters or instructions were in place, the workers had not been classified as workers engaged in radiation practices, and they had not been duly trained. STUK prohibited the company from starting operations until the fulfilment of the requirements and the granting of the safety licence. The safety licence was granted later, after the company had taken corrective measures and STUK had visited the facilities to verify the sufficiency of radiation protection measures.

$^{60}$Co contamination was found in the clothes of a Finnish worker during a visit to a nuclear installation abroad. The origin of the contamination was a Finnish workplace where the worker had processed active metal pieces before the visit. No protective clothing was worn during the work, and no contamination measurements were taken with a hand-and-shoe monitor after the work was completed. Because of the incident, the responsible party specified the work instructions further and began monitoring compliance with them. Furthermore, STUK inspected the facilities, especially its procedures and contamination measurements.

# 3 Regulatory control of practices causing exposure to natural radiation

## 3.1 Radon at workplaces

In 2013, STUK received 383 radon measurement notifications concerning either a radon concentration exceeding the action level of 400 Bq/m$^3$ measured in a work area, or further investigations of previously reported excessive levels. Based on measurement results, 167 reports were sent to enterprises, requiring the performance of radon repairs or an investigation of radon concentration during working hours at 116 work areas, and a measurement at another time of year in order to determine an annual average at 37 work areas.

Radon concentrations were successfully reduced at 42 workplaces during the year. STUK discontinued regulatory control at 50 work areas on the basis of further investigations (measurement during working hours or determination of annual averages). Regulatory control was terminated at a total of 134 work areas for other reasons (e.g. short working periods or discontinued use of premises). 390 work areas at 190 workplaces were subject to regulatory control by STUK during the year.

A statutory radon inspection was conducted in five subterranean mines. In one of them, the action level was found to have been exceeded, but with corrective measures the radon concentration was brought to a permissible level.

Some 38 inspections were conducted at 24 underground quarries and construction sites. The radon concentration of seven sites exceeded 400 Bq/m$^3$. Six of these sites were ordered to reduce their radon concentration, but on one of them, the concentration did not exceed the action level due to short working hours. An order for radiation exposure monitoring was issued for one site because their radon concentration could not be reduced below the action level.

Workers' radon exposure was monitored by regular radon measurements and the monitoring of working hours at four conventional workplaces and one underground construction site, in all of which the radon concentration exceeded the action level. In addition, the radon exposure information for four persons who worked in several different underground tunnels was recorded in the Dose Register. A total of 36 workers, whose doses (effective doses) were recorded in the Dose Register, were subject to radon exposure monitoring during 2013. In conventional workplaces, the highest single annual dose resulting from radon to a worker was 19.6 mSv and, in underground workplaces, 14.2 mSv.

Two new approval decisions for radon measuring equipment were issued in 2013. A list of organizations with measuring methods that have been approved in accordance with the requirements of Guide ST 1.9 appears on the STUK website (http://www.stuk.fi/proinfo/valvonta/luonnonsateily/radon_tyopaikoilla/fi_FI/radonin_mittaaminen/ (in Finnish only)). These orgaizations have given permission for their names to be published on the approval list. It is a condition of such approval that the measuring instrument is properly calibrated.

## 3.2 Other natural radiation from the ground

STUK monitors exposure caused by radioactive nuclides that occur naturally in water intended for human consumption, construction materials and other materials. Seventy-seven inspection reports on the radioactivity of construction materials were prepared during 2013. These reports imposed restrictions on the use of materials where necessary. The regulation of construction products that came into effect in July 2013 has notably increased the amount of radioactivity measurements of construction materials. 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

harmonized product standard. The harmonized product standards are drafted by the European Committee for Standardization CEN.

Inspection reports on the radioactivity of water intended for human consumption were prepared for two waterworks or foodstuffs manufacturers. In both cases, the radioactivity of the water was found to be at a permitted level after corrective measures or further investigations had been carried out.

STUK drafted two decisions concerning water management at the Talvivaara mine in 2013. STUK also participated in drafting several statements related to mining and concentration activities.

## 3.3 Cosmic radiation

The doses sustained by the employees of six airlines were entered in STUK's Dose Register in 2013. In no case did the annual dose (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 were 4.9 mSv sustained by a pilot and 5.1 mSv sustained by a cabin crew member. The average annual dose sustained by pilots in 2013 was 2.4 mSv and the average annual dose of cabin crew members was 2.3 mSv. The average doses over the period from 2009 to 2013 are shown in Figure 10.

The total number of workers in flight crews has diminished by almost 5%, and the total dose has increased by about 5% compared to the preceding year. The number of workers subject to individual monitoring of radiation exposure and their total dose are shown in Table 13 of Appendix 1.

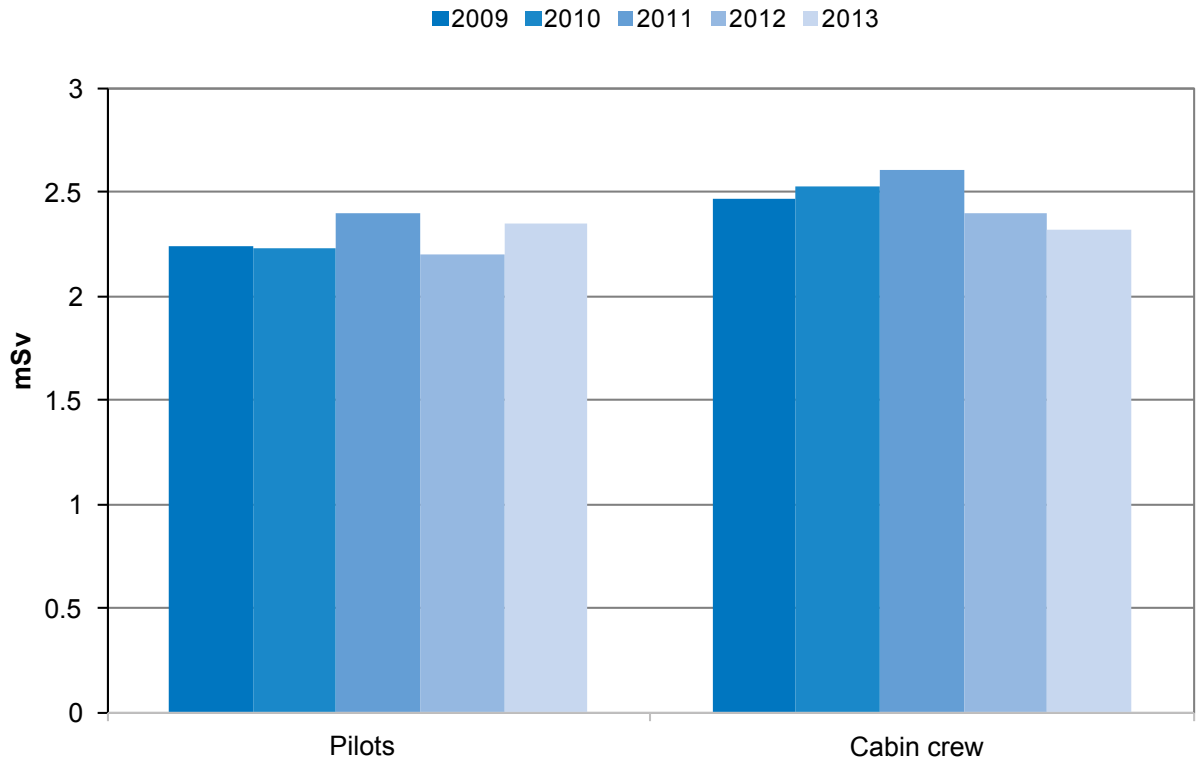


**Figure 10.** Average doses of air crews, 2009–2013.

# 4 Regulatory control of the use of non-ionizing radiation

## 4.1 General

The expression non-ionizing radiation refers to ultraviolet radiation, visible light, infrared radiation, radio frequency radiation, and low frequency and static electric and magnetic fields. Coherent light, or laser radiation, is a special type of visible light. The use of non-ionizing radiation is subject to licence only in the case of laser devices used in public performances. In other respects, the Non-Ionizing Radiation (NIR) Surveillance unit of STUK conducts market surveillance for devices and practices that expose the public to non-ionizing radiation. Market surveillance is targeted at the following practices:

- sunbed services
- consumer lasers
- wireless communication devices and high-powered radio transmitters causing public exposure
- cosmetic treatment devices and services that utilise non-ionizing radiation.

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-ionizing radiation between 2004 and 2013 is shown in Tables 14–17 of Appendix 1. The number of dangerous laser devices on the market was high, which has increased the need for regulatory control of lasers, as in the preceding years. In 2013, STUK intervened in the sales or importing of a dangerous device 57 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 statements on power line projects in particular.

In addition to the regulatory control activities, the discussion on the health effects of electromagnetic fields has been very active. This has been reflected in an increasing number of inquiries by citizens and information requests by the authorities and ministries.

## 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 July 1st 2012. The facilities are inspected by health inspectors as part of the regulatory control of the Health Protection Act. Health inspectors submit a report on their findings concerning radiation safety to STUK for evaluation and decision. In addition, STUK carries out its own inspections where necessary.

The health protection authorities submitted reports of 40 inspections (Table 16 of Appendix 1). In addition to these, STUK inspected three sunbed establishments; one of the inspections was based on a notification from a municipal health inspector, another on a skin burn notification sent to STUK and the third was found as part of STUK's own market surveillance.

Two sunbed devices inspected by STUK were withdrawn from use due to excessively powerful sunbed lamps. The maximum UV radiation values stipulated in the Decree (294/2002) of the Ministry of Social Affairs and Health were exceeded by factor 2 in both cases. The risk of skin burns was assessed high and therefore the use of the devices was prohibited under section 55 of the Radiation Act.

The most likely reason for the sunbed customer's

skin burn was the use of 100W UV fluorescent lamps in the device instead of the recommended 160W lamps. The power supply of the device was designed for 160 W lamps worked in a way which notably increased the amount of UV radiation when used with a 100W fluorescent lamp. The long irradiation time of 15 minutes for the first tanning session also contributed to the burning of the skin.

No deficiencies were found in the inspections in around one-third (29%) of all establishments (12/42). Twenty-seven establishments (64%) had erroneous instruction manuals. A total of 51 devices were inspected, and the timer start-up time was too long, exceeding 5 minutes, in 15 of them (29%).

## 4.3 Regulatory control of laser devices

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

Information requests were sent for four laser devices as part of the market surveillance. In one case, the laser equipment was shown to be compliant with the requirements by the importer, while in two cases, the devices were withdrawn from sale voluntarily. The unauthorized use of lasers in the TV show "Suorana: Kortesmäki" led to the prohibition of transfer of the device.

There were 42 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. Moreover, two enquiries were submitted concerning the online sales of laser pointers. The processing of these two cases is still in progress.

Finnish Customs solicited advice from STUK in 49 cases involving the importation of lasers from outside the European Union. In 17 of these cases, the importation of the laser devices was prevented and the devices were classified as dangerous as per the Consumer Protection Act (920/2011). The highest power was 1000 mW, while the highest permitted power of laser pointers is 1 mW.

A total of nine laser shows were inspected on site. In addition, 22 notifications were issued to STUK on the shows arranged by responsible parties using approved laser devices. In the inspections, the security arrangements and the pointing of the laser beams were found to comply with the requirements in most cases. Table 14 of Appendix 1 contains a summary of the laser inspections.

The government decree concerning laser equipment and their inspection (291/2008) was amended on 1 September 2013, allowing the police, the Border Guard and the Finnish Defence Forces to use certain high-powered lasers.

## 4.4 Regulatory control of devices producing electromagnetic fields

A total of 11 wireless terminal devices were tested as part of the market control. The tests were conducted on the 900 MHz, 1800 MHz and 1950 MHz frequencies of GSM and 3G systems, in accordance with the IEC 62209 standard. The highest measured 10-gram average SAR value was 0.9 W/kg. The maximum value stipulated by Decree 294/2002 of the Ministry of Social Affairs and Health is 2 W/kg. Mobile broadband modems were a new target for regulatory control. Two devices of this kind were tested (see Table 17 of Appendix 1).

Several preliminary investigations were carried out on the installations of wireless base stations, as requested by citizens and municipalities, for instance. Faulty installations were not found.

## 4.5 Regulatory control of cosmetic NIR applications

In 2013, the regulatory control measures of cosmetic NIR applications focused on ten responsible parties using laser and light-pulse RF devices. Four of the responsible parties were tattoo removal service providers and six were cosmetic service providers using light-pulse RF devices. The responsible parties were sent initial and then further investigation requests. In addition, the regulatory control procedures and regulations were clarified.

A new market surveillance target were devices used for curing nail enhancements with UV. STUK has acquired the devices selected for testing and the measurements were taken in early 2014.

## 4.6 Other tasks

The number of statement requests to STUK on power line projects and land use plans near power lines increased notably. STUK issued a total of nine statements. In addition, several investigations were carried out concerning power lines located near dwellings, following requests by citizens.

The Finnish Defence Forces were provided with statements on the radiation safety guide and the radiation safety of radars.

## 4.7 Abnormal incidents

In 2013, STUK received two notifications of incidents caused by non-ionizing radiation that required immediate attention.

Figure 3 (in Item 1.1) shows abnormal incident results between 2004 and 2013.

The first incident requiring immediate intervention on the use of non-ionizing radiation by STUK was the TV show "Suorana: Kortesmäki", which featured the use of a dangerous laser. An investigation request was filed with the Finnish Broadcasting Company Yleisradio and the device was subjected to a prohibition of transfer. The equipment was checked at STUK and was found non-compliant with the requirements. However, according to STUK, the incident did not damage the eyes of the audience or the performers.

Another abnormal incident featured a sunbed customer who notified STUK of skin burns. The sunbed establishment was inspected, and the lamps used in the device were found to be inappropriate. The service provider was requested to repair the device with appropriate lamps (see also item 4.2).

# 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 2013:

- ST 1.1 Safety in radiation practices
- ST 1.3. Warning signs for radiation sources
- ST 1.5 Exemption of the use of radiation from the safety licence
- ST 1.11 Security arrangements for radiation sources
- ST 3.8 Radiation safety in mammography examinations
- ST 6.3 Radiation safety in nuclear medicine
- ST 9.1 Radiation safety requirements and regulatory control of tanning appliances
- ST 12.4 Radiation safety in aviation.

## 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. The work was started at the end of October and it will be completed in early 2014.

The new directive concerning workers' exposure to electromagnetic fields, 2013/35/EU, was approved on 26 June 2013. It must be implemented in national legislation by 1 July 2017. In Finland, the implementation is steered 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 was involved in the preparation of the directive and its national implementation as an expert organization, upon 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 ionizing radiation concerns medical uses of radiation and focuses on the radiation safety of patients. There is a growing need for research owing to rapid progress in examination and treatment methodologies. Research into non-ionizing radiation focuses on the exposure determination methods needed in regulatory control and the development of regulation.

Research and development work was performed in the following projects:

## European Metrology Research Programme (EMRP)

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 2013, the characteristics of the films used for measuring the doses of electron radiation therapy were investigated and a new phantom prototype was developed within the MetrExtRT project.

A metrology project launched in 2011 continued with the aim of developing radiation measurement methods for smelting works that process recycled metal. In 2013, STUK participated in the comparison measurements within the MetroMetal project and was involved in developing gamma spectrometric activity measurement methods (summing corrections of measurements). The project seeks to improve radiation safety at smelting works processing recycled metal and to establish a uniform method of determining the radioactive contamination level of steel. The project will be completed in 2014.

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

The project seeks 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 are aimed at the education of young people and adults who are radiation users, and for lower and higher university degree curricula. The results will be used in training in the Nordic countries and Estonia.

## Determining the patient dose in mammography

The aim of the project is to investigate the relationship between the estimated doses based on standard phantoms and the average doses to real patients treated with current device types. The measurement data collected in the inspections and the patient doses reported by users were used in the research. The results helped to evaluate the uncertainty of the dose estimate that is based on the phantom and to find ways to improve the dose measurement instructions and inspection procedures, for example. The survey results will be used as training material.

## Determining the skin dose in interventional radiology and cardiology patients

The research project, which was carried out within the EURADOS framework, mapped out the skin doses to interventional radiology and cardiology patients with film measurements in co-operation

with Finnish hospitals. The results shed light on the relationship between the radiation dose reported by the X-ray device and the skin dose on the patient. The results will be used, for instance, for determining the alarm limits of skin doses.

### Personnel well-being in magnetic resonance imaging work

STUK and 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 work). The project involves investigating the exposure of workers to magnetic fields and drafting the safety guide for magnetic resonance imaging work. The project was launched in January 2012 and it will be completed in December 2014.

### 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 will be published and used as the basis of the Finnish reference level proposition drafted in 2014.

### 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, and its final report was updated based on the EC requirements. In addition, the report provides information on the reference levels of X-ray and nuclear medicine examinations reported by other European countries. The report will be published in 2014. The radiation dose to the European population is around 1.1 mSv per capita, of which 5% are from nuclear medicine examinations. The largest share of the dose from X-ray examinations, around 52%, is caused by computed tomography examinations.

### Assessing radiation risks and abnormal incidents in radiotherapy

The aim of the project, funded by the European Commission, was to prepare the recommendation for the assessment of radiation safety risks and the handling of abnormal incidents in radiotherapy, and the final report was updated based on the EC requirements. The report will be published in 2014. The recommendation was released at the radiotherapy physicists' conference. A national guide will be drafted on the basis of the recommendation, the aim of which is to support the harmonized application of the recommendation to Finnish radiotherapy clinics.

### Other research activity

The central safety aspects and requirements for the use of particle accelerators in Finland and in other countries were analysed in 2013. The need for a separate ST guide for the use of particle accelerators will be determined on the basis of the analysis.

### Academic thesis work

STUK aims to supervise academic theses, taking into account the available resources, because the results of academic thesis work may be used in the activities of STUK and their results will help to improve radiation safety in Finland. In 2013, an expert at the STUK Department of Radiation Practices Regulation acted as the supervisor of one academic thesis carried out at a university of applied sciences.

The thesis analysed the situation of non-medical X-ray examinations and provided information that can be used for controlling and guiding the examinations. The title of the thesis was "Non-medical Imaging Exposures in Finland 2012". The results of the study revealed that hundreds of people are exposed to X-ray examinations for non-medical reasons in Finland every year (see also Item 2.1).

# 7 International co-operation

## Participation in the work of international organizations and commissions

Representatives of the Department of Radiation Practices Regulation are involved in several international organizations, commissions and expert groups dealing with the regulatory control and the development of safety regulations and measuring methods in the use of ioniszng and non-ionizing radiation, and in standardizing 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).

## Participation in meetings of international working groups

In 2013, representatives of STUK took part in meetings with the following international organizations and working groups:

- EURAMET's (European Association of National Metrology Institutes) annual meeting of contact persons
- Meeting of the Nordic Dosimetry 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-Ionizing Radiation Protection).
- NACP Radiation Physics Committee
- Nordic Ozone Group (including UV questions)
- The annual co-operative meeting of the Nordic laser inspection authorities
- IEC TC 61 MT 16 meeting (sunbed standards).

# 8 Co-operation in Finland

## Participation in the work of Finnish organizations and commissions

Representatives of STUK are involved in several Finnish organizations and commissions dealing with regulatory control of and research into the use of ionizing and non-ionizing radiation, and with standardizing activities in the field of radiation, such as the Advisory Committee on Metrology, the Radiation Safety Conference Committee, Eurolab-Finland, SESKO and the Finnish Advisory Committee for Clinical Audit, appointed by the Ministry of Social Affairs and Health. STUK experts take part in several meetings in the field of radiation safety in Finland, giving presentations and lectures in them.

## Participation in meeting of Finnish working groups

During 2013, representatives of STUK took part in meetings of the following Finnish organizations 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)
- Radiation safety committee of the Finnish Defence Forces (NIR matters).

## Finnish conferences arranged by STUK

STUK arranged the following conferences in 2013:

- Conference of radiotherapy physicists 13–14 June 2013 in Helsinki.
- Conference of medical X-ray technology experts 5–6 September in Hirvensalmi.
- Radiation safety and quality in nuclear medicine 21–22 November 2013 in Helsinki.

## Other co-operation in Finland

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

STUK took part in the steering group of the Finnish Institute of Occupational Health project on the development of an operative model for RF overexposure situations.

The co-operation agreement on UV radiation with the Finnish Meteorological Institute was renewed.

# 9 Communication

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

For the last 11 years, STUK has organized an annual UV press event in association with the Finnish Meteorological Institute and the Cancer Society of Finland. The theme of the event held on 18 April 2013 was "Sun cream is not enough on a holiday in the south" and STUK's theme was "The solarium K18 ban (prohibited under age of 18) protects the young from the dangers of UV radiation".

The joint statement by Nordic countries on the health effects of mobile phones, installations and wireless networks was released on 17 December 2013.

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

- STUK requires Talvivaara Sotkamo to regularly monitor the uranium content of its effluents
- Large radon concentrations are a potential risk in places of work
- A laboratory worker exposed to radioactive iodine
- Radiation exposure for workers below dose limits
- Sun cream is not enough on holiday in the south
- The Nordic radiation protection authorities: No evidence of the health effects of wireless technology radiation
- STUK continues to monitor the uranium concentration near Talvivaara (online news)
- STUK has monitored the radiation levels of mobile phones for ten years (online news)
- A radiation source found in metal load in Tornio (online news).

The first electronic newsletter targeted at health care professionals engaged in radiation practices was published in 2013. The aim is to make the newsletter an integral part of communication.

# 10 Metrological activities

## 10.1 General

STUK serves as the national standard laboratory for radiation quantities and maintains standards to ensure the accuracy and traceability of radiation measurements taken in Finland. STUK calibrates its own standards at regular intervals at the International Bureau of Weights and Measures (BIPM) or other primary laboratories. In the field of radiation metrology, STUK is involved in the work of the Advisory Committee on Metrology and 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 the Radiation Metrology Laboratory (the DOS Laboratory) for ionizing radiation and the NIR Unit for non-ionizing radiation. Metrology of ionizing radiation activity quantities is the responsibility of the Department of Environmental Radiation Surveillance (VALO) at STUK.

### The maintenance of metrological standards and development work on irradiation apparatus and methods of measurement

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

### Meter and measurement comparisons

The DOS Laboratory took part in the annual TLD comparison measurement of the absorbed dose of $^{60}$Co radiation (radiotherapy dose accuracy) between calibration laboratories belonging to the network of SSDL laboratories maintained by the IAEA/WHO. The deviation of the laboratory result from the IAEA reference value was 0.6%. This result is well within the IAEA's acceptable variation of results. Figure 11 shows the deviations from the reference value in these comparisons from 2003 to 2013 in the measurement results of STUK.

In addition, the laboratory took part in the EURAMET comparison of free dose equivalent with photon radiation (dose accuracy of the radiation protection level). Measurements were taken in autumn 2013, and the results of the comparison are not yet available. The laboratory received the preliminary results of the calibration comparison of the air kerma and air kerma-surface area meters in X-ray diagnostics from 2011. Based on the preliminary results, the deviation of STUK's results from the reference value is small.

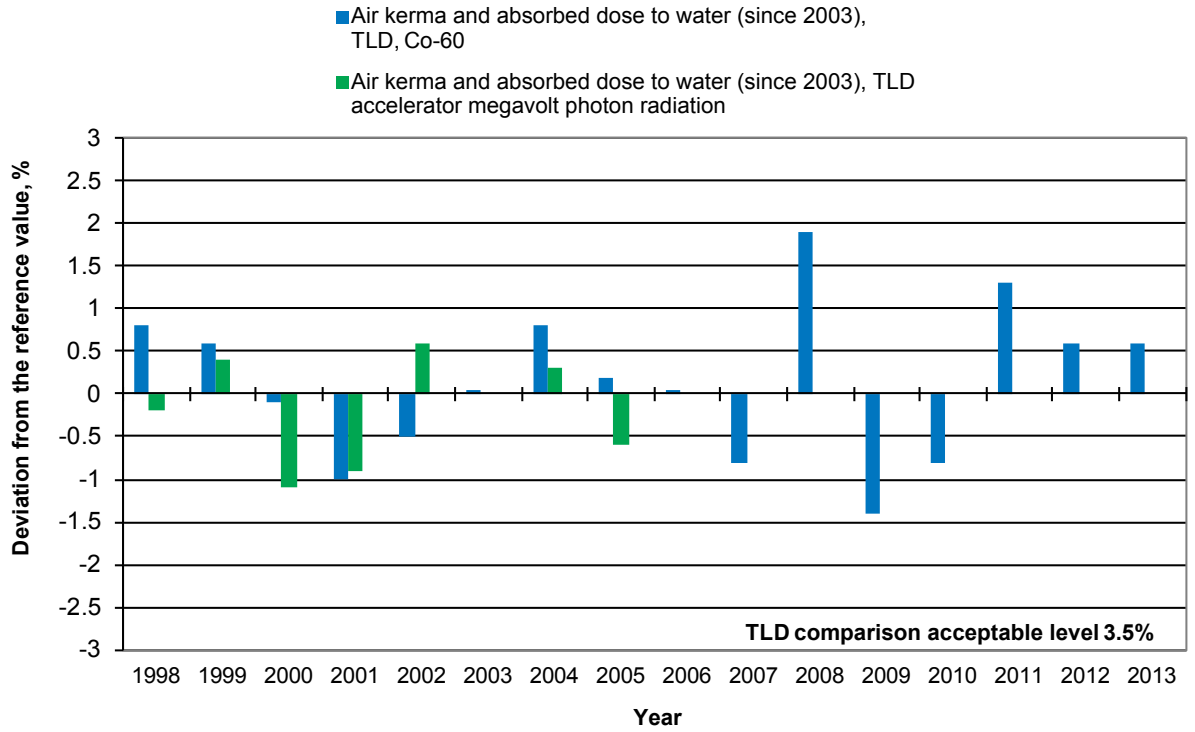


**Figure 11.** Deviations (%) in measurement results of STUK from the reference value in IAEA/WHO measurement comparisons (radiotherapy dose accuracy), 1998–2013.

# 11 Services

## Calibration, testing and irradiation

The DOS Laboratory performed radiation meter calibrations and testing on request. Some 136 radiation meter calibration, inspection and testing certificates and 92 irradiation certificates were issued. About 16% of the calibrations and around 17% of the irradiations were performed for STUK's own instruments and samples.

The NIR Unit performed a total of five radiation meter calibrations and tests and five safety assessments and radiation measurements. The service work of the NIR Unit between 2004 and 2013 is shown in Table 15 of Appendix 1.

## Other services

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

# APPENDIX 1 TABLES

**Table 1.** Radiation practices in the use of radiation in health care and veterinary practices at the end of 2013.

| Use of radiation | Number of practices |
|---|---|
| X-ray practices | 90 |
| Veterinary X-ray practices | 273 |
| Extensive X-ray practices | 91 |
| C-arm practices | 83 |
| Minor X-ray practices | 90 |
| X-ray practices outside X-ray departments | 56 |
| Screening with X-rays | 54 |
| Use of unsealed sources | 29 |
| Use of sealed sources | 24 |
| Radiotherapy | 13 |

**Table 2.** Radiation sources and appliances and radionuclide laboratories in the use of radiation in health care and veterinary practices at the end of 2013.

| Appliances/Sources/Laboratories | Number |
|---|---|
| **X-ray diagnostic appliances (generators)**[*)] | **1543** |
| fixed conventional X-ray appliances | 508 |
| portable fluoroscopy appliances | 255 |
| portable conventional X-ray appliances | 214 |
| mammography appliances, of which | 168 |
| • screening mammography | 83 |
| • tomosynthesis | 1 |
| fixed fluoroscopy appliances, of which | 110 |
| • angiography | 47 |
| • fluoroscopy | 29 |
| • cardioangiography | 34 |
| CT-appliances, of which | 103 |
| • SPECT-CT | 28 |
| • PET-CT | 9 |
| CBCT appliances (other than dental imaging) | 7 |
| dental X-ray appliances (licensed) | 145 |
| • CBCT appliances | 60 |
| • panoramic scanners | 57 |
| • conventional dental X-ray appliances | 28 |
| bone mineral density measurement appliances | 66 |
| other appliances | 4 |
| **Dental X-ray appliances (notifiable)** | **5775** |
| conventional dental X-ray appliances | 5131 |
| panoramic scanners | 644 |
| **Radiotherapy appliances** | **130** |
| accelerators | 41 |
| X-ray imaging appliances | 34 |
| afterloading appliances | 10 |
| manual afterloading appliances | 3 |
| X-ray therapy appliances | 1 |
| radiotherapy simulators | 17 |
| sealed sources (check sources) | 24 |

| | |
|---|---|
| **Sealed sources** | **250** |
| calibration and testing equipment | 239 |
| attenuation correction units | 8 |
| gamma irradiators | 2 |
| other sealed sources in health care | 1 |
| **X-ray appliances in veterinary practices** | **338** |
| conventional X-ray appliances | 260 |
| bone mineral density measurement appliances | 3 |
| fluoroscopy appliances | 4 |
| intra oral appliances | 54 |
| CT scanners, of which | 10 |
| • SPECT-CT | 3 |
| • PET-CT | 2 |
| other appliances | 2 |
| **Radionuclide laboratories** | **41** |
| B-type laboratories | 24 |
| C-type laboratories | 17 |

*) 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 2013.

| **Use of radiation** | **Number** |
|---|---|
| Use of sealed sources | 582 |
| Use of X-ray appliances | 500 |
| Installation, test operations and services | 163 |
| Importing and exporting of radioactive materials or trading in them | 111 |
| Use of unsealed sources | 100 |
| Use of particle accelerators | 17 |

**Table 4.** Radiation sources and appliances and radionuclide laboratories in the use of radiation in industry, research and education at the end of 2013.

| **Appliances/Sources/Laboratories** | **Number** |
|---|---|
| **Appliances containing radioactive materials** | **6100** |
| level switches | 2010 |
| continuous level gauges | 1120 |
| density gauges | 980 |
| weight scales | 615 |
| basis weight meters | 533 |
| appliances or sources used for calibration, testing or education | 243 |
| moisture and density gauges | 132 |
| particle analyzers | 73 |
| fluorescense analyzers | 72 |
| radiography appliances | 36 |
| other appliances | 286 |
| **X-ray appliances and accelerators** | **1632** |
| X-ray screening appliances | 630 |
| diffraction and fluorescense analyzers | 463 |
| radiography appliances | 378 |
| basis weight meters | 41 |
| particle accelerators | 23 |
| other X-ray appliances | 97 |

| | |
|---|---|
| **Radionuclide laboratories** | **137** |
| A-type laboratories | 6 |
| B-type laboratories | 27 |
| C-type laboratories | 101 |
| 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 2013.

| Radionuclide | Number of sources |
|---|---|
| **Other than high-activity sealed sources** | |
| Cs-137 | 3980 |
| Co-60 | 1036 |
| Kr-85 | 348 |
| Am-241 (gamma sources) | 321 |
| Am-241 (AmBe neutron sources) | 111 |
| Fe-55 | 109 |
| Pm-147 | 109 |
| Sr-90 | 66 |
| Ni-63 | 62 |
| **High-activity sealed sources** | |
| Cs-137 | 49 |
| Co-60 | 27 |
| Ir-192 | 10 |
| Am-241 (gamma sources) | 8 |
| Sr-90 | 5 |
| Am-241 (AmBe neutron sources) | 4 |

**Table 6.** Inspections of licensed practices in 2012 (itemized by type of inspection).

| Type of inspection | Number of inspections | |
|---|---|---|
| | **Industry, research and education** | **Health care and veterinary practices** |
| Initial inspection | - | 74 |
| Periodic inspection | 164 | 235 |
| Repeat inspection | 1 | 7 |
| Other inspection or measurement | 7 | 6 |
| **Total** | **172** | **322** |

**Table 7.** Deliveries of sealed sources to and from Finland in 2013.

| **Radionuclide** | **Deliveries to Finland** | | **Deliveries from Finland** | |
|---|---|---|---|---|
| | **Actiivity (GBq)** | **Number** | **Actiivity (GBq)** | **Number** |
| Ir-192 | 76 305 | 22 | 7672 | 19 |
| Se-75 | 5365 | 3 | 547 | 2 |
| Co-60 | 3712 | 32 | 2072 | 1 |
| Kr-85 | 1053 | 69 | 559 | 38 |
| Pm-147 | 538 | 61 | 77 | 15 |
| Fe-55 | 190 | 42 | 164 | 32 |
| I-125 | 52 | *) | -**) | - |
| Ni-63 | 40 | 106 | 38 | 102 |
| Cs-137 | 38 | 86 | 25 | 3 |
| Gd-153 | 7 | 17 | - | - |
| Am-241 (gamma- and alpha sources) | 3 | 19 | 2 | 282 |
| Am-241 (AmBe neutron sources) | 4 | 3 | 1 | 1 |
| Sr-90 | 3 | 6 | 3 | 5 |
| others total ***) | 8 | 70 | 1 | 21 |
| **Total** | **87 318** | **536** | **11 161** | **521** |

*) The exact number of small sources of I-125 used in radiotherapy is not known.
**) The symbol "-" indicates no deliveries from Finland.
***) Deliveries to Finland, nuclides: H-3, Co-57, Ba-133, C-14, Cd-109, Eu-152, Ge-68, Mn-54, Na-22 and Zn-65.
Deliveries from Finland, nuclides: Eu-152, Ni-65 and H-3.

**Table 8.** Manufacturing of radioactive substances (unsealed sources) in Finland in 2013.

| **Radionuclide** | **Actiivity (GBq)** |
|---|---|
| F-18 | 114 567 |
| C-11 | 17 583 |
| O-15 | 4250 |
| Br-82 | 3503 |
| others total *) | 85 |
| **Total** | **139 988** |

*) Nuclides, such as: Cu-64, La-140, Zn-63, Co-58 and Au-198.

**Table 9.** Number of workers subject to individual monitoring in 2009–2013.

| 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 | | | | | | | |
| 2009 | 4440 | 992 | 458 | 1232 | 810 | 15 | 49 | 3704 | 11 571 |
| 2010 | 4467 | 989 | 491 | 1192 | 817 | 21 | 73 | 4151 | 12 062 |
| 2011 | 4320 | 1050 | 550 | 1209 | 742 | 22 | 79 | 3830 | 11 659 |
| 2012 | 3989 | 1083 | 582 | 1286 | 720 | 22 | 107 | 3676 | 11 341 |
| 2013 | 3953 | 1147 | 636 | 1329 | 727 | 20 | 125 | 3715 | 11 540 |

*) 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 2009–2013.

| 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 | | | | | | | |
| 2009 | 1.27 | 0.09 | 0.08 | 0.15 | 0.06 | 0.01 | 0 | 2.37 | 4.04 |
| 2010 | 1.25 | 0.08 | 0.08 | 0.15 | 0.09 | 0.004 | 0 | 2.59 | 4.25 |
| 2011 | 1.33 | 0.11 | 0.09 | 0.13 | 0.07 | 0.007 | 0.001 | 1.83 | 3.56 |
| 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 |

*) $H_p(10)$ 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 2013.

| Group | Numbers 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**) | 201 | 0.58 | 3.5 | 2.9 | 19.7 |
| Interventional radiologists**) | 32 | 0.24 | 8.8 | 7.4 | 45.1 |
| Radiologists**) | 354 | 0.22 | 2.9 | 0.6 | 21.9 |
| Consultant physicians**) ***) | 287 | 0.06 | 1.4 | 0.2 | 5.7 |
| Nurses**) | 1171 | 0.06 | 0.5 | 0.1 | 3.8 |
| Radiographists (X-rays)**) | 1427 | 0.04 | 0.4 | 0.0 | 2.6 |
| Radiographers (other than X-rays) | 549 | 0.04 | 0.7 | 0.1 | 2.6 |
| Veterinary nurses and assistants**) | 379 | 0.07 | 1.1 | 0.2 | 5.9 |
| Veterinary surgeons**) | 247 | 0.05 | 1.6 | 0.2 | 9.7 |
| Industrial material inspection technicians****) | 520 | 0.13 | 1.0 | 0.3 | 5.0 |
| Industrial tracer testing technicians | 26 | 0.05 | 2.6 | 1.8 | 6.6 |
| Researchers | 582 | 0.03 | 0.8 | 0.1 | 3.8 |
| Nuclear power plant workers | | | | | |
| • mechanical duties and machine maintenance | 648 | 0.42 | 1.3 | 0.7 | 7.6 |
| • cleaning | 239 | 0.15 | 1.3 | 0.6 | 8.6 |
| • material inspection | 169 | 0.12 | 1.1 | 0.7 | 8.1 |

*) 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 2013).

| Radionuclide | Actiivity (GBq) or mass |
|---|---|
| H-3 | 39 582 |
| Cs-137 | 2726 |
| Am-241 | 2447 |
| Kr-85 | 1704 |
| Pu-238 | 1537 |
| Ra-226 | 235 |
| Sr-90 | 235 |
| Cm-244 | 116 |
| Co-60 | 112 |
| U-238 *) | 1270 kg |
| *) Depleted uranium | |

**Table 13.** Number of air crew members subject to individual monitoring of radiation exposure and total dose of crew members (sum of effective doses) in 2009–2013.

| Year | Number of workers | | Total dose (Sv) | |
|---|---|---|---|---|
| | Pilots | Cabin crew | Pilots | Cabin crew |
| 2009 | 1195 | 2460 | 2.68 | 6.07 |
| 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 |

**Table 14.** The work of the NIR Unit in regulatory control of the use of non-ionizing radiation in 2004–2013.

| Year | Regulatory inspections | Decisions | Statements | Co-operation with Finnish Customs in the import of lasers: cases (prohibited items) | Prohibition of dangerous laser devices sold on the Internet | Total |
|---|---|---|---|---|---|---|
| 2004 | 55 | 3 | 1 | | | 59 |
| 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 | 166 |

**Table 15.** The service work of the NIR Unit in 2004–2013.

| Year | Calibrations and tests | Safety assessments and radiation measurements | Total |
|---|---|---|---|
| 2004 | 30 | 12 | 42 |
| 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 |

**Table 16.** Inspections of sunbed facilities in 2004–2013. In addition to STUK's own inspections also health inspectors of municipalities inspected the sunbed facilities 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 |
|---|---|
| 2004 | 30 |
| 2005 | 36 |
| 2006 | 25 |
| 2007 | 31 |
| 2008 | 26 |
| 2009 | 19 |
| 2010 | 16 |
| 2011 | 7 |
| 2012 | 6 (16) |
| 2013 | 3 (40) |

**Table 17.** SAR tests of mobile phones and other wireless devices in 2004-2013.

| Year | Number of tests |
|---|---|
| 2004 | 18 |
| 2005 | 15 |
| 2006 | 15 |
| 2007 | 15 |
| 2008 | 10 |
| 2009 | 15 |
| 2010 | 10 |
| 2011 | 5 |
| 2012 | 15 |
| 2013 | 11 |

# APPENDIX 2

# PUBLICATIONS IN 2013

The following publications completed in 2013.

## International publications

Barjaktarovic Z, Anastasov N, Azimzadeh O, Sriharshan A, Sarioglu H, Ueffing M, Tammio H, Hakanen A, Leszczynski D, Atkinson MJ, Tapio S. Integrative proteomic and microRNA analysis of primary human coronary artery endothelial cells exposed to low-dose gamma radiation. Epub 2012 Nov 9. Radiation and Environmental Biophysics 2013; 52 (1): 87–98.

Koskelainen Markku. Stakeholder involvement: an integral part of radiation protection decision making. Doctoral thesis. University of Manchester, Faculty of Engineering and Physical Sciences, 2012.

Laakso I, Kännälä S, Jokela K. Computational dosimetry of induced electric fields during realistic movements in the vicinity of a 3 T MRI scanner. Physics in Medicine and Biology 2013; 58 (8): 2625–2640. DOI:10.1088/0031-9155/58/8/2625.

Nylund R, Lemola E, Eklund E, Hakanen A, Leszczynski D. The lack of acute effect of low-to-moderate-dose ionising radiation on endothelial proteome. International Journal of Low Radiation 2013; 9 (2): 127–137.

Pöllänen R, Peräjärvi K, Siiskonen T, Turunen J. In-situ alpha spectrometry from air filters at ambient air pressure. Radiation measurements 2013;53-54;65–70.DOI:10.1016/j.radmeas.2013.01.008

## Conference proceedings, abstracts, posters

Bly R, Jahnen A, Olerud H, Vassileva J, Järvinen H, Vogiatzi S. European population dose and differencies in radiologiacal procedures between European countries [abstract]. In European congress of Radiology. 2013 Mar 7–11; Vienna, Austria.

Bly R, Jahnen A, Olerud H, Vassileva J, Järvinen H, Vogiatzi S. Patient dose project in Europe: Overview and future prospective [abstract]. In 2nd ESTRO Forum. 2013 April 19–23; Geneva, Switzerland.

Nylund R, Lemola E, Hartwig S, Lehr S, Acheva A, Jahns J, Hildebrandt G, Lindholm C. Proteomics profiling of low molecular weight plasma proteins from locally irradiated individuals [abstract]. In: 2nd International Radiation Proteomics Workshop. 2013 Jan 30–31; Munich, Germany.

## Regulatory control reports

Hellstén Santtu. Selvitys avolähteiden käytöstä syntyvistä radioaktiivisista jätteistä ja päästöistä aiheutuvasta säteilyaltistuksesta (teollisuus, tutkimus ja terveydenhuolto) (Investigation into radiation exposure caused by radioactive waste and emissions (industry, research and health care)). STUK-A258. Helsinki: Radiation and Nuclear Safety Authority; 2013.
http://www.stuk.fi/julkaisut_maaraykset/tiivistelmat/a_sarja/fi_FI/stuk-a258/

Helasvuo Timo (toim.). Radiologisten tutkimusten ja toimenpiteiden määrät vuonna 2011 (The number of radiological examinations and interventions in 2011). STUK-B 161. Helsinki: Radiation and Nuclear Safety Authority; 2013.
http://www.stuk.fi/julkaisut_maaraykset/tiivistelmat/b_sarja/fi_FI/stuk-b161/

Rantanen E. (toim.). Säteilyn käyttö ja muu säteilylle altistava toiminta. Vuosiraportti 2012 (Radiation practices. Annual report 2012). STUK-B 160. Helsinki: Radiation and Nuclear Safety Authority; 2013.

Rantanen E. (ed.). Radiation practices. Annual report 2012. STUK-B 166. Helsinki: Helsinki: Radiation and Nuclear Safety Authority; 2013.
http://www.stuk.fi/julkaisut_maaraykset/tiivistelmat/b_sarja/en_GB/stuk-b166/

## Regulatory guides

### Finnish language

Säteilytoiminnan turvallisuus. Ohje ST 1.1 (Safety in radiation practices. Guide ST 1.1). STUK (23 May 2013).

Säteilylähteiden varoitusmerkit. Ohje ST 1.3 (Warning signs for radiation sources. Guide ST 1.3). STUK (9 Dec. 2013).

Säteilyn käytön vapauttaminen turvallisuusluvasta. Ohje ST 1.5 (Exemption of the use of radiation from the safety lisensing. Guide ST 1.5). STUK (12 Sep. 2013).

Säteilylähteiden turvajärjestelyt. Ohje ST 1.11. (Security arrangements of radiation sources. Guide ST 1.11). STUK (9 Dec. 2013).

Säteilyturvallisuus mammografiatutkimuksissa. Ohje ST 3.8 (Radiation safety in mammography examinations. Guide ST 3.8). STUK (25 Jan. 2013).

Säteilyturvallisuus isotooppilääketieteessä. Ohje ST 6.3 (Radiation safety in nuclear medicine. Guide ST 6.3). STUK (14 Jan. 2013).

Solariumlaitteiden säteilyturvallisuusvaatimukset ja valvonta. Ohje ST 9.1 (Radiation safety requirements and regularoty control of tanning. Guide ST 9.1). STUK (1 July 2013).

Säteilyturvallisuus lentotoiminnassa. Ohje ST 12.4 (Radiation safety in aviation. Guide ST 12.4). STUK (1 Nov. 2013).

### Swedish language

Säkerhet vid strålningsverksamhet. Direktiv ST 1.1 (Safety in radiation practices. Guide ST 1.1). STUK (23 May 2013).

Befrielse från kravet på säkerhetstillstånd vid användning av strålning. Direktiv ST 1.5 (Exemption of the use of radiation from the safety lisensing. Guide ST 1.5). STUK (12 Sep. 2013)

Strålskyddsutbildning inom hälso- och sjukvården. Direktiv ST 1.7 (Radiation protection training in health care. Guide ST 1.7). STUK (10 Dec. 2012).

Strålsäkerhet vid mammografiundersökningar. Direktiv ST 3.8 (Radiation safety in mammography examinations. Guide ST 3.8). STUK (25 Jan. 2013).

Strålsäkerhet inom nukleärmedicin. Direktiv ST 6.3 (Radiation safety in nuclear medicine. Guide ST 6.3). STUK (14 Jan. 2013).

### English language (translations)

Radiation user's organization. Guide ST 1.4 (2.11.2011).

Radiation protection training in health care. Guide ST 1.7 (10.12.2012).

Qualifications and radiation protection training of persons working in a radiation user´s organization. Guide ST 1.8 (17.2.2012).

Radiation safety in nuclear medicine. Guide ST 6.3 (14.1.2013).

## Other publications

Hallinen E, Pirinen M. Viranomaispohdintoja nykyaikaisesta säteilyturvallisuudesta (Reflections of authorities on modern radiation safety). Radiografia 2013 (4): 12-13.

Heikkilä P, Henner A, Ahonen S-M, Pirinen M. Leikkaussalien säteilyturvallisuudessa parantamisen varaa (Room for improvement in the radiation safety of operating theatres). Radiografia 2013 (3): 16–19.

Helasvuo T. Röntgentutkimusten määrät edelleen laskussa (Number of X-ray examinations continues to drop). Radiografia 2013 (3): 20–23.

Lehtinen M. Työntekijöiden säteilyannokset pienentyneet terveydenhuollossa (Radiation doses to workers decreased in health care). Radiografia 2013 (3): 11–13.

Toroi P. Mittauksella tärkeä merkitys säteilyannoksen määritysketjussa (Measurement is an important link in the radiation dose determination chain). Radiografia 2013 (3): 6–8.

## Academic thesis work

Heikkilä Piia. Säteilyn käyttötavat leikkaussaleissa. Kartoitus säteilyn käytön turvallisuuskulttuuriin vaikuttavista tekijöistä suomalaisissa leikkaussaleissa (Use of radiation in operating theatres. Survey of factors affecting safety culture in operating theatres in Finland). Pro Gradu Thesis, Institute of Health Sciences, Radiography, University of Oulu, September 2013.

Koskelainen Markku. Stakeholder involvement: an integral part of radiation protection decision making. Doctoral thesis. University of Manchester, Faculty of Engineering and Physical Sciences, 2012.

## Bulletins and brochures

Radioaktiivisten aineiden kuljetus. STUK opastaa/ Syyskuu 2012. 2. korjattu painos (Transport of radioactive materials. Advice from STUK/ September 2012. Second, revised edition). Helsinki: Radiation and Nuclear Safety Authority; 2013.

Guidelines for paediatric CT examinations. Advice from STUK/September 2012. Helsinki: Radiation and Nuclear Safety Authority; 2013.
http://www.stuk.fi/julkaisut_maaraykset/en_GB/stuk-opastaa/_files/89449395333694113/default/Advice-from-STUK-lasten-TT-2012.pdf

# APPENDIX 3

## ST GUIDES PUBLISHED BY STUK. SITUATION AS OF 30 APRIL 2014.

### General guides

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 the use of radiation from the safety licensing, 12 September 2013 (in Finnish)
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, 20 August 2011
ST 3.3 X-ray examinations in health care, 20 March 2006
ST 3.8 Radiation safety in mammography examinations, 25 January 2013

### 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 wastes and discharges, 1 July 1999
ST 6.3 Radiation safety in nuclear medicine, 14 January 2013

### Radiation doses and health surveillance

ST 7.1 Monitoring of radiation exposure, 2 August 2007
ST 7.2 Application of maximum values for radiation exposure and principles for the calculation of radiation doses, 9 August 2007
ST 7.3 Calculation of the dose caused by internal radiation, 23 September 2007
ST 7.4 The dose register and data reporting, 9 September 2008.
ST 7.5 Medical surveillance of occupationally exposed workers, 4 May 2007

### Veterinary medicine

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

### Non-ionizing radiation

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)
ST 9.3 Radiation safety during work on masts at FM and TV stations, 2 September 2003 (in Finnish)
ST 9.4 Radiation safety of high power display lasers, 28 February 2007 (in Finnish)

### Natural radiation

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

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