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Eija Venelampi (ed.)

Radiation practices

Annual report 2021

THIS REPORT WAS PREPARED BY

Siiri-Maria Aallos-Ståhl
Ritva Bly
Timo Helasvuo
Santtu Hellstén
Heli Hoilijoki
Anne Höytö
Sampsa Kaijaluoto
Antti Kallio
Anne Kiuru
Milla Korhonen
Venla Kuhmonen
Päivi Kurttio
Iida Kuurne
Sami Kännälä
Antti Latomäki
Maaret Lehtinen
Reetta Nylund
Pasi Orreveteläinen
Iisa Outola
Lauri Puranen
Teemu Siiskonen
Petri Sipilä
Tuomas Siru
Antti Takkinen
Petra Tenkanen-Rautakoski
Emmi Tikkanen
Tim Toivo
Tommi Toivonen
Paula Toroi
Reijo Visuri
Lasse Ylianttila

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Radiation practices

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Abstract

A total of 2 887 safety licences for the use of ionizing radiation were current at the end of 2021, in addition to three safety licences for aviation operations. The use of radiation was controlled through regular inspections performed in places of use, regulatory control queries, and maintenance of the Dose Register. The Radiation and Nuclear Safety Authority (STUK) conducted 137 inspections of safety-licensed practices in 2021.

A total of 13 660 workers were subject to individual monitoring in 2021. Around 76 500 dose entries were recorded in the Dose Register maintained by STUK.

In 2021, the regulatory control of non-ionizing radiation (NIR) use focused on laser equipment, sunbeds, mobile phones, torches and cosmetic NIR applications. As part of the regulatory control, STUK intervened four times in online auctions of hazardous laser equipment. Two on-site inspections of show lasers were conducted. Municipalities' health protection authorities submitted the details on inspections of 18 sunbed facilities for STUK to evaluate and make decisions on. In addition, four sunbed facilities were supervised based on monitoring carried out by STUK. An inspection based on documentation was conducted on 25 beauty care facilities. The radiation levels of ten mobile phones were checked during the year.

In metrological activities, national metrological standards were maintained, and radiation meters used in radiotherapy, radiation protection and X-ray imaging as well as radon meters used for measuring radon in the air were calibrated. In measurement comparisons, STUK's results were clearly within the acceptable range. As a significant recognition of the Dosimetry laboratory, STUK was accepted as a member in the the Dosimetry section of the Consultative Committee for Ionizing Radiation (CCRI) of the International Committee for Weights and Measures (CIPM).

STUK was accepted as a participant in a research project coordinated by the IAEA which aims to examine the need to update dosimetry practices in X-ray imaging.

There were 42 radiation safety deviations related to radiation use in 2021. Of these incidents, 21 concerned the use of radiation in industry and research, 18 in health care and one in veterinary practices. Two incidents were related to the use of non-ionizing radiation. In addition, 2 434 incidents and near misses assessed to be of minor significance for safety were reported in health care, and a summarized notification was submitted of four radiation safety deviations in industry and research.

Over 12 000 radon measurements at around 3 000 workplaces were recorded in the national radon database in 2021. At approximately 14% of the measured conventional workplaces, the annual average for radon concentration exceeded the reference level of 300 Bq/m^3. One safety licence was granted to an underground construction site where reducing radon concentrations was not possible.

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Management review

An extensive recommendation to work remotely continued to affect the regulatory control of radiation practices in 2021. Few on-site inspections could be conducted. No serious incidents putting radiation safety at risk were reported, but the exceptional circumstances that continued for two years clearly began to affect STUK's situational picture. STUK naturally had to adapt to the prevailing circumstances, which is why several webinars were organized to keep in touch with undertakings, and procedures based on remote meetings and surveys were developed for regulatory control. In addition, the market surveillance of radiating products was very active. As the restrictive measures have been finally lifted, we have noticed that while many of the practices learned during the pandemic are worth keeping, traditional face-to-face meetings also have their place.

Tasks related to the new requirements under the Radiation Act continued in 2021. STUK had a backlog of processing safety assessments in 2020, which could only be cleared in 2021. Unfortunately, some undertakings had to wait rather a long time for their safety assessment to be confirmed.

The Sammio guidance database was published in 2021 and continues to be complemented. This database contains all statutes of radiation legislation at different levels and their rationales as well as instructions for applying them prepared by STUK. We hope that as many undertakings as possible will learn to find answers in the database and give feedback to support its development.

We began to lay the groundwork for updating our regulatory control information system in 2021. The current system has reached the end of its technical service life and hampers the development of control. We have examined the possibilities of joining forces with Tukes in system development. Our goal is to be able to offer an effective electronic tool for licensing services in the future and speed up processing by automation.

In 2021, STUK prepared for an international peer review of radiation and nuclear safety (IRRS) and a peer review of radioactive waste and spent fuel safety (Artemis) led by the IAEA. These reviews will be conducted in late 2022. In the field of radiation safety, preparations are also being made for updating the basic recommendations of the International Commission on Radiation Protection (ICRP). STUK participates in this work by commenting on the process through international committees.

The recommendation to work remotely was revoked in spring 2022. Rather than returning to our Roihupelto premises in Helsinki, STUK employees will return to the office in our new facilities in Jokiniemi, Vantaa, in spring 2022. Preparing for the move was one of our key tasks in 2021, especially in laboratory activities.

1 General

"Use of radiation" refers to the use and manufacture of and trade in radiation sources, and to associated activities, such as possession, safekeeping, servicing, repairing, installing, importing, exporting, storing and transporting them, and rendering radioactive waste harmless.

"Radiation practice" refers to the use of radiation and to any practices or circumstances in which exposure to natural radiation (such as radon) is or may be hazardous to health.

"Radiation" refers to both ionizing and non-ionizing radiation.

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

1.1 Principal key figures

For key indicators for the use of radiation and other practices causing exposure to radiation, see Figures 1 to 4.

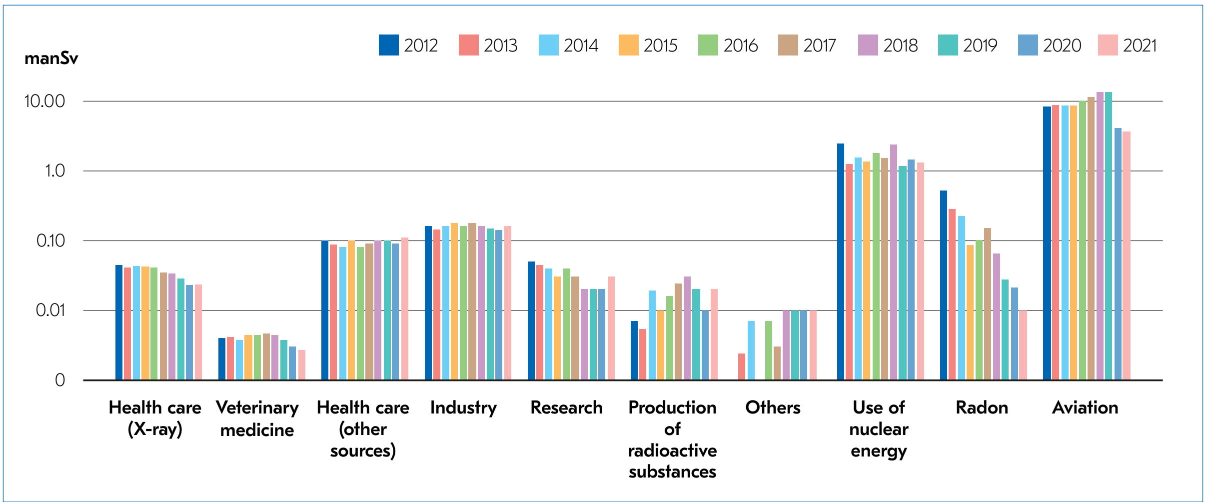


FIGURE 1. Collective effective doses (manSv) of workers subject to individual monitoring by occupational category, 2012–2021. In addition to the occupational categories specified in the graph, a few people subject to individual monitoring work in the following fields: manufacturing of radioactive materials, installation/servicing/technical test operation, trade/import/export and services pertaining to the use of radiation and radioactive materials (see Tables 10 and 11 in Appendix 1).

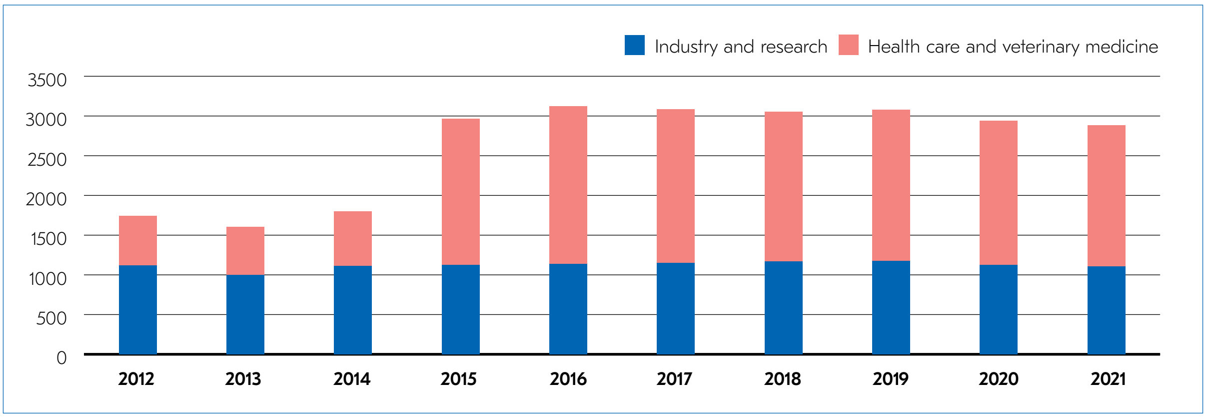


FIGURE 2. Number of safety licences in 2012–2021. In addition, three safety licences issued for aviation operations were current in 2019–2021. The increase in health care licences in 2015 is due to the dental X-ray practices being changed from registered activities to activities that are subject to a licence.

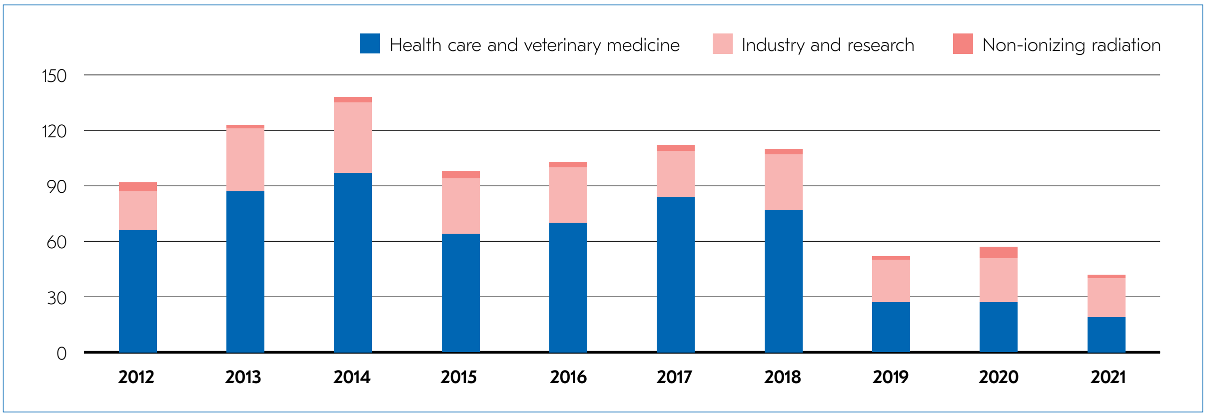


FIGURE 3. Number of radiation safety deviations radiation safety deviations to be reported immediately in 2012–2021. From 2019 onwards, some of the radiation safety deviations which previously had to be reported immediately can be reported annually.

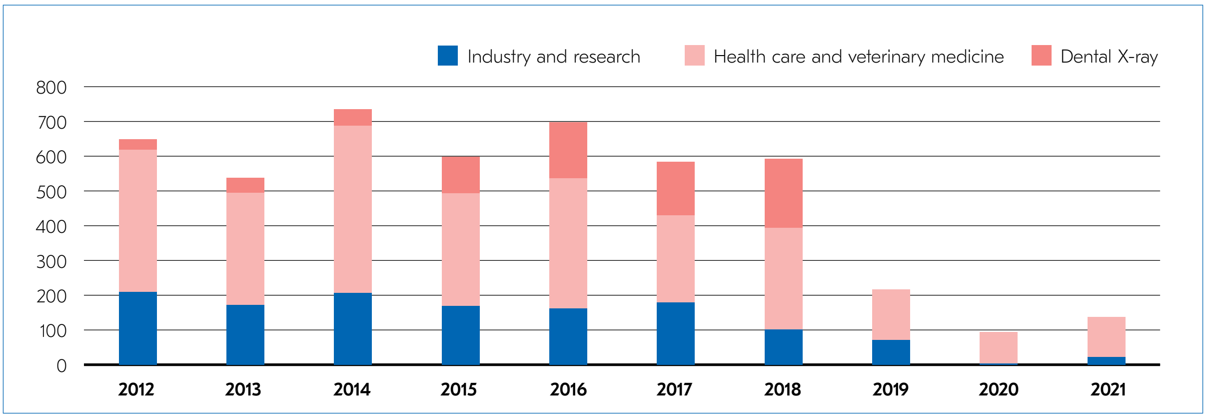


FIGURE 4. Numbers of on-site inspections in 2012–2021. From 2019, dental x-ray examinations are included in the section "health care and veterinary medicine".

2 Regulatory control of the use of ionizing radiation

The deadline for submitting safety assessments concerning radiation practices to STUK for confirmation laid down in the Radiation Act expired in mid-June 2020. Once this period had expired, there was a backlog of safety assessments to process, and this work continued in early 2021. On the other hand, a significant proportion of undertakings did not submit a safety assessment to STUK by the deadline. These undertakings were sent requests urging them to submit their safety assessments to STUK without delay. Considering the risks associated with their operations, it has been necessary to impose administrative coercive measures on some undertakings to ensure that their safety assessments are submitted. STUK has also sharpened its focus on licence supervision in other safety licence matters, for example by sending out requests earlier than before and, if necessary, using other enforcement procedures.

While no physical seminars were organized due to the coronavirus situation, STUK was able to respond to some of the training needs by means of webinars. A number of webinars were consequently organized on a variety of topics and for different target groups. Regulatory control of practices also relied on remote methods to some extent.

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

Safety licences

At the end of 2021, there were 1 477 current safety licences for the use of radiation in health care and 306 licences for veterinary practices (see also Figure 2). A total of 653 licensing decisions and 327 licensing notifications (new licences, amendments to existing licenses, or terminations of licences) were made during the year. The average time for processing a health care safety licence application was approx. 8 days. In addition, safety assessments related to 169 safety licences were confirmed by a separate decision. The processing times of safety assessments were considerably longer than those of other licence matters. The safety assessments confirmed in 2021 were mainly related to safety licences in cases where the safety assessments had not been submitted by the deadline and could only be obtained for confirmation by means of administrative coercive measures. This continued to take up a considerable amount of working time in early 2021. See Table 1 in Appendix 1 for the numerical distribution of the practices referred to in these licences.

Radiation appliances, sources and laboratories

See Table 2 in Annex 1 for detailed information on the numbers of sources and appliances as well as radionuclide laboratories used in health care and veterinary radiation at the end of 2021.

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

For the number of sealed sources which are used in health care, industry and research and which will be 40 years old or older in 2021–2023 unless they are decommissioned before that date, see Table 6 in Appendix 1. A sealed source must be decommissioned no later than 40 years after its compliance has been demonstrated. The transition period ends on 15 December 2023.

2.2 Use of radiation in industry and research

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

Around one hundred safety assessments related to use of radiation in industrial contexts were still waiting for processing at the end of 2021. In addition, no safety assessments have been received from about a hundred undertakings, despite sending out reminders. Reviewing the safety assessments created a considerable workload.

Safety licences

At the end of 2021, there were 1 104 current safety licences for the use of radiation in industry and research (see also Figure 2). Besides confirming safety assessments, a total of 572 other licensing performances concerning new licences, amendments to existing licenses or terminations of licences (357 decisions and 215 notifications), were issued during the year. The number of new licences issued was 38, whereas 57 licences were terminated. The average processing time of safety licence applications and notifications was 32 days, excluding the time required for obtaining additional information. See Table 3 in Appendix 1 for the numerical distribution of the radiation practices referred to in these licences.

Radiation appliances and laboratories

See Figure 5 for the number of appliances containing radioactive materials used in industry and research in the last ten years.

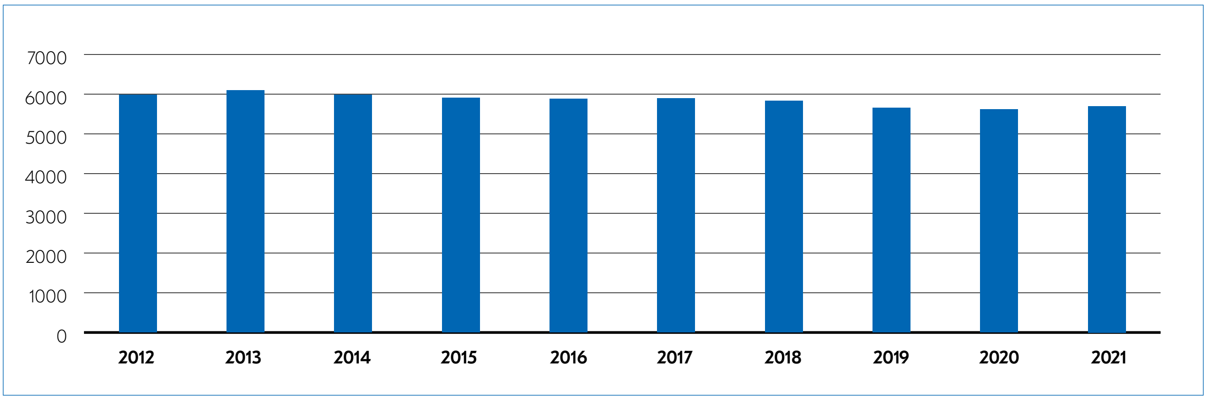


FIGURE 5. Number of appliances containing appliances containing radioactive materials in industry and research in 2012–2021.

See Figure 6 for the number of X-ray appliances in the last ten years.

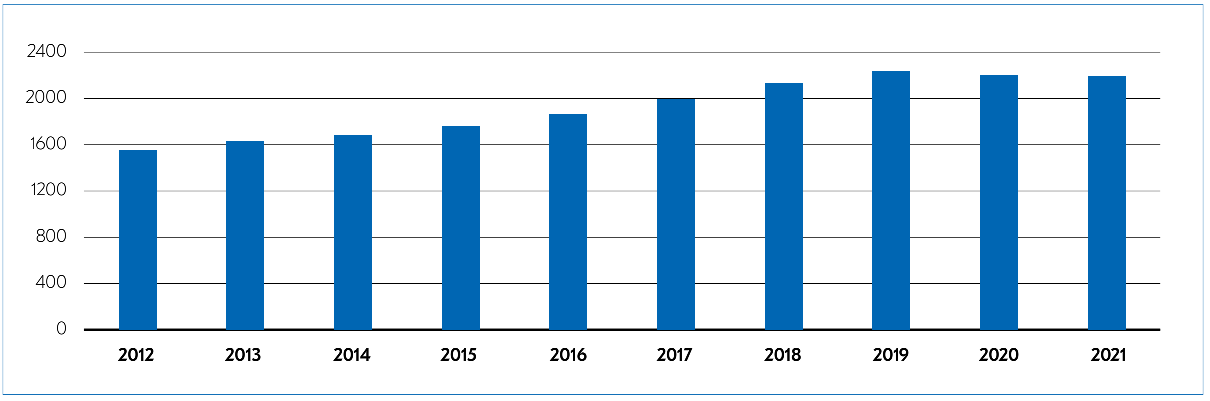


FIGURE 6. Number of X-ray appliances in industry and research in 2012–2021.

See Table 4 in Appendix 1 for details of the numbers of radiation appliances as well as radionuclide laboratories in industry and research at the end of 2021.

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

For the number of sealed sources which are used in health care, industry and research and which will be 40 years old or older in 2021–2023 unless they are decommissioned before that date, see Table 6 in Appendix 1. A sealed source must be decommissioned no later than 40 years after its compliance has been demonstrated. The transition period ends on 15 December 2023.

2.3 Inspections of licensed radiation practices

In 2021, the coronavirus situation continued to affect on-site inspections and other work requiring physical presence. On-site inspections were conducted on risk-based grounds, ensuring that inspections of such areas as radiotherapy practices were carried out more or less as planned. In regulatory control of health care practices, cardiological radiation use, nuclear medicine, dental X-ray practices and new undertakings were additionally emphasized.

Instead of physical presence, the focus was on webinars aimed at radiation users.

In industry and research, on-site inspections were mainly carried out as part of the supervision project focusing on the Finnish Defence Forces. Additionally, a few reactive inspections were carried out, for example when an orphan source was discovered.

Health care, dental care and veterinary practices

In 2021, a total of 98 inspections of radiation use were conducted in health care and 17 in veterinary practices. These inspections resulted in 14 orders to remedy shortcomings, as well as 20 observations requiring changes, being issued to the responsible undertakings. In 2021, the use of communication as an instrument of control was also enhanced: one of the tools used was webinars for radiation users, seven of which were held during the year for health care, dentistry and veterinary undertakings on a variety of topics and for different target audiences. While the webinars were found to be a good low-threshold method of disseminating information to radiation users, users would also like to see events involving physical presence.

Dental X-ray practices

Approximately 1 200 undertakings were engaged in dental X-ray practices in 2021.

The regulatory control of dental X-ray practices focused on the use of panoramic tomography x-ray appliances outside the dental clinic. Surveys addressed to places of use contained questions about the division of both responsibilities and tasks related to practical imaging work and quality assurance. The results of the survey were verified and additional information was obtained by means of on-site inspections. The fact that there were significant differences between the survey results and observations made during the inspections was a significant finding. The survey was often responded to by an administrator, whereas persons conducting imaging examinations in practice participated in the inspections. The regulatory control project will continue until spring 2022, and its results will be compiled in a STUK-B series report in early 2022. Inspections were additionally conducted on new undertakings with CBCT activities.

The suppliers of X-ray equipment notified STUK of dental X-ray equipment installed in 2021. The notifications revealed 30 cases in which the undertaking had not applied for a safety licence for the X-ray appliance before the activities were launched or the appliance was taken possession of, or in which STUK had not been notified rapidly enough after the appliance's commissioning. These undertakings were instructed to ensure compliance with the licence requirements.

X-ray practices

In the regulatory control of X-ray practices, the emphasis was on cardiological use of radiation and supervision of new undertakings.

In early 2021, STUK carried out a preliminary survey addressed to units conducting cardiological examinations and procedures. The preliminary survey examined the use of radiation shields and dosemeters, the optimization of equipment software and radiation protection training in units, among other things. STUK conducted on-site inspections at units selected on the basis of the survey responses and previous control observations in 2021–2022. On the inspections, the units' patient activities were monitored for a day, and their personnel were interviewed. Particular attention was paid to the personnel's radiation safe working methods, including the use of radiation shields, placement in facilities were radiation is used and other procedures that reduce the personnel's and patients' radiation exposure. The results of the supervision project will be released in a STUK-B series report in spring 2022.

In addition, special emphasis was placed on inspections of new undertakings that had been postponed due to the coronavirus pandemic, especially towards the end of the year. In the field of veterinary X-ray practices, a report on the use of radiation safety experts in practices requiring a safety licence was produced. Undertakings that engage in these practices have an obligation to rely on a radiation safety expert when starting new activities and when necessary while the activities are in progress.

The report found that undertakings' obligation to describe the use of a radiation safety expert as part of the management system of radiation practices is emphasized in established veterinary X-ray practices, in which the use of radiation safety experts may be limited. Undertakings need be aware of situations in which a radiation safety expert should be used in connection with changes and incidents associated with veterinary X-ray practices. The findings of the report will be released in early 2022.

Suppliers of X-ray equipment notified STUK of health care and veterinary X-ray equipment installed in 2021. In connection with the notifications, ten cases were discovered in which the undertaking had not applied for a safety licence for an X-ray appliance before the practices were launched, or in which STUK had not been notified rapidly enough after the appliance's commissioning. These undertakings were requested to ensure compliance with the licence requirements.

Nuclear medicine

Regulatory control of nuclear medicine focused on confirming safety assessments and targeting control on their basis. The work on confirming safety assessments continued in 2021, which was due to the scope of the assessments and a lack of uniform approval criteria. In late 2021, on-site inspections were conducted at seven health care sites using nuclear medicine, and remote ones at 16. The inspections focused on ensuring that the operating models presented in the safety assessment were followed in practice. In addition, the practices of discharging patients and handling any radioactive waste generated after discharge as well as the calibration practices of activity meters continued to lead to a great deal of discussion between nuclear medicine undertakings and supervisors.

Radiotherapy

Radiotherapy was provided in all five university hospitals, seven central hospitals and in one private clinic for approximately 16 700 patients. In 2021, STUK carried out initial inspections of three radiotherapy appliances, one afterloading therapy appliance as well as four CT simulators and one MRI simulator, in addition to 31 other periodic inspections.

The comparative measurements between STUK and hospitals revealed that the treatment dose accuracy at hospitals was very good: the average difference was less than 0.1% for photon beams and 0.5% for electron beams. The comparative measurements did not reveal any dose deviations that would compromise the safety of treatment.

When controlling the accuracy of the patient dose in radiotherapy, multi-field plans calculated using the dose calculation system were compared with the corresponding measurement results. Inspections of dose calculation systems that affect patient doses were conducted on more than 700 radiotherapy beams. The calculation accuracy of the dose planning programmes of hospitals and the accuracy of the input data can be considered very good. No deviations of over 3% were detected in clinically used fields.

Use of radiation in industry and research

Few inspections were carried out as part of the regulatory control of radiation use in industry and research. Supervision of practices also included the processing of safety assessments, which created a heavy workload.

In 2021, 22 inspections were carried out at sites where radiation was used. A total of 35 orders to rectify practices were issued on the inspections. In addition, control relied on surveys and requests for specification more than before. If an undertaking had not complied with the time limits laid down for an application or notification, a reminder or a request for specification was sent out. The number of separate written requests was 223.

Transportation of radioactive materials including high-activity sealed sources

A safety licence is required to transport high-activity sealed sources by road and rail. One application for a new safety licence for transport was submitted to STUK in 2021. The carrier of a high-activity sealed source must notify STUK of each transport operation before it takes place or before the radiation source arrives in Finland. In 2021, the STUK received 70 notifications. The police conducted one ADR inspection of road transport of high-activity sealed sources while STUK provided expert support. No deficiencies were found in the inspected transport operation. STUK additionally provided expert support for the supervision of the transport of radioactive materials carried out by Customs, in connection with which shortcomings were found in the waybill of a consignment. STUK investigated the matter with the consignee, and the transport operation was completed normally.

Own-check survey addressed to industry and research

In 2020 and 2021, STUK sent an own-check survey to 149 industrial and research undertakings in two batches to find out if the undertakings have addressed the amendments to radiation legislation in their practices. While the purpose of the survey was to facilitate risk-based targeting of control at undertakings in occupational exposure categories 1 or 2, the responses showed that more than a half of the respondents did not belong to the correct target group. When preparing the survey, STUK had only confirmed a few safety assessments, which made it impossible to select respondents based on the categories presented in undertakings' safety assessments. The survey aimed to check background information on safety licences, radiation practices, classification of radiation workers and the use of personal, eye and finger dosemeters. All respondents answered questions about their management system, radiation safety officer, use of a radiation safety expert and the work areas. Additional questions were specifically addressed to undertakings whose practices are subject to security arrangements and those whose field of operation involves industrial radiography.

The survey helped build situational awareness of industrial and research undertakings. As positive observations, it was noted that a large number of respondents provided an apt description of the radiation safety officer's tasks and had relied on the assistance of a radiation safety expert when preparing their safety assessments. Some undertakings also noticed shortcomings in their practices when responding to the survey and stated in their responses that they would update their documents and operating methods. The survey did not produce sufficient information on security arrangements and, consequently, regulatory control will be targeted especially at undertakings whose activities are subject to security arrangements. STUK selected 33 undertakings based on the survey and will strive to conduct use of radiation inspections on them in 2022.

Control project on use of radiation by the Defence Forces

STUK supervised the use of ionizing radiation by the Finnish Defence Forces in 2021. The project included compiling previous supervision observations, a summary of the undertaking's safety assessments and inspections at sites where radiation is used. A total of 16 inspections were carried out. A report on the control project will be made available to the undertaking to allow them to develop their activities.

News on security arrangements of radiation sources webinar

STUK organized a webinar for undertakings complying with security levels A and B in November 2021. The webinar discussed news related to regulatory control from the past year and the plans for the following year. Based on the positive feedback received, similar webinars will also be organised for a wider audience in the future.

High-activity sealed sources

According to section 22 of regulation STUK S/5/2019, annual notifications concerning the use and possession of high-activity sealed sources must be submitted to STUK by the end of January of the following calendar year. All notifications for 2020 were submitted to STUK at the beginning of 2021. STUK compared the data to the licence register and ensured that the data from sealed sources matched. No deviations were discovered.

2.4 Manufacture, import and export of radiation sources

For deliveries of sealed sources to and from Finland in 2021, see Table 7 in Appendix 1, and for the production volumes of radioactive substances (unsealed sources) in Finland in 2021, see Table 8. The figures in the tables are based on data gathered from holders of safety licences who are engaged in trade, import, export or manufacture.

The tables do not contain the following information:

- radioactive materials procured by undertakings for their own use from other countries within the European Union, and consigned from said use to other European Union countries.
- radioactive materials delivered to other countries via Finland.
- sealed sources with equal or lower activity than the exemption level.
- smoke detectors and fire alarm system ion detectors containing americium (Am-241). Approximately 26 300 of these devices were imported, with a combined activity of about 875 MBq.
- lamps and fuses containing radioactive substances imported to Finland. Some special lamps and fuses contain small quantities of tritium (H-3), krypton (Kr-85) or thorium (Th-232).
- unsealed radioactive sources imported to and exported from Finland. On the basis of activity, the most common unsealed sources imported were Mo-99, Lu-177, I-131, W-188, I-123, Br-82, Y-90, P-32, F-18, Tl-201, I-125.

For 2021, STUK also received notifications of X-ray appliances imported to Finland and handed over to Finnish undertakings from safety licence holders engaged in their trade, import and manufacture. Based on the annual notifications, STUK verifies that all notified sealed sources and X-ray appliances are appropriately linked to safety licences.

2.5 Radiation doses to workers

A total of 13 660 occupationally exposed workers were subject to individual monitoring in 2020, and their records were entered in the Dose Register for employees maintained by STUK. The workers were involved in the use of radiation or nuclear energy or exposed to natural radiation, either radon or cosmic radiation (aviation), in their work. For the numbers of these workers, see Figure 7.

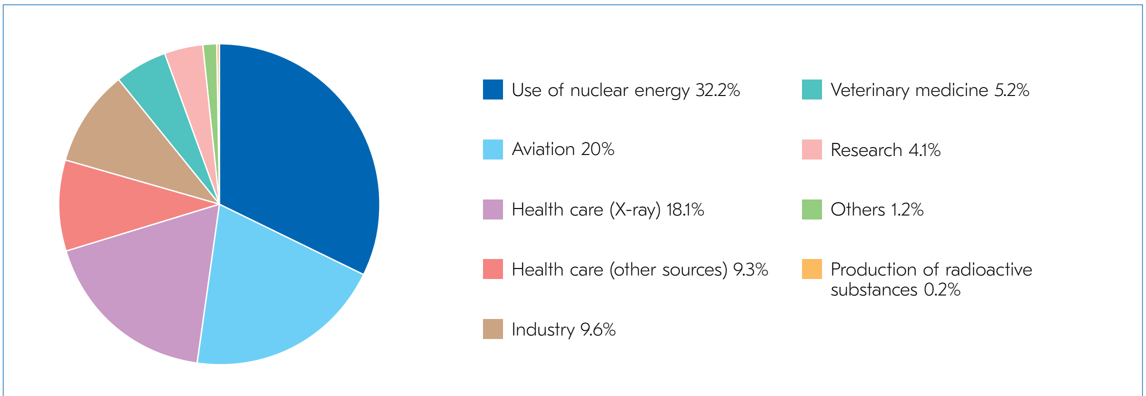
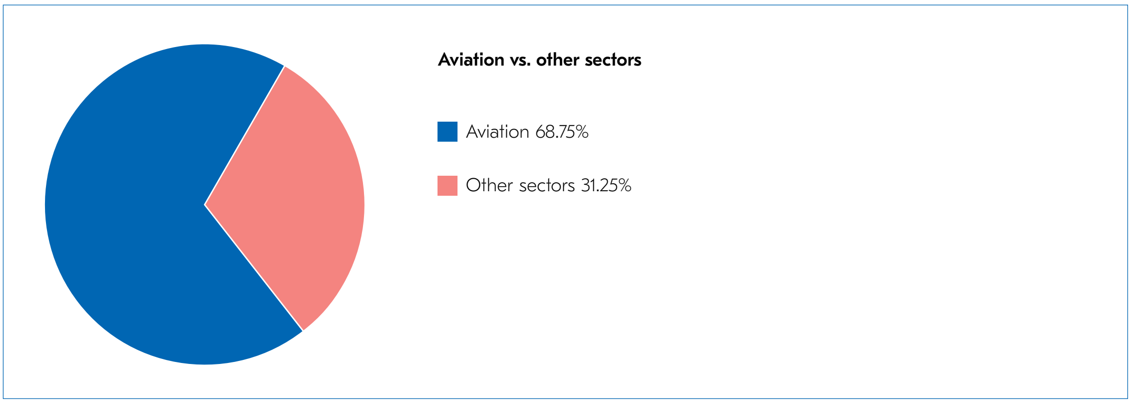


FIGURE 7. Numbers of workers subject to individual monitoring by sector in 2021. In addition to the occupational categories specified in the graph, a few people subject to individual monitoring work in the following fields: services, radon, installation/servicing/technical test operation and trade/import/export.

In 2021, there were no cases of an effective dose to a worker exceeding the annual dose limit of 20 mSv. Furthermore, the dose limits set for skin or eye lens were not exceeded for any workers. For the distribution of collective worker doses across various sectors, see Figure 8.



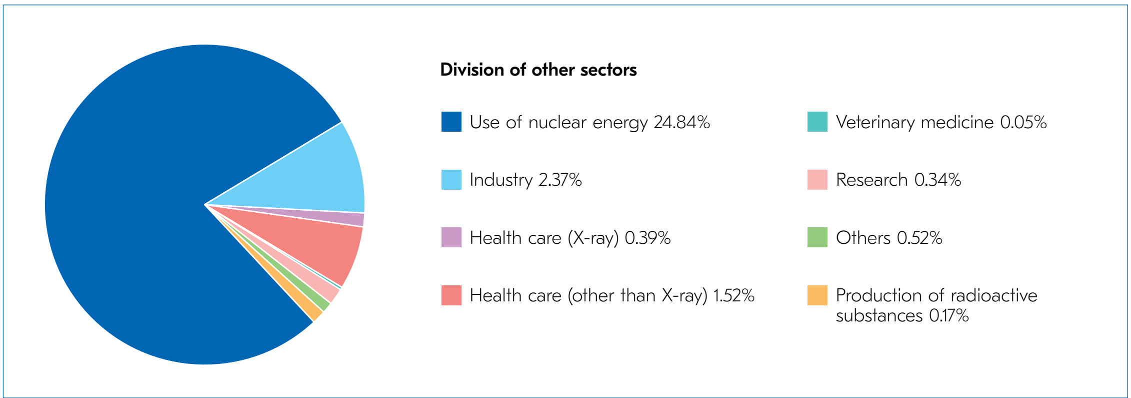


FIGURE 8. Distribution of collective effective doses for workers across various sectors in 2021. In addition to the occupational categories specified in the graph, a few people subject to individual monitoring work in the following fields: services, radon, installation/servicing/technical test operation and trade/import/export.

Table 12 of Appendix 1 shows dosage data for 2021 concerning large groups of workers with significant exposure to radiation or groups which are large in number.

Use of radiation

General trends in doses

Average worker radiation doses were of the same magnitude as in previous years. A declining trend can be observed in veterinary practices. In health care X-ray practices, other health care, research and industry, average doses have increased slightly compared to 2020. There have been major annual fluctuations in the average effective dose in the manufacture of radioactive substances, and the dose almost doubled compared to 2020. The collective effective dose of workers involved in the use of radiation was about 0.40 manSv and increased by about 24% compared to the previous year.

The average effective doses of workers by sector were: health care (radiography) 0.01 mSv, veterinary medicine 0.004 mSv, health care (other sources) 0.09 mSv, industry 0.12 mSv, research 0.05 mSv and manufacturing of radioactive substances 0.61 mSv. The median effective doses in all sectors were almost without exception zero, excluding the manufacture of radioactive substances, in which workers' median effective dose was 0.38 mSv in 2021. This is due to a large number of annual doses that are below the recording level. Consequently, it is more informative to examine the median annual doses that exceeded the recording level. The median doses that exceeded the recording level were: health care (radiography) 0.023 mSv, veterinary medicine 0.014 mSv, health care (other sources) 0.29 mSv, industry 0.32 mSv, research 0.53 mSv and manufacture of radioactive substances 0.61 mSv.

Highest doses by sector

In health care and veterinary medicine X-ray practices, the dose $H_p(10)$ measured with a dosemeter does not directly describe the effective dose. The effective dose is obtained by dividing the measured dose by a factor of 10–60. A factor of 30 is used in statistics.

An interventional radiologist was exposed to the highest dose $H_p(10)$ (40.3 mSv), followed by a radiologist (15.8 mSv) and a cardiologist (14.0 mSv). These doses $H_p(10)$ correspond to the effective doses of approximately 1.3 mSv, 0.5 mSv and 0.5 mSv. In the radiography practices of veterinary medicine, the three largest doses $H_p(10)$ were recorded for two animal attendants (7.5 mSv and 3.8 mSv) and a veterinarian (4.9 mSv). These doses $H_p(10)$ correspond to the effective doses of approximately 0.3 mSv, 0.1 mSv and 0.2 mSv. In other operations, the dose $H_p(10)$ is the approximate value of the effective dose. In the health care sector, the three largest doses $H_p(10)$ (5.6 mSv, 3.5 mSv and 3.3 mSv) caused by other radiation sources were recorded for radiographers using several sources of radiation.

In the field of industry, the largest doses $H_p(10)$ (6.5 mSv, 6.0 mSv and 5.3 mSv) were received by individuals carrying out tracer tests.

In the research sector, the five largest doses $H_p(10)$ (3.7 mSv, 3.2 mSv, 2.4 mSv, 2.1 mSv and 1.2 mSv) were received by researchers using unsealed sources.

In the manufacture of radioactive substances, the two largest doses $H_p(10)$ (7.1 mSv and 4.9 mSv) affected workers in the category "other".

Doses to the hands

In some tasks, such as the handling of unsealed sources, workers are exposed to radiation unevenly, and the dose to their hands, for example, may be considerably high, even when the effective dose is relatively low. Under the Radiation Act, the equivalent dose to hands, arms, feet and ankles may not exceed 500 mSv a year, and employees use a finger dosemeter to monitor radiation doses to the hands. In 2021, the dose to the hands did not exceed the annual dose limit for any worker. The three highest doses to the hands (164.7 mSv, 135.3 mSv and 125.4 mSv) were measured for a researcher handling unsealed sources and two laboratory attendants/bioanalysts. In addition to these three persons, the annual dose of only one radiographer exposed to multiple radiation sources exceeded 100 mSv.

In the fields of health care, research and manufacture of radioactive substances, the sum of doses to the hands was higher in 2021 than in 2020. The average doses to the skin of the hands were 9.7 mSv in health care, 1.2 mSv in industry, 6.8 mSv in research and 5.2 mSv in the manufacture of radioactive substances.

When examining the largest doses to the hands, clearer annual fluctuations are observed. Since 2015, the largest doses to the hands have remained significantly lower than before in the health care sector. In the industrial sector, the largest doses to the hands have remained low in 2016–2021 compared to 2012–2015. In research, the highest doses to the hands were the highest recorded since 2016. In the manufacture of radioactive substances, the highest doses to the hands have remained at the same level for an extended period.

Use of nuclear energy

Workers' collective dose in connection with the use of nuclear energy was approximately 1.32 manSv in 2021. This dose was 10.5% lower than in the previous year. In the use of nuclear energy, the collective dose varies considerably each year depending on the length of annual maintenance of nuclear power plants and the type of maintenance work carried out in the plants. In 2021, the highest individual radiation dose (8.1 mSv) resulting from radiation work at Finnish nuclear power plants was registered for a cleaner. The average of the employees' doses $H_p(10)$ in the use of nuclear energy was 0.3 mSv. The median dose of all employees was 0.0 mSv and the median dose of those who exceeded the recording level was 0.56 mSv.

Aviation

In 2021, the dose data of employees of three airlines were recorded in the STUK Dose Register. None of the employees' effective doses exceeded the 6 mSv dose constraint. The highest individual annual dose for cockpit personnel was 4.10 mSv and for cabin crews 4.91 mSv. The average annual doses of cockpit personnel was 1.45 mSv and the median was 1.36 mSv. The average annual doses of cabin crews was 1.26 mSv and the median was 1.03 mSv. For the average doses of flight crews in 2012–2021, see Figure 9.

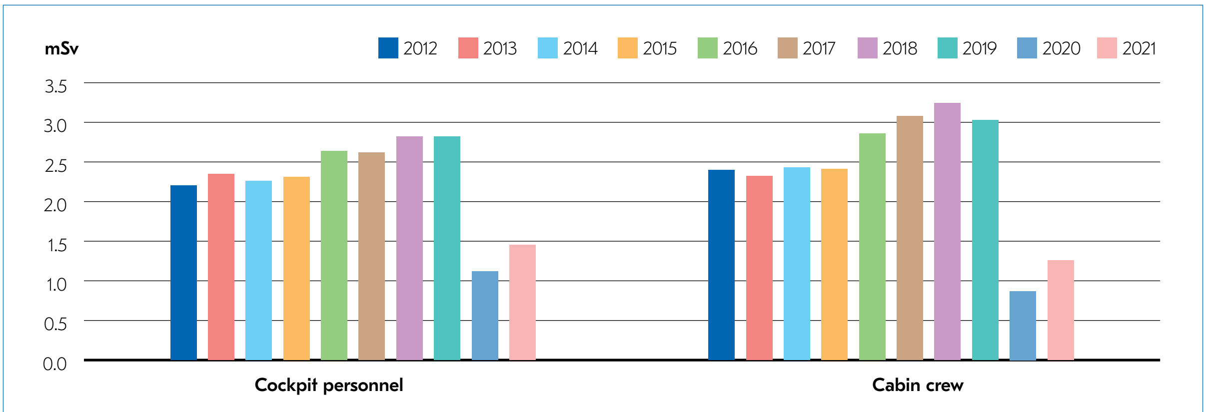


FIGURE 9. Average doses of flight crews in 2012–2021.

The total number of cabin crew members dropped by 36.1% in 2021 compared to the previous year, and their collective dose decreased by 10.2%. While the total number of cockpit personnel decreased by 22.0%, their collective dose (1.46 mSv) remained at a similar level (1.45 mSv) as in 2020. The impacts of the coronavirus pandemic remain clearly visible in the aviation sector. For the number of employees subject to individual monitoring of radiation exposure and the collective dose of employees, see Appendix 1, Table 9.

Changes over 10 years

For the numbers of radiation workers subject to individual dose monitoring by sector for the last ten years (2012–2021), see Appendix 1, Table 10. For collective employee doses by sector, see Figure 1 (chapter 1.1) and Table 11 in Appendix 1.

Radon at workplaces

Dose data concerning workers exposed to natural radiation at work are also recorded in the Dose Register.

The monitoring of radon doses in a workplace, which began in 2020, continued in 2021. Four workers were subject to radon exposure monitoring during the year, and their doses were recorded in the Dose Register. The average effective dose of workers subject to monitoring was 2.32 mSv, while the median was 2.31 mSv. The largest effective dose was 3.00 mSv.

One undertaking was obliged to apply for a safety licence due to the workers' radon exposure in 2021. However, the radon doses of the employees subject to the safety licence could not be recorded in 2021.

2.6 Approval decisions and verification of competence

Training organizations providing radiation protection training for radiation safety officers

Under section 46 of the Radiation Act, STUK approves the radiation protection training and exams for radiation safety officers provided by training organizations other than a institutions of higher education. Training organizations (excluding higher education institutions) that arrange training and competence exams for radiation safety officers must apply to STUK for approval to arrange such training and exams.

In 2021, four training organizations had an approval to organize radiation protection training and exams for radiation safety officers. No new approval decisions were made in 2021 for training organizations providing radiation protection training and exams.

The approved training organizations are listed on STUK's website.

Approval decisions for dose measurement services and methods

No changes took place in the activities of dose measurement services that would have required a new approval in 2021. The existing dose measurement services continued to operate as before.

Approval decisions for radon measurements

Under section 64 of the Radiation Act, STUK approves radon measurements compliant with the requirements laid down in section 59 of the Radiation Act and the following regulations: STUK S/7/2021 and STUK S/6/2022.

Six decisions related to radon measurement approvals were made in 2021. A list of organizations which have approval for radon measurements and appropriately calibrated radon measurement equipment and which have given their consent to having their names published on the list, is found on STUK's website.

In addition, STUK issued a restriction of practice decision related to radon measurements under section 178 of the Radiation Act after receiving reports of a company selling ventilation renovations that offered radon measurements without STUK's approval.

Verification of competence of radiation safety experts

STUK made decisions on a total of ten applications to verify the competence of radiation safety experts. Six of the applicants were granted the right to serve as radiation safety experts in industry and research, and three in the use of nuclear energy. The application of one person was rejected.

2.7 Radioactive waste

STUK maintains the national storage facility for low-level radioactive waste. For the amounts of the most significant types of waste kept in the storage facility at the end of 2021, see Table 13 in Appendix 1. In 2021, the storage facility received two lots of radioactive waste. The continuing coronavirus pandemic contributed to this low number. Since the beginning of 2017, some of the radioactive low-quantity waste has been disposed at TVO's final disposal repository for nuclear power plant waste. Waste placed in TVO's final disposal repository has been removed from the inventory of low-level waste since 2019. TVO is responsible for reporting on waste placed in the final disposal repository.

2.8 Radiation safety deviations

Radiation safety deviations are divided into those requiring immediate reporting and those reported annually in summarized form. Deviations of higher significance for radiation safety must be reported immediately, whereas summarized data on minor deviations can be reported to the Radiation and Nuclear Safety Authority on an annual basis.

For the number of radiation safety deviations subject to the immediate reporting obligation in Finland in 2012–2021, see Figure 3 (chapter 1.1), including radiation safety deviations occurring in the use of non-ionized radiation, a more detailed description of which is contained in chapter 4.7.

Radiation safety deviations to be notified immediately

Under section 130 of the Radiation Act, STUK must be notified without delay of

1. a radiation safety deviation due to which the radiation safety of the workers or members of the public at the facility and place where the radiation is used or its surroundings may be compromised;
2. any significant unplanned medical exposure;
3. the loss, the unauthorized use or holding of a radiation source subject to a safety licence;
4. any significant spreading of a radioactive substances indoors or in the environment;
5. any other abnormal observations and information which may be of material significance in terms of radiation safety.

Section 4 of regulation STUK S/2/2018 provides more detailed criteria for incidents that are regarded as a significant unplanned medical exposure, which must be reported to STUK without delay.

In 2021, there were 40 radiation safety deviations related to the use of ionizing radiation which were to be notified immediately. Of these deviations, 21 concerned the use of radiation in industry and research, 18 in health care and one in veterinary practices. STUK was additionally notified of two radiation safety deviations concerning the use of non-ionizing radiation.

Radiation safety deviations subject to summarized reporting

Under section 131 of the Radiation Act, an undertaking shall notify STUK of the summarized information on any radiation safety deviations related to radiation practices other than those requiring immediate notification. These radiation safety deviations must be reported to STUK annually by no later than 1 February.

A notification of unplanned medical exposure shall include the information set out in Table 1 of Appendix 1 to regulation STUK S/2/2018. A summarized notification of unplanned medical exposure differs from the notification submitted immediately in that it only indicates the number of radiation safety deviations in each event category. No format has been defined for a notification of other radiation safety deviations which are less important in terms of safety.

Radiation safety deviations requiring immediate notification in health care

The following section describes radiation safety deviations related to the use of radiation in health care, grouped according to the type of use. An example of typical or significant deviations is given.

Radiation safety deviations in X-ray practices

Twelve deviations were notified immediately in health care X-ray practices, while this figure was ten in 2020. In eight cases, the additional exposure of the patient was at least 10 mSv, while two cases involved exposure to employees. The largest single exposure was received by a foetus, caused by trauma radiology on a pregnant woman. A few months later, the unit treating the patient was informed that the patient had been pregnant on the day of the imaging examination. According to a subsequent assessment, the pregnancy was at a very early stage at the time of the examination (week 3). The estimated exposure of the womb was approximately 28 mSv.

Example case:
An unconscious patient brought to the emergency clinic was sent to a head CT examination as a matter of urgency. The routine testing function of the device did not complete, but the examination was performed regardless, as it was considered so urgent that the patient could not be transferred to another device or unit for scanning. While the CT image was good in quality, the examination exposed the patient to a dose that was estimated to be 4 to 5 times higher than in a normal head scan. The situation was discussed at the staff morning briefing and detail was added to the instructions for the device in question. A HaiPro notification was submitted of the situation, and the matter is being investigated by the site physicists and the equipment manufacturer. The patient was exposed to a total effective dose of 9.1 mSv, of which an estimated 75% to 80% was superfluous.

Radiation safety deviations in nuclear medicine units

Nuclear medicine units reported four radiation safety deviations. The number of notifications was halved compared to 2020, in which year eight notifications were made. Two of the radiation safety deviations concerned contamination in connection with the use of radiation, one concerned the transport of radiation sources, and in one case, a radiation source had gone missing. Exposure of workers, patients and the population caused by radiation safety deviations was low.

Example case 1:
On arrival at work, an employee found that the carrier of radioactive materials had left the consignment in the public lobby. The agreed procedure is that the driver must wait for an acknowledgement of receipt of deliveries, and the sources must not be left unattended.

The carrier has also been given a telephone number they can call if the recipient cannot be found at the time of delivery. The employee checked that all sources included in the consignment were present, moved the sources to the appropriate location, reported the incident to the radiation safety officer and contacted the consignor, who said that they would contact the carrier and stress the importance of the agreed procedures.

Example case 2:
An undertaking lost a sealed source used for the quality assurance of a SPECT-CT unit. According to the undertaking's account, the sealed source had gone missing as the unit was dismantled and removed. The source had inadvertently been delivered with the device for scrapping and further to recycling. An unsuccessful attempt was made to find the source located in the device in the scrapyard and later among scrap metal. The activity of the Gd-153 sealed source contained in the appliance was approximately 30 MBq at the time of its disappearance and, due to the low activity, finding the source among the scrap was unlikely. The activity of the source dropped below the exemption level in February 2022. Not only the undertaking but also the appliance's supplier and the device recycling operator were involved in the incident. According to the account received, the deviation was caused by a misunderstanding regarding the dismantling of the device between the undertaking and the equipment supplier. To prevent the reoccurrence of similar events, the procedures related to dismantling and removal of equipment will be recorded in detail in future contracts.

Radiation safety deviations in radiotherapy

In 2021, radiation therapy units submitted two notifications of radiation safety deviations subject to the immediate reporting obligation. In one case, damage to an acceleration electrode was discovered in connection with quality assurance, and in the other, there was an alignment deviation related to pain relief radiotherapy.

Radiation safety deviations in veterinary medicine

There was one radiation safety deviation requiring immediate notification related to radiation use in veterinary medicine in 2021, compared to seven notified incidents in 2020. In this incident, the X-ray room door had been left open during a scan, and an employee who walked past may have been exposed to radiation. The incident was discussed at the unit, stressing that the door must not be left open when using the X-ray appliance.

Summarized reports on radiation safety deviations in health care and veterinary medicine

A total of 99 parties (licence holders or undertakings) notified 2 467 minor radiation safety deviations or near misses in health care or veterinary medicine in 2021. While the numbers of both parties submitting notifications and incidents increased compared to the year before, the distribution of the types of radiation safety deviations as percentages of the total number reported has remained more or less the same.

In addition to nine pre-described categories and their subcategories, the health care radiation safety deviations involving medical exposure that were notified in summarized reports were divided into other minor radiation safety incidents and near misses. Additional information was also reported for some of the incidents. In X-ray practices, one half of the reported radiation safety deviations consisted of examinations or procedures which failed for various reasons. In 18 cases, the wrong patient was scanned. A total of 14 cases of additional exposure of a support person were reported.

In X-ray and dental X-ray practices, notifications were received from 74 parties, who reported 1 824 incidents and 450 near misses. Five deviations or near misses associated with occupational exposure were also reported. In addition, 24 licence holders reported that they had not had any radiation safety deviations during the previous year.

In nuclear medicine, a notification was received for 18 safety licences, and a total of 143 incidents were reported. One undertaking reported radiation safety deviations related to radiotherapy and nuclear medicine using the same form. It is later impossible to conclude which activity the deviations were related to, which is why these 32 incidents were included in nuclear medicine deviations.

A few radiation therapy undertakings reported radiation safety deviations in radiation therapy activities in a summarized form, with a total of 36 reported incidents. Most of these incidents belonged to the category *Other radiation safety incidents related to medical exposure/ Other reason*, whereas most of the rest belonged to the category *Failed examination or procedure (other than injection of a radiopharmaceutical or contrast medium or related additional exposure)/single hardware or system failure*.

Radiation safety deviations in veterinary medicine were notified by 21 licence holders in total. Summarized reports were received of 36 other radiation safety deviations or near misses. One licence holder reported that they had not had any radiation safety deviations during the previous year. The majority of the notifications concerned the presence of fingers or hands within the radiation beam during a scan. In one case, a pregnant employee accidentally opened the X-ray room door at the very beginning of a scan, but according to a radiation safety expert's assessment, her radiation exposure was low.

For the distribution of incidents in health care X-ray practices and in nuclear medicine practices reported in the categories specified in Appendix 1 to regulation STUK S/2/2018, see Tables 1 and 2.

TABLE 1. Radiation safety deviations in health care X-ray practices, medical exposures notified in summarized reports.

Type of radiation safety deviation	Cause and factor contributing to the radiation safety deviation	Number of radiation safety deviations per year
Referral made to the wrong person, resulting in the wrong person's exposure to radiation	Human error	9
	Other reason	1
Wrong examination, procedure, or anatomical object in the referral, which has resulted in an incorrect examination or procedure	Human error	52
	Other reason	14
Examination or procedure performed on the wrong person	The patient's identity was not verified by means of a reliable method before the examination or procedure	17
	Other reason	1
Wrong examination or procedure performed, or wrong anatomical object scanned	Human error	168
	Other reason	59
Failed examination or procedure (other than injection of a radiopharmaceutical or contrast medium) or related additional exposure	Incorrect or incomplete operating instructions	11
	Human error	448
	Single hardware or system failure	324
	Systematic hardware or system failure	129
	Other reason	301
Injection of radiopharmaceutical or contrast medium failed	Human error	17
	Technical failure of device or equipment	16
	Other reason	98
Unnecessarily repeated examination	No information on a previous similar examination, or results of a previous examination unavailable	29
	Other reason	42
Unintended foetal exposure	Pregnancy at such an early stage that it could not be confirmed	1
	The possibility of pregnancy was not determined using a reliable method before the procedure or examination	1
	Other reason	1
Extra exposure of a support person	Human error	9
	Incorrect or incomplete operating instructions or non-compliance with the instructions	3
	Other reason	2
A near-miss situation occurring more than once for the same reason	Operational error	295
	System or device error	84
	Other reason	71
Other radiation safety incidents related to medical exposure	Other reason	72

TABLE 2. Radiation safety deviations in nuclear medicine, medical exposures notified in summarized reports.

Type of radiation safety deviation	Cause and factor contributing to the radiation safety deviation	Number of radiation safety deviations per year
Referral made to the wrong person, resulting in the wrong person's exposure to radiation	Human error	0
	Other reason	0
Wrong examination, procedure, or anatomical object in the referral, which has resulted in an incorrect examination or procedure	Human error	2
	Other reason	0
Examination or procedure performed on the wrong person	The patient's identity was not verified by means of a reliable method before the examination or procedure	0
	Other reason	0
Wrong examination or procedure performed, or wrong anatomical object scanned	Human error	2
	Other reason	1
Failed examination or procedure (other than injection of a radiopharmaceutical or contrast medium) or related additional exposure	Incorrect or incomplete operating instructions	12
	Human error	6
	Single hardware or system failure	10
	Systematic hardware or system failure	0
	Other reason	3
Injection of radiopharmaceutical or contrast medium failed	Human error	12
	Technical failure of device or equipment	10
	Other reason	9
Unnecessarily repeated examination	No information on a previous similar examination, or results of a previous examination unavailable	2
	Other reason	2
Unintended foetal exposure	Pregnancy at such an early stage that it could not be confirmed	0
	The possibility of pregnancy was not determined using a reliable method before the procedure or examination	0
	Other reason	0
Extra exposure of a support person	Human error	0
	Incorrect or incomplete operating instructions or non-compliance with the instructions	0
	Other reason	0
A near-miss situation occurring more than once for the same reason	Operational error	6
	System or device error	43
	Other reason	0
Other radiation safety incidents related to medical exposure	Other reason	23

Radiation safety deviations subject to the immediate notification obligation in industry and research

A total of 21 notifications of radiation safety deviations related to the use of radiation requiring immediate reporting were made in industry and research. For example, these incidents were related to the use of sealed and unsealed sources, use of X-ray appliances, and discovery of radiation sources in the metal recycling process or otherwise.

Use of sealed sources and X-ray appliances

Five radiation safety deviations related to the use of unsealed sources and X-ray appliances were reported to STUK. In two cases, an employee was exposed while a fluoroscopy appliace was in use, and in one, lead rubber curtains had been removed from a fluoroscopy appliance. The other two cases were related to exposure to sealed sources.

Example case 1:
An employee ended up on the fluoroscopy appliance's conveyor belt while reaching for an item that was on it. The system was stopped by pressing on the emergency stop button when the fluoroscopic image showed that the employee had passed through the appliance. The employee could have pressed the emergency stop button before ending up in the X-ray machine, but they either did not notice the buttons or were not aware of them. Reminding the employees of the instructions and the location of the emergency stop buttons was identified as a measure helping to prevent similar situations.

Example case 2:
A food package of a certain size could not pass properly through the fluoroscopy appliance, which is why the appliance's lead rubber curtains were removed. No fluoroscopy was used for this package, but the device was part of the conveyor belt. When fluoroscopy using this appliance was restarted, replacing the lead rubber curtains was forgotten. Service company employees noticed higher than usual dose rates in the vicinity of the appliance and discovered that the lead rubber curtains were missing. The employees were instructed not to tamper with the structures of the fluoroscopy appliance. The undertaking also plans to bring this matter up in employee training.

Example case 3:
Two contractors were replacing the belt of a conveyor belt scale that contained a sealed source. One of them crawled through the measuring frame of the conveyor belt scale. An employee of the undertaking noticed the situation and told the contractor to leave this area. In breach of instructions, the shutter of the conveyor belt scale's sealed source had not been closed. The contractor's exposure was estimated at 3 μSv. To prevent similar situations in the future, the undertaking stated that they would provide training for their personnel and add detail to the contractors' orientation material.

Industrial radiography

A total of five radiation safety deviations related to industrial radiography were reported to STUK. There were shortcomings in such areas as communication, delimiting scan areas and checking the operating condition of appliances and peripheral devices before use.

Example case:
Scan technicians were conducting an inspection of welds in a ship's hull. The scan operator manned the device outside the hull, while their partner was inside the hull. Inadvertently, the unit operator gave their partner permission to change the position of the reception panel even though the radiation beam was still on. The technician inside the hull noticed that the radiation alarm was sounding and informed the unit operator, who immediately turned off the radiation source. The exposure lasted for a maximum of 10 seconds, and according to an assessment made after the incident, there was no reason to suspect exposure. The technician's dosemeter recorded no dose during the period in which the deviation occurred. As corrective measures, the undertaking proposed discussing the hazardous situation with its personnel and partners as well as issuing more detailed instructions regarding radiation protection at noisy sites.

Use of unsealed sources and radioactive waste

Four radiation safety deviations related to the use of unsealed sources and handling of radioactive waste were notified to STUK. These cases concerned non-use of dosemeters, exposure to contamination and a higher than usual radiation dose.

Example case 1:
A category A radiation worker changed duties. New dosemeters were ordered for them. The employee could not find dosemeters in their workplace, and their supervisor instructed them to use an electronic dosemeter. As the dosemeter measurement period ended, the employee did not return their dosemeter, and the radiation safety officer asked the employee about the matter. The employee explained that they could not find any dosemeters, and had not used them during the measurement period. Neither had they used an electronic dosemeter when performing radiation work. The radiation safety officer ensured that the employee did use a dosemeter during the next measurement period.

Example case 2:
An employee was getting ready to collect a sample of a raw material solution in a hot cell when they, during the cleaning operation, injected their finger with a needle containing radioactive material. The needle went through three pairs of nitrile gloves, and the puncture site started bleeding. The employee conducted measurements to verify that there was no contamination at the puncture site and in the protective clothing, after which they went to clean the wound. It was estimated that the skin of their finger had been exposed to a radiation dose of approximately 1.6 mSv as external radiation from beta radiation. Employees are advised to take special care when handling needles and needle covers.

Transportation of radioactive materials

No radiation safety deviations related to the transportation of radioactive materials were reported to STUK in 2021.

Radiation sources found and other deviations

Six of the radiation safety deviations reported to STUK in 2021 were about radiation sources or radiative loads found in the metal recycling process. One case was about an unauthorized sale of an X-ray appliance on social media. A social media user had noticed the sales advertisement and informed STUK. The unauthorized X-ray appliance on sale was quickly delivered for scrapping.

Example case 1:

A load of recycled metal that was leaving the scrapyard triggered the alarm at the radiation portal monitors. The load was tipped into a skip in the yard and the radiation source that had caused the alarm was searched for. A white, fist-sized piece that emitted radiation was found on top of the load. This item was not a typical radioactive sealed source.

The scrapyard contacted STUK. STUK inspectors visited the scrapyard and used radiation meters suitable for identifying nuclides to search for the radiation source and conduct activity measurements. Their goal was to identify the radionuclide. The item had contaminated a metal plate found under it, which was determined by measuring a sweeping test taken from it. The final nuclide identification was carried out at STUK using a liquid scintillation counter.

STUK revisited the site the following day, took possession of the radiating item and carried it away from the scrapyard. Radioactive contamination and other possible objects emitting radiation were also sought across a wider area in the scrapyard.

Radiation safety deviations to be reported in summarized form in industry and research

Undertakings in industry and research submitted to STUK a total of four notifications of radiation safety incidents to be reported in summarized form for 2021. In addition, three notifications were submitted to STUK stating that there were no radiation safety incidents in 2021.

These notifications came from undertakings whose operations involve extensive use of unsealed sources. The submitted notifications included a list of 35 deviations, 25 of which were related to low-level contamination cases that the undertakings were not under obligation to report to STUK immediately. Seven of the deviations were related to malfunctions in various devices or systems. The notifications also reported cases where radiation safety observations had been made but no radiation safety deviation had occurred.

3 Regulatory control of practices causing exposure to natural radiation

This Chapter describes the regulatory control of practices related to natural radiation from the ground and soil and cosmic radiation.

3.1 Radon at conventional workplaces

In recent years, radon data from new workplaces have increasingly been reported to the national radon database. At the end of 2021, there were more than 17 500 workplaces in the database. Of these, nearly 3 000 (12 260 measurements) were new workplaces in 2021, the measurement data of which had not previously been available to STUK. The target had been set to record the radon concentrations of more than 2 000 new workplaces in the national radon database, and this target was reached.

Around 14% of conventional workplaces where measurements were conducted in 2021 had annual average radon concentrations exceeding the reference level of 300 Bq/m³. The median radon concentration of conventional workplaces recorded in the national radon database was 33 Bq/m³.

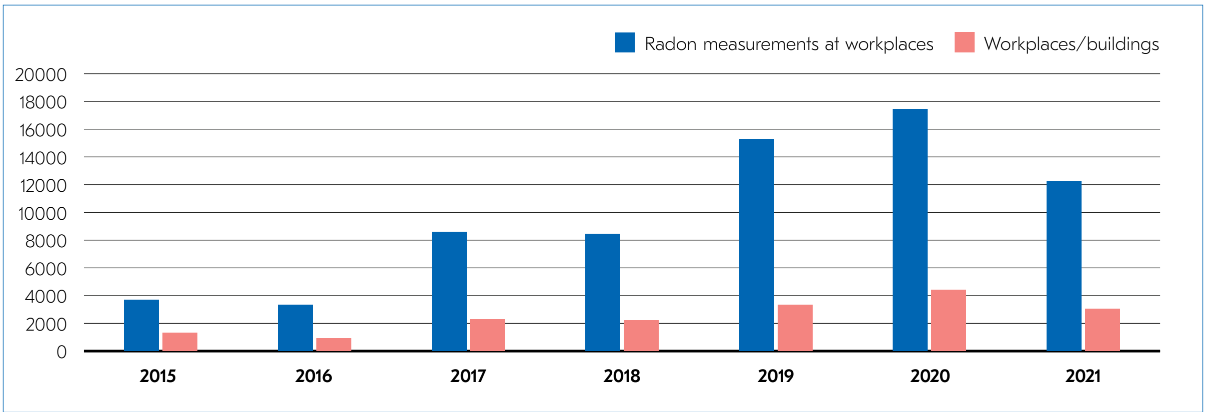


FIGURE 10. Number of workplace measurements/sites recorded in the national Radon Database in 2015–2021 by the end date of the measurement period.

More than 200 monitoring documents in which a workplace was ordered to reduce its radon exposure or to carry out additional investigations were issued. At the end of the year, 339 workplaces remained subject to radon monitoring, which means that either the employees' radon exposure was found to be excessively high and the employer had not yet been able to limit it, or more detailed radon measurements had to be made at the workplace. STUK monitors the implementation of these measures.

TABLE 3. Key figures of radon concentrations in conventional workplaces measured using STUK's and other suppliers' alpha track radon detectors in different years.

Annual average radon concentration (Bq/m³)	2015	2016	2017	2018	2019	2020	2021
	% of the entire year's measurements by workplace						
< 300	87	83	85	82	81	87	86
≥ 300	13	17	15	18	19	13	14
≥ 1 500	2	2	2	2	3	2	2
	Number of workplaces						
< 300	1 144	764	1 968	1 800	2 765	3 808	2 584
≥ 300	171	154	343	390	541	567	437
≥ 1 500	24	21	45	52	105	76	57
Total	1 477	1 074	2 639	2 563	3 916	4 903	3 021
	All workplace measurements (Bq/m³)						
median	48	58	44	42	44	30	33
average	147	188	144	143	141	109	111

3.2 Radon in underground mines and tunnels and at excavation sites

Workplace radon concentrations were monitored in five underground mines and at 15 underground excavation and construction sites. In two mines and at one excavation site, radon concentrations above the reference value of 300 Bq/m³ were measured. Of these, however, the radon exposure of workers in one mine proved to be below the reference value for exposure. Consequently, STUK ordered one mine and one excavation site to reduce their radon exposure.

At one underground construction site, radon concentrations that exceeded the reference value could not be sufficiently reduced. The party responsible for the activities consequently applied for a safety licence for activities causing exposure to natural radiation for the site in question. The licence was issued in November 2021. The activities are related to the construction of a new district heating pipeline in a tunnel where approximately 60 employees work full-time and about 90 employees for shorter periods.

3.3 Radioactivity of construction materials

STUK carries out regulatory control of exposure caused by natural radioactive substances contained in construction materials and other materials. More than 45 monitoring documents were drafted concerning the regulatory control of radioactive materials in building supplies.

3.4 Regulatory control of industry causing exposure to naturally occurring radioactive material (NORM control)

In industrial processes using natural materials, naturally occurring radioactive materials may accumulate in process fractions and equipment. Such activities include mining, the operation and maintenance of coal and peat power plants, and groundwater treatment. Naturally occurring radioactive materials usually refer to uranium or thorium with their progeny and potassium-40. An industrial process may change the structure of natural materials, including minerals, which may upset the equilibrium of naturally occurring radioactive materials, causing them to accumulate in different fractions based on the chemical properties of the base elements. Natural occurring radioactive materials may cumulate in waste, sludges, water, by-products, pipelines or filters, for instance. Such materials may also be referred to as NORMs (naturally occurring radioactive materials).

In NORM control, 33 new cases were initiated in 2021. NORM control cases mainly include notifications and reports of natural radiation exposure and some cases concerning waste. In addition, 18 statements were issued to other authorities concerning such matters as the EIA assessments and environmental permits of mines. At the end of 2021, 23 reports were pending, while the processing of 33 reports had been completed during the year. In particular, STUK has processed reports submitted by power plants burning coal and peat as well as mining operators.

The Monitoring and Situational Awareness unit in The Department of Environmental Radiation Surveillance's provides NORM control with information on natural radiation observations made by Customs. The NORM control unit was informed of 75 observations made by Customs in 2021. Most of these observations concerned firebricks and potassium used as a raw material for fertilisers.

3.5 Regulatory control of cosmic radiation in aviation operations

Three airlines have a safety licence for aviation operations. Previous experiences have shown that remote inspections are highly suitable for inspections of airlines.

4 Regulatory control of the use of non-ionizing radiation

4.1 General

In this context, "non-ionizing radiation" refers to ultraviolet radiation, visible light, infra-red radiation, radiofrequency radiation, low-frequency and static electric and magnetic fields as well as ultrasound. Coherent light, or laser radiation, is a special type of visible light. The use of non-ionizing radiation requires a preliminary inspection only in certain special cases, such as the use of high-powered laser equipment in public performances. In other respects, the Non-Ionizing Radiation (NIR) Surveillance Unit of STUK conducts market surveillance of devices and practices that cause public exposure to non-ionizing radiation.

Market surveillance is targeted at the following services:

- sunbed services
- consumer laser devices and other products emitting optical radiation
- wireless communication devices and high-powered radio transmitters causing public exposure
- radiative devices at home and in the office
- cosmetic treatment devices that utilize non-ionizing radiation and their use in services.

In addition to regulatory control, STUK approves the methods and instructions for radio and radar devices used by the Finnish Defence Forces for inspections and monitoring.

For the work of the NIR Unit in regulatory control of the use of non-ionizing radiation in 2012–2021, see Tables 14 to 17 in Appendix 1. In 2021, STUK intervened a total of four times in the online auction of a dangerous laser pointer. As in previous years, STUK received a high number of requests for official statements and information requests related to electromagnetic fields from the authorities. In particular, STUK received several requests for statements on power line projects.

Society's restrictive measures imposed because of the coronavirus pandemic in 2021 continued to have an impact on the supervision of laser shows as well as sunbed facilities. While very few laser shows were organized in the spring, activities picked up slightly in the autumn. In the control of sunbed facilities, an experimental remote monitoring project focusing on fitness centres in Southern Finland turned out to be successful. Through a remote supervision survey, the project covered a considerably larger number of sites than in previous years.

The increased online trade with consumers ordering products directly from outside the EU poses a challenge to the regulatory control of consumer goods. In addition, the prices of such products as high-powered laser equipment have decreased considerably as a result of the advancement of technology. In many product categories, traditional branded products have been joined by cheap non-branded models. STUK has been actively monitoring the situation for several years. In 2021, the number of hazardous laser pointers sold in online auctions was lower than ever before.

In addition to carrying out regulatory control, STUK alleviates the harmful effects of such phenomena as UV radiation through active communication. Concerns related to mobile phone base stations and wireless networks have been particularly prominent in citizens' inquiries and information requests addressed to STUK.

4.2 Regulatory control of devices emitting UV radiation and visible light

Regulatory control of sunbed devices and facilities is carried out in co-operation with the municipal health protection authorities. The Radiation Act prohibits the use of sunbeds by those aged under 18. Health inspectors inspect the facilities as part of regulatory control pursuant to the Health Protection Act and submit a report on their findings to STUK, which makes decisions on potential measures. In addition, STUK carries out its own inspections where necessary.

The transition period for the Radiation Act amendment that prohibited self-service sunbed facilities ended already on 1 July 2015. In 2021, non-compliance with the requirement was still discovered, and enhanced regulatory control was continued. Altogether 18 inspections of sunbed facilities were carried out by municipal health protection authorities. In addition to this, four sunbed facilities were supervised on the basis of monitoring carried out by STUK (Appendix 1, Table 16). Two companies gave up sunbed activities during the proceedings. No deficiencies were detected in 30% of the facilities inspected. In 20% of the supervised facilities, the responsible person required by law was not present during all hours of use of sunbed equipment. Deficiencies relating to radiation safety instructions were detected in 40%, operating instructions in 35%, and device timers in 10% of the facilities. No shortcomings were found in the availability of eye protection.

Due to the coronavirus pandemic, a monitoring survey was developed for the remote supervision of sunbed facilities. It was sent to 56 operators of sports venues in Uusimaa. To this survey, 61 responses were received from different sites. In connection with the survey, undertakings were also provided with instructions and information on requirements under the Radiation Act related to sunbed facilities. Of the responding facilities, 17 (28%) no longer had a sunbed, 27 (44%) were compliant with the Radiation Act, and 14 (23%) had shortcomings in their practices. The survey found shortcomings in the following areas: presence of the person responsible for the activities (7 sites), sunbed timer (6), UV radiation safety instructions (5) and instructions for using the sunbed (4). All undertakings with shortcomings in their operations corrected their practices to ensure compliance with the Radiation Act (12 sites) or gave up sunbed practices (2 sites).

The coronavirus pandemic has increased interest in disinfection by UVC radiation. STUK targeted market surveillance at UVC disinfectors intended for consumers. Compared to the international market, the number of devices offered in Finland was relatively low. Of the four available devices, one had no shortcomings, while the labelling and instructions for use of two needed improvements. One of the tested devices emitted no UVC radiation, and the vendor withdrew it from the market. As a new technology for UVC disinfection, farUVC devices, which use 222 nm wavelength for disinfection, came to the market. STUK assessed the user safety of farUVC lamps and found that using farUVC lamps is safe if the instructions in the operator's manual are followed. The safety of installations was assessed at two sites where the farUVC lamps were used following instructions.

An assessment of the safety of devices emitting visible light focused on efficient torches intended for consumers. Seven torches were tested. The end result of the testing was that under the expected conditions of use, the exposure limit values were not exceeded.

4.3 Regulatory control of laser devices

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

In connection with market and on-site surveillance, STUK intervened four times in the sales or use of laser devices. These devices were laser pointers sold on websites focusing on trade between consumers.

Reports on 25 laser devices were made to the EU Safety Gate for dangerous non-food products/RAPEX. These devices were not found on the Finnish market.

STUK received 38 notifications of the use of laser devices in public shows and inspected two of them on site. As a result of the coronavirus restrictions, the number of shows was in the same range as in the previous year also marked by the COVID-19 pandemic, and they were smaller 'underground' performances. While the inspections mainly found that the safety arrangements and laser beam alignment complied with the requirements, some features of concern came up particularly in 2021. No notification at all was submitted of around 21% of the shows (8), and 13% (5) of the notifications were submitted to STUK late. Two undertakings were issued with a written request to rectify the matter, and one with two reprimands. It was also reported to STUK that in one show, the alignment of the laser beams and the placement of the laser equipment did not correspond to the notification given after the show. An investigation request was made to the police in this matter. Three licences valid until further notice were issued in 2021, and the total number of valid licences was 13. No fixed-term licences were applied for in 2021.

4.4 Regulatory control of devices producing electromagnetic fields

In 2021, STUK tested ten mobile phones as part of a regulatory control project focusing on SAR testing of 4G phones. The results of the measurements will be posted on STUK's website in 2022. Mobile phone base stations were monitored through preliminary safety analyses based on contacts made by citizens. All base stations were found to be safe and installed in a compliant manner. In 2021, STUK launched a project aiming to develop a measurement method for assessing the exposure caused by 5G base stations. The development project continues in 2022.

A report was produced on anti-theft gates used in stores. The proportions of different gate types were mapped in shopping centres in the Helsinki Metropolitan Area. Of the 327 inspected gates, 78.3% were RF gates operating on a 8.2 MHz frequency, and 21.7% were AM gates operating on a 58 kHz frequency. EM gates operating on audio frequencies were no longer in use. The magnetic fields generated by the gates were measured in accordance with the standard on eight RF ports and six AM ports. Based on the measurement results, the exposure caused by all RF gates was lower than the action level for population exposure, whereas the exposure caused by AM gates exceeded the action level with five gates. However, the exposure limit value was not necessarily exceeded. To verify this, a numerical modelling and calculation of the exposure situation would have been required, which were not possible for the purposes of this report. Exceeding the action level does not cause health hazards in the case of anti-theft gates, however, as in normal use people walk through them and the exposure remains short. However, the pulsating magnetic field of AM gates may interfere with a pacemaker if the person stops and leans on the gate.

The electric and magnetic fields created by medium voltage (20 kV) overhead power lines were studied through measurements and calculations. In addition, magnetic fields in the vicinity of underground cables and transformer substations were measured. The goal was to post information based on studies conducted by STUK on STUK's website. A comparison of calculation and measurement results showed that the calculations provided reliable results. Under the overhead lines, the electric and magnetic fields were small; the strength of the electric field was less than 2% and the magnetic flux density was less than 0.1% of the action level for population exposure. The magnetic fields created by underground cables were also small, or less than 0.2% of the action level for population exposure. Near a transformer substation wall (20 cm), the highest measured magnetic flux density was about 5% of the action level for population exposure, and the maximum magnetic flux density scaled for maximum current was 26% of the action level. Consequently, the population exposure caused by medium voltage overhead lines, underground cables and containerised substations is very low.

4.5 Regulatory control of cosmetic NIR applications

Initiated in 2016, an extensive campaign focusing on regulatory control of companies providing cosmetic treatments continued in 2021. A total of 25 requests for information were sent to undertakings providing cosmetic services in 2021. In particular, the regulatory control focused on strong laser devices and their use, on which STUK received information based on both its observations and reports received. In five of the investigated cases, use of an excessively powerful laser device was discovered. The regulatory control resulted in the voluntary suspension of the use of laser devices or the initiation of a licence application process to operate as a health care unit. One undertaking was issued with a decision to suspend the practice in connection with the use of a laser device exceeding the limit values. In one case, a laser device had not yet been procured, and the service was marketed in advance to survey demand.

In addition to laser devices, beauty care devices transmitting radiofrequency radiation were also targeted in regulatory control. In two cases, drafting more detailed care instructions was regarded sufficient as a corrective measure that justified the continued use of the devices, excluding use in health care units. If the prepared care instructions are followed, the exposure limit values are not exceeded during the procedures.

Following a transition period, the limit values for light impulse and ultrasound equipment will be applied in market surveillance from the end of 2023 onwards. In connection with the regulatory control of these device types, efforts have been made to inform undertakings about the situation of their devices after the transition period.

In other respects, regulatory control focused on supervising compliance with other obligations under the Radiation Act. They included the undertaking's obligation to inform the customer of the risks of a cosmetic procedure if the exposure limit values laid down in the Ministry of Social Affairs and Health Decree are exceeded, and the obligation to take into account the contraindications of the procedure before it is initiated and to specify them in writing. In addition, STUK gave three lectures on the requirements under the Radiation Act to students of the beauty care field in 2021.

4.6 Other tasks

STUK received a request for a statement on power line projects and land use plans near power lines. Altogether seven statements were issued on projects. Four statements were issued on other matters related to non-ionizing radiation.

In addition to regulatory control, STUK's NIR unit replied to 700 citizen inquiries in 2021. Of these inquiries, 212 were made by telephone and 488 by email. In particular, these inquiries concerned radiation related to mobile phones, base stations and power lines as well as household appliances and electrical wiring. Citizens were concerned over the new 5G technology in mobile communication devices, and a high number of inquiries were made related to it. Additionally, STUK's web pages on this theme attracted an extremely high number of visits. Many inquiries also concerned laser equipment and, motivated by the coronavirus pandemic, UVC radiation and devices. The number of inquiries concerning the use, sale or import of beauty care devices also went up significantly in 2021 compared to a few previous years.

4.7 Radiation safety deviations in the use of non-ionizing radiation

In 2021, STUK received two notifications of incidents associated with non-ionizing radiation. STUK received a notification of injuries caused in beauty care services related to superficial burning of the skin during hair removal. The treatment had been offered using a device that utilized radio frequency radiation and light pulses.

STUK was informed of a laser show for which the required advance notification had not been submitted. In addition, there was reason to suspect that the alignment of the beams may have put human health at risk. An investigation request was made to the police in this matter (see section 4.3).

5 Regulation work

The amendments to the Radiation Act drafted on the basis of proposals made by STUK in 2021 were circulated for comments in connection with the Government proposal on radiation legislation. Proposals for amendments to the decrees issued by virtue of the Radiation Act were also circulated for comments. STUK additionally issued four revised regulations, two of which concerned non-ionizing radiation, one the measurement of ionizing radiation, and one the security arrangements for radiation sources requiring a safety licence.

6 Research

The objective of STUK's research activities is to produce new information on the occurrence and measuring of radiation, the harmful effects of radiation and their prevention, and the safe and optimal use of radiation sources and radiation use methods. Research supports the regulatory and metrological activities of STUK and the maintenance of emergency preparedness.

Other objectives of the research related to the use of radiation includes building up knowledge and expertise in this field and enabling reliable measurement of radiation. Research on ionizing radiation is mainly related to medical uses of radiation. There is a continuous need for research because of the rapid progress of examination and treatment methods. Research on non-ionizing radiation focuses on the exposure determination methods necessary for regulatory control and the development of regulations.

The Finnish Consortium for Radiation Safety Research (Cores) continued its active operation and expanded its work to all five university hospitals in Finland. Cooperation with universities also continued with the Helsinki Institute of Physics (HIP). Through the Helsinki Institute of Physics, STUK is a member of the Knowledge Transfer for Medical Applications group of the European Organization for Nuclear Research (CERN). STUK has been actively involved in updating the strategic plans and research roadmaps of European research consortia.

Research and development projects

The majority of research related to radiation use is carried out in cooperation with Finnish and foreign research institutes, universities and (university) hospitals. Through joint projects, STUK expands the competence base of radiation safety research and, on the other hand, improves the effectiveness of research.

Horizon Europe, a research programme funded by the European Commission, was launched. Horizon Europe comprises the Euratom programme. STUK will participate in its partnership programme in the field of radiation and nuclear safety. This programme and project (PIANOFORTE) will organize three calls for proposals for research funding. STUK will assess the scientific quality and interdisciplinary cooperation of the selected research projects.

STUK participated in the work of the EURADOS working groups 2 (Harmonization of individual monitoring), 7 (Internal dosimetry), 9 (Radiation dosimetry in radiotherapy) and 12 (Dosimetry in medical imaging). STUK was also involved in the EURADOS research strategy update. With regard to the use of radiation, the EURADOS study focused on methods for determining patient exposure and the optimization of exposure. A project aiming to analyse the total dose caused by radiotherapy (incl. imaging) was continued in collaboration between EURADOS, IAEA and EFOMP. STUK participates in the computational determination of patient doses and the characterisation of imaging devices as well as coordinates the project. The project includes the use of machine learning methods in determining patient doses. The Finnish project partners were Helsinki University Hospital and Tampere University Hospital.

STUK assessed doses to the eye of a group of employees exposed to radiation in nuclear medicine using thermoluminescence detectors (TLDs). Doses to the eye were also examined in interventional radiology and cardiology. At the same time, methods were developed for reliable evaluation of the dose to the eye based on the available exposure parameters and artificial intelligence (AI) models. The results will be used for directing the regulatory control of the authorities.

STUK convened a national working group to consider how the calibration of activity meters used in nuclear medicine imaging and therapies can be carried out in practice (Calibration of activity meter, Akka).

STUK was selected to participate in a research project coordinated by the IAEA (Coordinated Research Project, CRP, E24024), which examines the need to update dosimetry practices in X-ray imaging. Eight partners from different countries are involved in this project, including calibration laboratories and hospitals. This five-year project was launched in November 2021. Its aim is to collect and produce data that can be used to update international dosimetry guidelines.

A doctoral dissertation was completed in STUK that examined the levels of patient exposure caused by radiological examinations and the collective effective dose of the population and looked into how they have changed in the past twenty years (Bly Ritva. Patient exposure levels and collective effective dose to the population from radiological examinations – changes from 2008 to 2018 in Finland. Academic dissertation. STUK-A 265. Helsinki; Radiation and Nuclear Safety Authority: 2021).

A four-year detector development project funded by the Academy of Finland was concluded in 2021. The work was carried out in cooperation with the Helsinki Institute of Physics. The project developed position-sensitive detectors that identify the type of radiation to respond to the needs of diagnostic radiation practices and radiotherapy dosimetry. The detectors can also measure the radiation energy spectrum.

The main purpose of the RATPA project was to produce more information and expertise for assessing employees' radon exposure. In this project, 700 Finnish workplaces participated in measurements (using an alpha track radon detector, RadonEye, and gamma measurements). The project resulted in two publications: "Kojo K, Vahtola J, Kurttio P. Radonkysely työsuojeluhenkilöille (Radon survey for occupational health and safety persons). STUK-B 261. Helsinki; Radiation and Nuclear Safety Authority: 2020" and "Turtiainen T, Kojo K, Laine J-P, Holmgren O, Kurttio P. Improving the Assessment of Occupational Exposure to Radon in Above-Ground Workplaces. Radiat Prot Dosimetry 2021;196(1–2):44–52". Some of the analyses of the project and reporting of its results have not yet been completed, which means that the actual work will continue after the conclusion of the project.

The FINNORM project mapped the NORM (naturally occurring radioactive material) situation in Finland, developed tools and procedures for NORM control, informed undertakings of changes in legislation, developed exposure assessment procedures, and produced two theses and a separate study related to groundwater plants. The project collected information on historical and current industrial activities and waste cases related to NORMs. For NORM control, a NORM database was developed in STUK's NAMIT information system. In the future, new sites will be added to the database as the parties responsible for the activities prepare reports or information is obtained from other projects. In this project, communication addressed at the industry took the form of press releases, surveys, brochures, lectures, webinars and websites. A thesis on extractive waste areas in Vihanti and Korsnäs and on materials emitting natural radiation in the Finnish energy industry was produced as part of the project. A separate study on groundwater treatment plants was also produced as part of the project, and it mapped NORMs at groundwater treatment plants. The FINNORM project additionally developed regulatory control. The operating methods, tools and instructions developed in the project have improved the efficiency of control.

The RadoNorm project investigates issues related to radon and NORM exposure, including variations in radon concentrations, radon repairs at workplaces (incl. underground tunnels) as well as the characterisation of NORMs, the exposure caused by them, and limiting this exposure. RadoNorm is a research project involving 56 partners funded by the European Commission. The objective of this five-year project launched in September 2020 is to support the implementation of the European Basic Safety Standards Directive (BSS), also at the levels of administration and practical control.

In late 2019, STUK continued a project launched in cooperation with the University of Eastern Finland which studies a potential causal link between very low frequency magnetic fields and Alzheimer's disease using new experimental models and with a progressive hypothesis concerning the interaction mechanism. The project also includes an epidemiological study, which investigates the link between exposure to magnetic fields generated by distribution substations and Alzheimer's disease. The results of the study can be used to assess the health risks of very low frequency magnetic fields and to communicate about the risks.

European Metrology Programme for Innovation and Research (EMPIR) and European Partnership on Metrology (EMP)

In 2020, two European metrology research programme projects were launched with the aim of creating a network-based consortium in the field of ionizing radiation metrology. In the future, the networks will coordinate metrology research needs and cooperation between laboratories. STUK participates in both projects. Underpinned by one of these projects, a new European Metrology Network for Radiation Protection was established in autumn 2021, in which STUK is a founding member. The other project aims to create a European metrology network for the medical use of radiation in 2022.

In 2021 calls for proposals, STUK received funding for a project that will be launched in 2022. This project harmonizes measurement methods for radioactive particles in the environment.

7 International cooperation

Representatives of the Department of Radiation Practices Regulation and the Department of Environmental Radiation Surveillance are involved in a number of international organizations and commissions dealing with regulatory control and the development of safety instructions and measuring methods relating to the use of ionizing and non-ionizing radiation, and in standardizing activities in the field of radiation. These organizations and commissions include IAEA, NACP, EURADOS, EURAMET, ESTRO, ESOREX, AAPM, IEC, ISO, CEN, CENELEC, ICNIRP, EAN, EUTERP, HERCA, EURATOM/Article 31 Group of Experts, WHO and UNSCEAR. In 2021, STUK was accepted as a member in the Dosimetry section of the Consultative Committee for Ionizing Radiation (CCRI (I)) of the International Committee for Weights and Measures (CIPM) as a recognition of STUK's expertise in metrological standards related to dosimetry.

Due to the coronavirus pandemic the practice of replacing physical meetings with remote ones, which began in March 2020, also continued in 2021. A decision was also made to postpone some of physical meetings.

STUK representatives lead the nuclear medicine division of the HERCA Medical Applications working group. The nuclear medicine division investigated the use of new nuclear medicine therapies and radiation safety issues related to them among the authorities in HERCA countries. A STUK representative also chairs HERCA's working group on Research and Industrial Sources and Practices (WG RISP). STUK has additionally participated in the activities of the Nordic Working Group on Medical Applications (NGMA), the chairperson of which is similarly a STUK employee.

Participation in the work of international organizations and commissions

Representatives of the Department of Radiation Practices Regulation will chair the expert group referred to in Article 31 of the Euratom Treaty and the IAEA Radiation Safety Standards Committee.

In 2021, radiation practice experts from STUK participated in the meetings of the following international organizations and working groups:

Ionizing radiation

- IAEA: Radiation Safety Standards Committee (RASSC), chaired by a STUK representative
- IAEA: Transport Safety Standards Committee (TRANSSC)
- Euratom Article 31 expert group, chaired by a STUK representative
- HERCA (Heads of the European Radiological Protection Competent Authorities) and its working groups

- EURAMET (European Association of National Metrology Institutes) annual meeting of contact persons
- CCRI(I): Consultative Committee of Ionizing Radiation, meeting of Dosimetry Group contact persons
- IEC SC62C JWG 5 meeting (activity indicators)
- The annual meeting of EURADOS (European Radiation Dosimetry Group) and its working groups
- EACA (European Association of Competent Authorities on the transport of radioactive material)
- CERN: Knowledge Transfer for Medical Applications
- EURAMED (EURopeAn MEDical application and Radiation prOteCtion Concept: strategic research agenda aNd ROadmap interLinking to heaLth and digitisation aspects – EURAMED rocc-n-roll project), working group meetings
- QuADRANT (Constant improvement in quality and safety of radiology, radiotherapy and nuclear medicine through clinical audit) work of the project's steering group
- Meeting of the heads of Nordic authorities and its working groups ('Chefsmöte')
- NACP (Radiation Physics Committee).

Non-ionizing radiation

- ICNIRP (International Commission on Non-Ionizing Radiation Protection)
- WHO EMF project and InterSun Programme; International Advisory Committee
- IEC TC 61 MT 16 meeting (including sunbed standards)
- IEC PT 60335-2-115 meetings (standardization of beauty care devices)
- Nordic-NIR general meeting, chaired by a STUK employee.

8 Cooperation in Finland

Participation in the work of Finnish organizations and commissions

Representatives of STUK are involved in many Finnish organizations and commissions that deal with the regulatory control of and research in the use of ionizing and non-ionizing radiation, and with standardization activities in the field of radiation. They include the Advisory Body on Metrology, the Radiation Safety Day committee, the Education Committee of Medical Physicists, editors of the journal Kliininen Radiografiatiede, Eurolab-Finland, SESKO and the Finnish Advisory Committee for Clinical Audit (KLIARY) funded by the Ministry of Social Affairs and Health and appointed by the Finnish Institute for Health and Welfare, the authorities' radon working group and the USVA working group led by the Ministry of Economic Affairs and Employment. STUK experts take part in several meetings in the field of radiation safety in Finland every year, giving presentations and lectures.

STUK continued its cooperation with other authorities supervising the transportation of dangerous goods by participating in a group of supervisory authorities coordinated by Traficom and the Dangerous Goods Transportation Day. In addition, STUK participated in the steering groups for monitoring the overhaul of the Act on the Transport of Dangerous Goods and the implementation of Regulation (EU) 2020/1056 of the European Parliament and of the Council on electronic freight transport information.

Participation in meetings of Finnish working groups

In 2021, representatives from STUK participated in, among other things, the meetings of the following Finnish organizations and working groups:

- Subordinate working groups of the Ministry of Social Affairs and Health for the comprehensive revision of radiation legislation
- SESKO SK 34 committee (luminaries)
- SESKO SK 61 committee (safety of domestic electrical appliances)
- SESKO SK 106 committee (electromagnetic fields)
- The EMF Advisory Committee
- The Education Committee of Medical Physicists (radiation protection matters)
- The RDI coordination group of the administrative branch of the Ministry of Social Affairs and Health
- Authorities' radon working group
- Coordination group of STUK and Customs
- Finnish network of metrological standard laboratories
- Advisory Board coordinating radiation safety expert training (STAKONE)
- Advisory Board on Radiation Safety
- Advisory Board on Metrology.

Finnish conferences arranged by STUK

A large number of webinars on different topics, or aimed at different target audiences, were organized for radiation users in 2021.

In January, a free online course titled *Measuring radon* was published, primarily aimed at those performing radon measurements in workplaces and other living areas.

9 Communication

In 2021, STUK received a number of radiation-related inquiries through its website, by e-mail and by phone from citizens, radiation users, the media and other parties interested in radiation. Most of the questions were related to non-ionizing radiation. Several interviews on current radiation topics were given to the media.

Press releases and online news articles were prepared by the staff of the Radiation Practices Regulation Department with the following headings:

- STUK's name has been associated with misleading marketing of radon measurements
- STUK provides training for radon measurers
- An update of the policy on and national programme for spent nuclear fuel and radioactive waste management was launched - statements can be given until 19 March
- Measurements performed by Customs support the monitoring of natural radiation by the Radiation and Nuclear Safety Authority
- Laser interference may have serious consequences in aviation - a laser pointer is not a toy
- Missing radiation sources plague the steel industry
- Requirements for the use of radiation can be found in Sammio
- The high season for UV radiation is here, remember to protect your skin
- Draft national programme for spent nuclear fuel and radioactive waste management and environmental impact assessment report circulated for comments
- International recognition for STUK's dosimetry laboratory
- Radiation source found among scrap metal.

In 2021, one newsletter for radiation users in health care and one in the industrial sector as well as four radon newsletters were published.

10 Metrological activities

10.1 General

STUK serves as the national metrological laboratory for radiation dose quantities. STUK maintains national and other metrological standards to ensure the accuracy and traceability of radiation measurements carried out in Finland. STUK calibrates its own standards at regular intervals at the International Bureau of Weights and Measures (BIPM) or other primary laboratories. In connection with radiation metrology, STUK participates in the following activities, among other things:

- Advisory Board on Metrology
- EURAMET (European Association of National Metrology Institutes)
- CCRI (I) (Dosimetry section in the Consultative Committee for Ionizing Radiation (CCRI (I)) of the International Committee for Weights and Measures
- European Metrology Network for Radiation Protection.

With respect to dose quantities, STUK also participates in the international equivalence agreement (CIPM MRA), the implementation of which is coordinated in Europe by EURAMET, and in the network of secondary standard dosimetry laboratories (SSDL), which is jointly coordinated by IAEA and WHO.

Metrological activities are the responsibility of STUK's Radiation Metrology Laboratory for the dose quantities of 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).

Irradiation equipment and national metrological standards were maintained for calibrations of radiation meters for radiotherapy, radiation protection and X-ray imaging. The metrological standards laboratory for radon has been used for radon meter calibration and research alike.

10.2 Meter and measurement comparisons

In 2021, STUK participated in two dosimetry comparisons (RPLD and OSDL comparisons) arranged by the IAEA/WHO calibration laboratory network. STUK's results were well within the acceptable range and thus efficiently support STUK's calibration activities (Figure 11). STUK also participated in a European calibration comparison of surface contamination meters, the results of which are not yet available, and leads a calibration comparison of ionization chambers used in radiation therapy dose measurements.

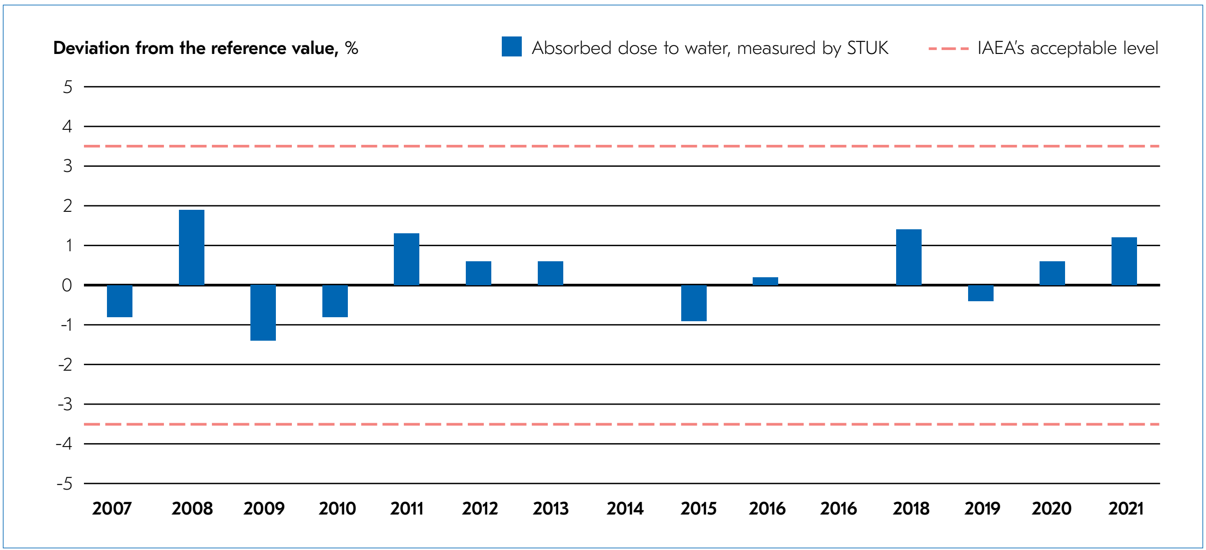


FIGURE 11. Results of IAEA dosimetry comparisons in which STUK has participated in 2007–2021.

11 Services

11.1 Calibration, testing and irradiation

STUK performed radiation meter calibrations and testing according to demand. The Dosimetry laboratory performed 717 radiation meter calibrations and irradiated 2 884 samples. Around 8% of the calibrations and irradiation operations were carried out for foreign customers, and 20% of the calibrations concerned STUK's own measuring instruments. For the trend in service output in 2012–2021, see Table 18 in Appendix 1.

The Radon metrology laboratory also produced two exposure certificates with a large number of exposures. The number of radon meters calibrated was 101.

The Non-Ionizing Radiation Surveillance Unit performed a total of five radiation meter calibrations and tests, along with four safety assessments and radiation measurements. For the service output of the NIR Unit from 2012 to 2021, see Table 15 in Appendix 1.

11.2 Other services

Altogether 33 copies of the PCXMC computer application designed for calculating patient doses in X-ray diagnostics were sold.

Appendix 1
Tables

TABLE 1. Radiation practices in the use of radiation in health care and veterinary practices at the end of 2021.

Radiation practices	Number of practices
Health care and dental care	1 385
Radiotherapy	13
Nuclear medicine	27
Veterinary practices	306
Installation/servicing/manufacture	49
Other use of medical devices (research, education)	15
Non-medical exposure in healthcare	144

TABLE 2. Radiation sources and appliances and radionuclide laboratories in the use of radiation in health care and veterinary practices at the end of 2021.

Appliances/sources/laboratories	Number
X-ray diagnostic appliances (generators)*	**1 472**
fixed conventional X-ray appliances	469
portable fluoroscopy appliances	303
portable conventional X-ray appliances	167
mammography appliances, of which	171
• screening mammograph	77
• tomosynthesis	26
fixed fluoroscopy appliances, of which	126
• angiography	41
• fluoroscopy	25
• cardioangiography	60
CT-appliances, of which	149
• SPECT-TT	37
• PET-TT	18
CBCT appliances (other than dental imaging)	21
O-arm appliances	11
bone mineral density measurement appliances	48
other appliances	7

Continues on the next page.

Appliances/sources/laboratories	Number
Dental X-ray appliances	**6 430**
intraoral X-ray appliances	5 638
panoramic tomography X-ray appliances	631
CBCT appliances	161
Radiotherapy appliances	**122**
accelerators	50
X-ray imaging appliances	51
automatic afterloading appliances	6
manual afterloading appliances	1
radiotherapy simulators	14
Sealed sources/sealed source appliances)**	**380**
calibration and testing equipment	339
radiotherapy check sources	42
attenuation correction units	1
other sealed sources in health care	1
X-ray appliances in veterinary practices	**568**
conventional X-ray appliances	354
fluoroscopy appliances	2
intraoral X-ray appliances	192
CBCT appliances	8
CT appliances	12
Radionuclide laboratories	**38**
unsealed sources in laboratories, category 1	1
unsealed sources in laboratories, category 2	32
unsealed sources in laboratories, category 3	5

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

** Sealed source appliances may be comprised of several sealed sources.

TABLE 3. Radiation practices in the use of radiation in industry and research at the end of 2021.

Use of radiation	Number of practices
Use of X-ray appliances	705
Use of sealed sources	470
Installation/servicing/manufacture	143
Import and export of radiation sources or trade in them	104
Use of unsealed sources	57
Use of particle accelerators	16
Waste treatment (if not part of practices)	5
Transport of high-activity sealed sources	4
Repeated handling or storage of orphan sources	3

TABLE 4. Radiation appliances and radionuclide laboratories in the use of radiation in industry and research at the end of 2021.

Appliances/laboratories	Number
Sealed source appliances	**5 700**
radiometric measuring instruments	4 903
calibration and testing devices	404
analysis devices	195
gamma radiography appliances	16
gamma irradiators	9
others	173
X-ray appliances	**2 189**
fluoroscopy appliances	915
analysis appliances	702
X-ray radiography appliances	403
measuring appliances	79
others	90
Particle accelerators	**29**
research	15
fluoroscopy	7
manufacturing of radioactive substances	7
Radionuclide laboratories	**90**
category 1	11
category 2	22
category 3	55
activities outside laboratories (tracer tests in industrial plants)	2

TABLE 5. The most common sealed sources used in industry, research and health care by radionuclide, and high-activity sealed sources at the end of 2021.

Radiation sources used in industry and research		**Radiation sources used in health care**	
Other than high-activity sealed sources			
Radionuclide	**Number**	**Radionuclide**	**Number**
Cs-137	3 876	Co-57	168
Co-60	688	Ge-68	75
Kr-85	273	Cs-137	37
Am-241 (gamma sources)	263	Gd-153	36
Fe-55	99	Sr-90	32
Sr-90	93		
Am-241 (AmBe neutron sources)	85		
Ni-63	75		
Pm-147	74		
High-activity sealed sources			
Radionuclide	**kpl**	**Radionuclide**	**kpl**
Cs-137	26	Ir-192	6
Co-60	11	Co-60	2
Ir-192	8		
Am-241 (AmBe neutron sources)	5		
Am-241 (gamma sources)	3		
Pu-Be	1		
Se-75	1		

TABLE 6. The numbers of sealed sources which are used in industry, research and health care and which are aged 40 years or older (unless they are decommissioned).

Radionuclide	Sealed sources aged 40 years during the transition period of the Radiation Act (pcs)		
	2021	2022	2023
Cs-137	102	137	165
Co-60	26	29	31
Am-241 (gamma sources)	14	16	16
Am-241 (AmBe neutron sources)	7	7	9
Sr-90	6	7	14
Ra-226	5	5	5
Pu-238	1	1	1
Kr-85	1	1	1
Sm-151	1	1	1
Cm-244	1	1	1
Pu-238 (PuBe neutron sources)	1	1	1

TABLE 7. Deliveries of sealed sources to and from Finland in 2021.

Radionuclide	Deliveries to Finland		Deliveries from Finland	
	Activity (GBq)	Number	Activity (GBq)	Number
Ir-192	31 243	21	1 213	22
Se-75	3 300	1	-	-
Kr-85	1 613	109	1 228	83
Cs-137	104	103	-	-
Fe-55	80	18	50	11
Ni-63	9	23	4	42
Gd-153	4	8	-	-
Pm-147	4	21	1	6
Sr-90	3	6	3	7
Am-241	3	525	3	440
Co-57	2	25	-	-
I-125	1	4	-	-
Ge-68	1	20	-	-
Others total **	<1	17	<1	2
Total	**36 367**	**901**	**2 502**	**613**

* The symbol "-" indicates no deliveries from Finland.
** Deliveries to Finland: Co-60, Sr-85, Th-228, Ra-226, Am-243.
Deliveries from Finland: Co-60

TABLE 8. Manufacturing of radioactive substances (unsealed sources) in Finland in 2021.

Radionuclide	Activity (GBq)
F-18	264 198
O-15	34 881
C-11	30 568
Ga-68	50
Total	**329 697**

TABLE 9. Number of air crew members subject to individual monitoring of radiation exposure and collective dose (sum of effective doses) in 2012–2021.

Year	Number of workers		Collective dose (manSv)	
	Cockpit crew	Cabin crew	Cockpit crew	Cabin crew
2012	1 182	2 419	2.60	5.80
2013	1 184	2 596	2.79	6.02
2014	1 213	2 441	2.74	5.93
2015	1 153	2 527	2.66	6.09
2016	1 118	2 534	2.95	7.24
2017	1 239	2 717	3.25	8.36
2018	1 306	3 042	3.68	9.86
2019	1 306	3 292	3.68	9.96
2020	1 289	3 070	1.45	2.68
2021	1 006	1 780	1.46	2.25

TABLE 10. Number of radiation workers subject to individual monitoring by sector in 2012–2021.

Year	Number of workers in each sector									
	Health care									
	Exposed to X-radiation	Exposed to other radiation sources	Veterinary practices	Industry	Research and education	Manufac-turing of radioactive substances	Radon	Others*	Use of nuclear energy**	Total ***
2012	3 989	1 083	582	1 286	720	22	79	107	3 676	11 341
2013	3 953	1 147	636	1 329	727	20	36	125	3 715	11 540
2014	3 743	1 243	653	1 257	686	22	50	143	3 621	11 197
2015	3 631	1 244	664	1 371	649	26	26	142	3 291	10 800
2016	3 548	1 218	703	1 322	644	27	34	163	3 511	10 951
2017	3 222	1 184	726	1 420	685	34	92	159	4 144	11 381
2018	3 106	1 254	762	1 439	647	31	21	168	4 794	12 002
2019	2 825	1 316	804	1 363	664	29	5	165	4 101	11 050
2020	2 651	1 287	772	1 316	563	27	4	163	3 738	10 342
2021	2 511	1 286	720	1 328	571	33	4	158	4 455	10 869

* 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 nuclear power plants.
*** The figures shown on 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 radiation sources, and there are workers in industry who are also engaged in the use of nuclear energy.

TABLE 11. Collective doses (sums of $H_p(10)$ values) to radiation workers subject to individual monitoring by sector in 2012–2021.

Year	Collective dose (manSv)									
	Health care									
	Exposed to X-radiation*	Exposed to other radiation sources	Veterinary practices*	Industry	Research and education	Manufac-turing of radioactive substances	Radon	Oth-ers**	Use of nuclear energy ***	Total
2012	1.33	0.10	0.12	0.16	0.05	0.007	0.52	0.001	2.47	4.76
2013	1.24	0.09	0.12	0.14	0.04	0.005	0.28	0.002	1.25	3.17
2014	1.29	0.08	0.11	0.16	0.04	0.019	0.23	0.007	1.57	3.28
2015	1.27	0.10	0.13	0.18	0.03	0.011	0.09	0.003	1.35	3.07
2016	1.22	0.08	0.13	0.16	0.04	0.016	0.10	0.007	1.81	3.46
2017	1.04	0.09	0.14	0.18	0.03	0.024	0.15	0.003	1.53	3.04
2018	1.01	0.10	0.13	0.16	0.02	0.030	0.07	0.010	2.37	3.83
2019	0.85	0.10	0.11	0.15	0.02	0.020	0.03	0.010	1.18	2.56
2020	0.69	0.09	0.09	0.14	0.02	0.01	0.02	0.01	1.47	2.54
2021	0.70	0.11	0.08	0.16	0.03	0.020	0.01	0.010	1.32	2.44

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

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

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

TABLE 12. Data $H_p(10)$ values) on certain occupational groups in 2021.

Group	Number of workers	Collective dose (manSv)	Average dose (mSv)		Highest dose (mSv)
			Workers whose dose exceeds recording level*	All workers subject to individual monitoringt	
Cardiologists and interventional cardiologists **	210	0.27	1.92	1.27	13.98
Radiologists **	195	0.21	3.48	1.09	15.83
Interventional radiologists **	36	0.13	4.62	3.60	40.33
Consultant specialists ** ***	286	0.03	0.71	0.11	5.18
Radiographers (other than X-radiation)	713	0.09	0.64	0.13	5.62
Animal attendants and assistants **	477	0.05	0.79	0.10	7.48
Veterinarians **	243	0.03	1.03	0.13	4.92
Industrial material inspection technicians ****	630	0.12	0.56	0.19	3.92
Other radiation worker	327	0.04	1.53	0.12	7.05
Nuclear power plant workers					
• mechanical work and machine maintenance	874	0.55	1.42	0.63	7.08
• cleaning	229	0.11	1.18	0.47	8.06
• electrical and automation work	809	0.11	0.64	0.14	5.28
• radiation protection personnel	109	0.10	1.28	0.94	5.20
• operating personnel	368	0.09	0.89	0.25	5.55

* Recording level is 0.10 mSv per month or 0.30 mSv per 3 months.

** $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. The doses to these worker groups are an exception. Workers engaged in the use of radiation (X-rays) in health care and veterinary practices use personal protective shielding, 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, orthopaedists, neuroradiologists and gastroenterologists.

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

TABLE 13. The most significant radioactive waste in the national storage facility for low-level waste (31 December 2021). Since 2019 the radioactive waste displaced to TVO's final depository has been removed from this activity inventory of low-level waste. TVO has the reporting responsibility of the waste in final depository.

Nuclide	Activity (GBq) or mass
Am-241	2 665
H-3	2 658
Cs-137	2 083
Pu-238	1 471
Kr-85	1 427
Am-241 (Am-Be)	670
Ra-226	234
Sr-90	136
Cm-244	127
Pm-147	102
Co-60	33
Ni-63	32
Fe-55	22
C-14	18
Pu-238 (Pu-Be)	7
Ra-226 (Ra-Be)	1
I-129	1
U-238 (depleted uranium)	917 kg
Th-232	11.81 kg

TABLE 14. Work of the NIR Unit in regulatory control of the use of non-ionizing radiation in 2012–2021.

Year	Regulatory inspections	Decisions	Statements	Prohibitions of dangerous laser equipment sold on the internet	Total
2012	53	0	15	43	111
2013	63	3	11	42	119
2014	53	2	23	41	119
2015	68	1	14	14	97
2016	72	2	10	18	102
2017	81	3	11	22	117
2018	56	0	10	45	111
2019	81	18	8	31	138
2020	83	0	18	22	123
2021	98	1	11	4	114

TABLE 15. Service work of the NIR Unit in 2012–2021.

Year	Calibrations and tests	Safety assessments and radiation measurements	Total
2012	8	16	24
2013	5	5	10
2014	6	8	14
2015	2	7	9
2016	8	4	12
2017	6	3	9
2018	5	4	9
2019	9	2	11
2020	1	2	3
2021	7	5	12

TABLE 16. Inspections of sunbed facilities in 2012–2021. In addition to STUK's own inspections in 2012–2020, decisions on sunbeds were also made on the basis of inspections reported by health inspectors of municipalities (number in brackets) for decision-making. Compliance with the requirements was inspected by sending requests for specification.

Year	Number of inspections
2012	6 (16)
2013	3 (40)
2014	1 (20)
2015	4 (17)
2016	4 (55)
2017	6 (31)
2018	5 (30)
2019	17 (23)
2020	5 (26)
2021	65 (18)

TABLE 17. SAR tests of mobile phones and other wireless devices in 2012–2021.

Year	Number of tests
2012	15
2013	11
2014	10
2015	14
2016	11
2017	0
2018	0
2019	0
2020	10
2021	10

TABLE 18. Service work pertaining to ionising radiation in dosimetry laboratory in 2012–2021.

Year	Calibrations and tests, Number of meters	Number of irradiations	PCXMC-licences
2012	457	344	89
2013	471	1 250	78
2014	370	1 281	68
2015	235	612	63
2016	340	1 203	49
2017	1 158	983	52
2018	465	1 851	42
2019	436	1 489	48
2020	478	2 091	58
2021	717	2 884	33

Appendix 2
Publications in 2021

Sähköisestä julkaisuarkistosta Julkarista (julkari.fi) löytyvät STUKin sarjajulkaisut pdf-muodossa. Julkari toimii myös julkaisurekisterinä. Osasta julkaisuja löytyy siksi vain metatiedot.

The following publications concerning safe use of radiation were completed in 2021:

Scientific articles by STUK employees

Kavaluus Henna, Nousiainen Katri, Kaijaluoto Sampsa, Seppälä Tiina, Saarilahti Kauko, Tenhunen Mikko. Determination of acceptance criteria for geometric accuracy of magnetic resonance imaging scanners used in radiotherapy planning. Physics and Imaging in Radiation Oncology 2021; 17: 58–64. https://doi.org/10.1016/j.phro.2021.01.003

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Khanbabaee B, Röttger A, Behrens R, Röttger S, Feige S, Hupe O, Zutz H, Toroi P, Leonard P, de la Fuente Rosales L, Burgess P, Gressier V, José–Gutiérrez Villanueva J-L, Cruz Suárez R, Arnold D. Support for a European metrology network on reliable radiation protection: gaps in radiation protection and related metrology. RAD Conference Proceedings, vol. 5, pp. 21–27, 2021. https://doi.org/10.21175/RadProc.2021.04

Khoury HJ, de Barros VSM, Asfora VK, Toroi P. 1st Latin American and Caribbean interlaboratory comparison exercise for SSDLs on reference irradiation capabilities in personal dose equivalent. Journal of Radiological Protection 2021; 41: 37-45. https://doi.org/10.1088/1361-6498/abe16f

Kojo K, Laine J-P, Turtiainen T, Kurttio P. Radon in Finnish underground mines 2011-2019. Journal of Radiological Protection 2021: 41 (4): 619-627. https://doi.org/10.1088/1361-6498/ac08f0

Lindgren Jussi, Liukkonen Jukka. Maxwell's equations from spacetime geometry and the role of Weylcurvature. Journal of Physics: Conference Series 2021; 1956 (1) Suppl 012017. http://dx.doi.org/10.1088/1742-6596/1956/1/012017

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Monaca S, Dini V, Grande S, Palma A, Tkaczyk A, Koch R, Murakas R, Perko T, Duranova T, Salomaa S, Roivainen P, Willrodt C, Grigioni M, Bouffler S. Assessing radiation risk perception by means of a European stakeholder survey. Journal of Radiological Protection 2021; 41: 1145-1165. https://doi.org/10.1088/1361-6498/abf75a

Turtiainen T, Kojo K, Laine J-P, Holmgren O, Kurttio P. Improving the assessment of occupational exposure to radon in above-ground workplaces. Radiation Protection Dosimetry 2021; 196 (1-2): 44-52. https://doi.org/10.1093/rpd/ncab127

STUK's own serial publications

Bly Ritva. Patient exposure levels and collective effective dose to the population from radiological examinations – changes from 2008 to 2018 in Finland. Academic dissertation. STUK-A 265. Helsinki; Radiation and Nuclear Safety Authority: 2021. https://www.julkari.fi/handle/10024/142732

Bly Ritva. Esiselvitys säteilylaissa tarkoitettujen lähettämissuositusten kehittämistä varten. Työryhmän loppuraportti sosiaali- ja terveysministeriölle. (A preliminary assessment on the development of the referral guidelines referred to in the Radiation Act. Final report of the working group for the Ministry of Social Affairs and Health.) STUK-B 273. Helsinki; Säteilyturvakeskus: 2021. https://www.julkari.fi/handle/10024/140970

Jokelainen Ilkka. Annosmääritykset sädehoidon lineaarikiihdyttimien pienissä fotonisäteilykentissä. Terveydenhuollon valvontaraportti. (Dose determinations in small fields of radiotherapy linear accelerators. Supervision report in health care.) STUK-B 272. Helsinki; Säteilyturvakeskus: 2021. https://www.julkari.fi/handle/10024/140967

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Suutari Juha. Säteilylain uusien vaatimusten toteutuminen säteilyn käytössä. Terveydenhuollon valvontaraportti. (Regulatory compliance with the new radiation act in radiation practice. Supervision report in health care.) STUK-B 262. Helsinki; Säteilyturvakeskus: 2021. https://www.julkari.fi/handle/10024/140912

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STUK brochures/Other publications

Cinelli G, De Cort M, Tollefsen T, Achatz M, Ajtić J, Ballabio C, Barnet I, Bochicchio F, Borelli P, Bossew P, Braga R, Brattich E, Briganti A, Carpentieri C, Castellani C, Castelluccio M, Chiaberto E, Ciotoli G, Coletti C, Cucchi A, Daraktchieva Z, Di Carlo C, De France J, Dehandschutter B, Domingos F, Dudar T, Elio J, Falletti P, Ferreira A, Finne I.E., Fontana C, Fuente Merino I, Galli G, Garcia-Talavera M, German O, Grossi C, Gruber V, Gutierrez-Villanueva J, Hansen M, Hernandez Ceballos M.A., Hoffmann M, Hurst S, Iurlaro G, Ivanova K, Jobbagy V, Jones A, Kovalenko G, Kozak K, Lawley R, Lehné R, Lister B, Long S, Lucchetti C, Magnoni M, Matolin M, Mazur J, Mazzoli C, Mclaughlin J, Mollo M, Mostacci D, Mundigl S, Nesbor D, Neves L, Neznal M, Nikolov J, Nilsson P, Nogarotto A, Onischenko A, Orgiazzi A, Pacherová P, Panagos P, Pereira A, Perez M.D.R., Pokalyuk V, Pressyanov D, Quindós Poncela L.S., Ringer W, Rossi F, Sangiorgi M, Sassi R, Simic Z, Smedley P, Socciarelli S, Soligo M, Stoulos S, Szabo K, Täht-Kok K, Todorović N, Tolton R, Tuccimei P, Turtiainen T, Tye A, Udovicic V, Vasilyev A, Venoso G, Verdelocco S, Verkhovtsev V, Voltaggio M, Zhukova O, Zhukovsky M. European Atlas of Natural Radiation. Publication Office of the European Union, Luxembourg, 2019. https://publications.jrc.ec.europa.eu/repository/handle/JRC116795

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STUK
Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

Jokiniemenkuja 1
01370 Vantaa
Puh. (09) 759 881 (vaihde)
www.stuk.fi