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Eija Venelampi (ed.)

Radiation practices

Annual Report 2020

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Abstract

A total of 2 944 safety licences for the use of ionising radiation were current at the end of 2020, 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 the maintenance of the Dose Register. The Radiation and Nuclear Safety Authority (STUK) conducted 103 inspections of safety-licensed practices in 2020. The inspections resulted in ten orders to remedy deficiencies.

A total of 14 700 occupationally exposed workers were subject to individual monitoring in 2020. Around 72 600 dose entries were recorded in the Dose Register maintained by STUK.

In 2020, regulatory control of non-ionising radiation (NIR) use focused on laser equipment, sunbeds, mobile phones, UV torches and cosmetic NIR applications. As part of the regulatory control, online auctions of hazardous laser equipment were intervened in 22 times. Two on-site inspections of show lasers were conducted. Municipal health protection authorities submitted the details of the inspections of 26 sunbed facilities to STUK for evaluation and decision. In addition, five sunbed facilities were surveyed based on monitoring carried out by STUK. An inspection based on documentation was conducted on 24 beauty care facilities, and the radiation level of one laser device was measured in the place of use.

In metrological activities, national metrological standards were maintained for the calibration of radiation meters used in radiotherapy, radiation protection and X-ray imaging as well as radon meters used for measuring radon in the air. In measurement comparisons, STUK's results were clearly within the acceptable range.

Research related to the use of ionising and non-ionising radiation produced new information on, among other things, the exposure of the lens of the worker's eye and IPL (intense pulsed light) devices. This research also helped develop the regulatory control of nuclear medicine.

There were 57 radiation safety deviations related to radiation use in 2020. Of these events, 24 concerned the use of radiation in industry and research, 21 the use of radiation in health care, six the use of radiation in veterinary practices and six the use of non-ionising radiation. In addition, 1 541 events and near misses assessed to be of minor significance for safety were reported in health care, and five radiation safety deviations were compiled for summarized reporting in industry and research.

Over 17 000 radon measurements at around 4 400 workplaces were recorded in the National radon database in 2020. At conventional workplaces, the radon concentration exceeded the reference level of 300 Bq/m^3 at approximately 13 per cent of the measured workplaces.

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Management review

Year 2020 was rather different from previous years in terms of the regulatory control of radiation practices. The COVID-19 situation made it necessary for nearly the entire personnel at STUK to work remotely in March. At the same time, inspection activities in places of use practically came to an end. After initial confusion, other methods of supervision and communication with undertakings (parties running a radiation practice) were put in place. Conventional meetings were replaced with series of webinars, inspections were carried out remotely, and the focus of regulatory control was shifted from on-site inspections to other means of supervision. The change in control practices has been promoted in line with STUK's strategy, and due to the pandemic, even faster than expected in some respects. However, inspectors' personal contacts and visits to places of use are an important part of forming a situational picture and providing STUK's customer service. At the time of writing of this report, we have still been unable to relaunch more extensive inspection activities. Based on feedback from customers and personnel, a time when this will be possible is eagerly expected on both sides.

Strict teleworking practices at STUK made it possible to safely carry out any work that required being present. For example, special arrangements were made to allow the metrological laboratory staff to stay at the workplace, and we were able to keep the laboratory's services running almost without disruption. We also managed to continue laboratory measurements related to the regulatory control of non-ionising radiation.

The radiation legislation overhaul continued to have an impact in 2020. Under the Radiation Act, undertakings must produce safety assessments. The safety assessment is a new requirement, the purpose of which is to support good safety culture and emphasise the undertaking's responsibility in radiation practices. Undertakings were expected to submit their safety assessments to STUK for evaluation by June 2020. Roughly one half of the safety assessments were received by this deadline, most of them at the last minute. To obtain the statutory safety assessment from the rest, reminders had to be sent out, and it was even necessary to resort to coercive measures. This resulted in a significant backlog in processing the assessments, and work to clear it continues in 2021. After the initial difficulties, however, the safety assessments will provide a good tool for improving safety.

The structure of the code has been modified, and the traditional ST Guides have been abandoned. However, a need for guidance material has been identified. As a response to this need, STUK began to develop a radiation legislation guideline service (Sammio) in 2019, in which all the relevant levels of legislation regarding specific subject can be easily accessed and examples can be found to illustrate the meaning of the statutes. The service underwent active development in 2020, and it was published in early 2021.

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 ionising and non-ionising radiation.

The Department of Radiation Practices Regulation (STO) at the 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.

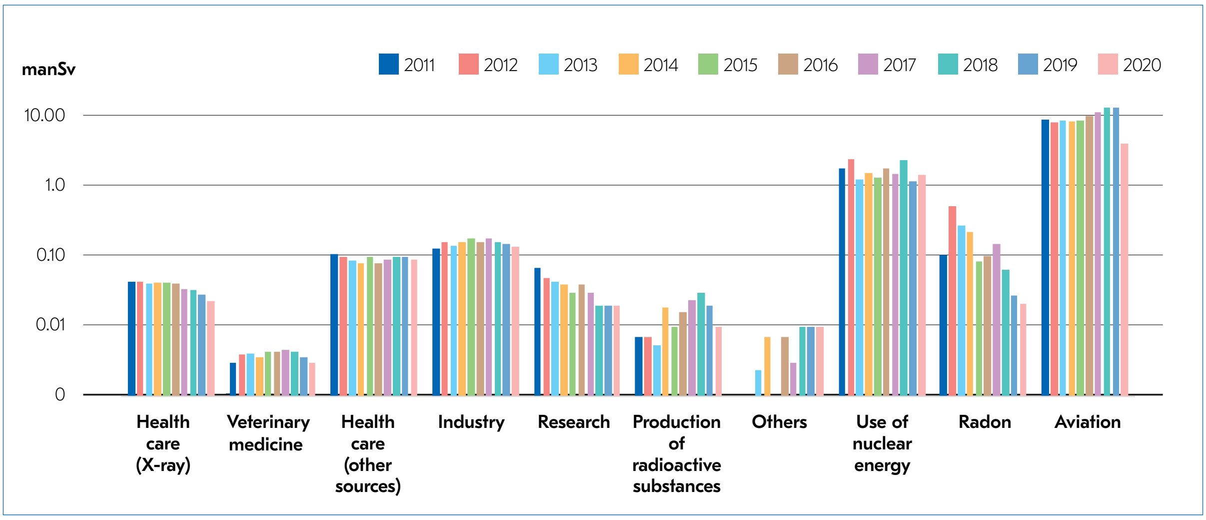

FIGURE 1. Collective effective doses (manSv) of workers subject to individual monitoring by occupational category, 2011–2020. In addition to the occupational categories specified in the graph, a few people subject to individual monitoring work in the following fields: manufacturing of radioactive materials, 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).

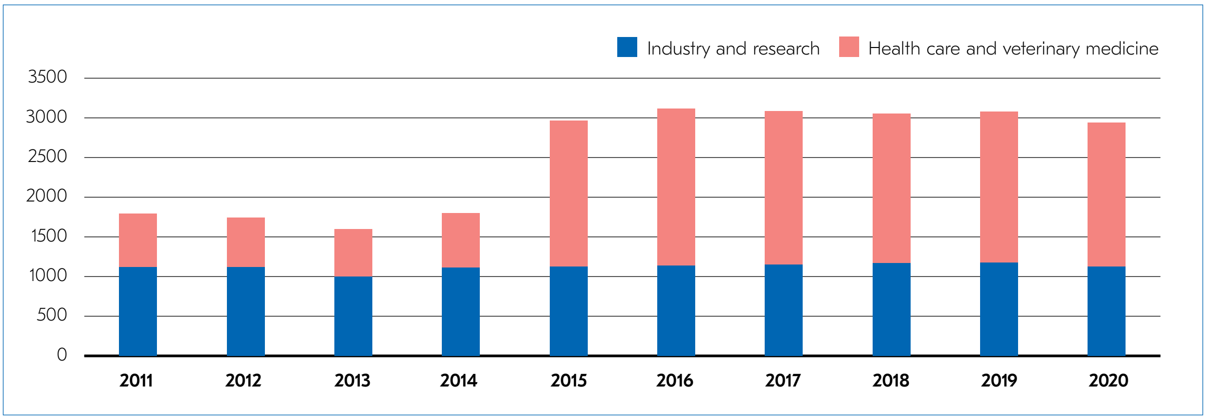

FIGURE 2. Number of safety licences in 2011–2020. In addition, three safety licences issued for aviation operations were current in 2019–2020. The increase in health care licences in 2015 is due to the dental X-ray practices being changed from registered activities to activities that are subject to a licence.

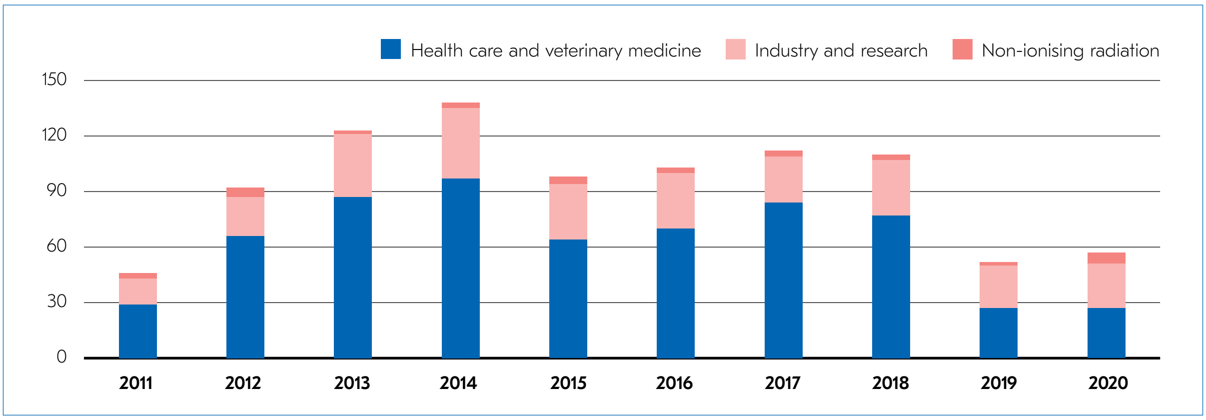

FIGURE 3. Radiation safety deviations to be reported immediately in 2011–2020. From 2019 onwards, some of the radiation safety deviations which previously had to be reported immediately could be reported annually.

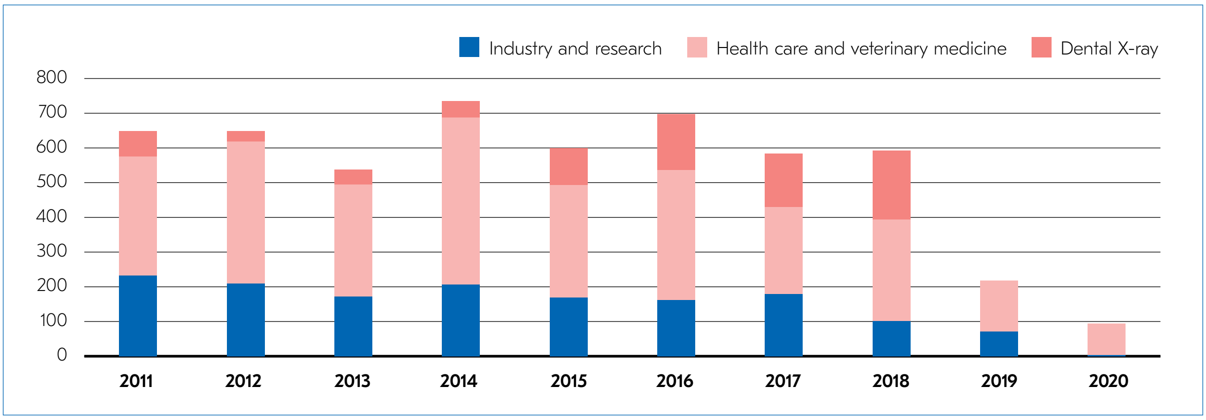

FIGURE 4. Numbers of on-site inspections in 2011–2020. From 2019, dental x-ray examinations are included in the section "health care and veterinary medicine".

2 Regulatory control of the use of ionising 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. After this period expired, there was a backlog of safety assessments to process, and this work still continues 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. On risk-based grounds, administrative coercive measures had to be targeted at some undertakings to ensure that they submit their safety assessments.

As the COVID-19 situation deteriorated, STUK switched almost exclusively to remote work in March, and the number of on-site inspections was minimised. Several conferences planned for 2020 had to be cancelled due to the pandemic. However, STUK was able to respond to some of the needs by means of webinars.

The information system used for regulatory control was updated in early 2020. These updates addressed the impacts of the legislative amendment that entered into force in late 2018. On the other hand, a new electronic service with forms for submitting applications and notifications was also introduced. These changes facilitated daily safety licence control and the processing of applications and notifications received by STUK. Conversely, deficiencies in applications and notifications and failures to comply with requests for additional information within the deadline significantly slowed down the supervision of safety licences. STUK has sharpened its focus on licence supervision, for example by sending out requests earlier than before and, if necessary, using other enforcement procedures.

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

Safety licences

At the end of 2020, there were 1 523 current safety licences for the use of radiation in health care and 298 licences for veterinary practices (see also Figure 2). A total of 739 licensing decisions and 329 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. 19 days. In addition, safety assessments related to 1 560 safety licences were confirmed by a separate decision. The processing times of safety assessments were considerably longer than those of other licence matters. See Table 1 in Appendix 1 for the numerical distribution of the practices referred to in these licences.

Operational changes

To support safety assessment work in undertakings, form templates for both veterinary and dental x-ray practices were prepared in early 2020. In addition, instructions were drawn up for other undertakings to support the preparation of safety assessments. During the spring and especially after the expiry of the transition period laid down in the Radiation Act in June, the reviewing and confirming of safety assessments created a significant workload. As the COVID-19 epidemic rapidly took a turn for the worse in the spring, the hospital districts prepared for the situation by purchasing more equipment, including mobile X-ray devices. Due to the peak demand for these devices they also procured, or considered procuring, equipment that differed from the existing stock. Inquiries and licence applications related to these devices were prioritised to ensure that administrative procedures would not unnecessarily hamper the effectiveness of health care.

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 2020.

2.2 Use of radiation in industry, research and education

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.

By the transition period laid down in the Radiation Act (15 June 2020), 595 safety assessments had been submitted to STUK for confirmation, corresponding to about one half of all safety licences. A total of 946 safety assessments had been received by the end of 2020. Instructions were drawn up to support the preparation of a safety assessment, and in late 2020, they were supplemented with a template. Reviewing the safety assessments created a considerable workload.

Safety licences

At the end of 2020, there were 1 123 current safety licences for the use of radiation in industry and research (see also Figure 2). A total of 636 licensing performances that concerned new licences, amendments to existing licenses or terminations of licences (255 notifications and 381 decisions) were issued during the year. The number of new licences issued was 48, whereas

92 licences were terminated. The average processing time of safety licence applications and notifications was 30.4 days. 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.

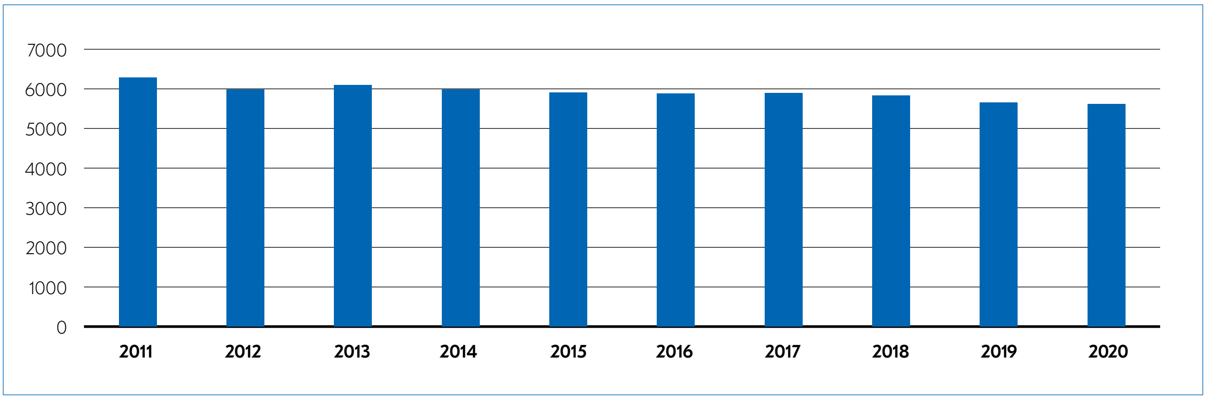

FIGURE 5. Appliances containing radioactive materials in industry and research in 2011–2020.

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

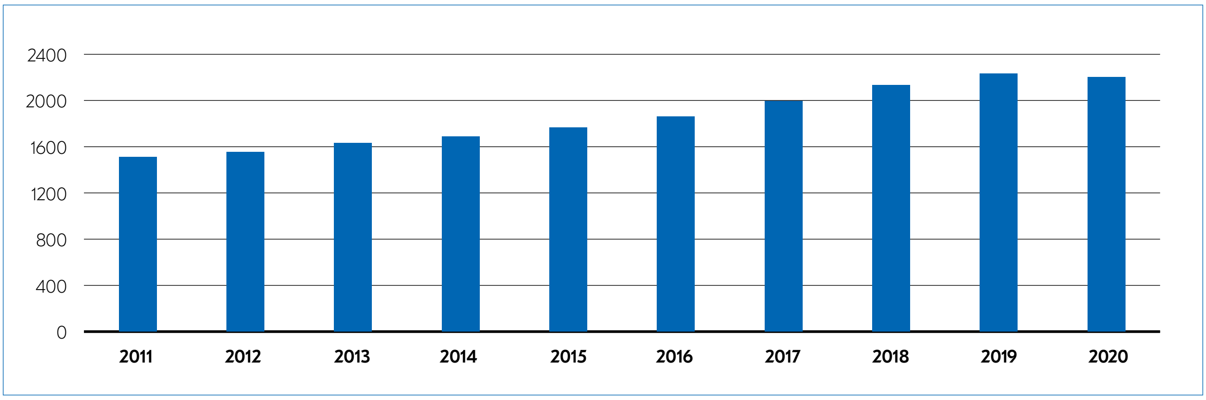

FIGURE 6. Number of X-ray appliances in industry and research in 2011–2020.

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 2020.

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

For the number of sealed sources which are used in industry and research and which are 40 years old or older in 2020–2023, see Table 6 in Appendix 1, unless they are decommissioned before that date. The Radiation Act stipulates that 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

As the COVID-19 situation deteriorated in spring 2020, inspections in places of use were reduced to a minimum. In practice, only individual commissioning inspections of radiotherapy accelerators were carried out. In the autumn and late 2020, on-site inspections as part of the regulatory control of radiotherapy practices were carried out as normal, however observing the restrictions in place because of the pandemic. In the autumn, on-site inspections and some remote inspections were carried out as part of regulatory control in connection with new practices and supervision projects initiated earlier.

In industry and research, few inspections in the place of use were conducted in the early part of the year. Additionally, a few reactive inspections were carried out, for example when an orphan source was discovered.

Health care, dental care and veterinary practices

In 2020, a total of 90 inspections of radiation use were conducted in health care and nine in veterinary practices. These inspections resulted in ten orders to remedy deficiencies issued to the responsible undertakings. The operational inspections focused on larger entities than previously, and the themes of the inspections were compliance with the requirements of the amended radiation legislation and implementation of the prerequisites for a justification assessment in practical work.

Dental X-ray practices

Approximately 1 300 undertakings were engaged in dental X-ray practices in 2020.

The inspections of dental X-ray practices focused on the operations of large undertakings instead of appliance inspections. Most of the deficiencies observed in these inspections were related to quality control, an appliance and its auxiliary instruments or accessories, or the accuracy of the registration information.

Regarding dental X-ray practices in particular, several cases emerged during the year in which the designated radiation safety officer was no longer available for this task but no application concerning the officer’s replacement had been submitted on time to STUK. This means that the activities are carried out without a designated safety officer, which leads to uncertainty and requires investigation work.

X-ray practices

STUK conducted a survey concerning the adequacy of radiology units’ personnel resources, the impacts of insufficient resources on practices, and the effects of the amended Radiation Act on the need for resources in 2019 at the national level. A STUK B series report on the findings of the survey was completed in 2020.

The survey found that personnel resources were insufficient, especially for the part of radiologists but also medical physicists and radiographers. The findings indicate that the key impacts of inadequate resources were felt in work with patients, realisation of the statutory care guarantee and quality work. Radiation and patient safety were seen as the areas that the lack of resources affected the least. The Radiation Act overhaul has increased the need for resources in radiology units during the transitional period laid down in the Act as changes to the practices are being implemented.

STUK investigated compliance with the requirements under the amended radiation legislation by means of a regulatory control project which focused on the use of radiation in health care and veterinary medicine. As part of this project, which ended in late 2020, 47 inspections at 58 sites were conducted in 11 different hospital districts. The findings indicate a good level of compliance with the new requirements. Few shortcomings were observed in university, central and regional hospitals, in particular. When examining all undertakings, the greatest deficiencies were found in keeping the management system for radiation practices up to date. The findings show that health care undertakings had made plans and met the requirements regarding the use of a radiation safety expert in line with the previous practices related to using a medical physics expert. In veterinary x-ray practices, the use of experts is less well established. While most of the undertakings had started preparing their safety assessments before the transition period expired, almost one half of the respondents were still working on them as the inspections were conducted. A STUK B series report on the survey was published in January 2021.

As part of regulatory control of radiation use in health care, STUK examined the implementation of the prerequisites for a justification assessment of X-ray examinations at different sites in 2019 and 2020. The prerequisites in this context refer to guidelines and operating methods that support the justification assessment. The technical quality of examination referrals was also scrutinised during the inspections. A total of 28 inspections were carried out, and a total of 943 referrals to an X-ray examination were assessed. Based on the information obtained during the inspections, it can be noted that the undertakings' instructions and practices mainly make implementing justification assessments possible. The responses indicate, however, that the prerequisites were not fully in place at all sites. The most significant shortcomings were associated with documenting the tasks and responsibilities of the persons taking part in the justification assessment. For example, the responsibilities of the physician responsible for medical exposure had not been documented, and the site did not always know who the responsible physician was. The referrals to examinations scrutinised during the inspections were mainly consistent with good practices, but poor-quality referrals were also found: about one out of four referrals did not contain a clinical question for the examination.

STUK participated in the scientific board of a EUCLID project coordinated by the European Society of Radiology. The project provided European reference levels based on indications for the most common CT studies and radiological procedures.

Suppliers of X-ray equipment notified STUK of health care and veterinary X-ray equipment installed in 2020. In connection with the notifications, four cases were discovered in which a safety licence had not been applied for the X-ray appliance before the operation was launched, or in which STUK had not been notified rapidly enough after the commissioning of the appliance. In addition, 44 dental X-ray appliances were discovered for which an appropriate safety licence had not been applied, either for possession or commissioning. These undertakings were instructed to comply with the licence requirements.

Nuclear medicine

Three remote inspections of health care units practising nuclear medicine and one routine inspection of a place of use were carried out in 2020. The inspections focused on examining how and where unsealed sources are used in units and to what extent the operation of the units meets the new legal requirements. In addition, two nuclear medicine webinars were organised in 2020, the first one of which focused on the number of nuclear medicine examinations and treatments carried out in 2018 and the radiation exposure to patients caused by the examinations. A STUK-B series report was published on this topic. The second webinar discussed waste from nuclear medicine practices using unsealed sources. In addition, the practices of discharging patients and handling any radioactive waste generated after discharge as well as the calibration practices of activity meters led to a great deal of discussion between nuclear medicine actors 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 2020, STUK conducted seven commissioning inspections of radiotherapy equipment, one commissioning inspection of a CT simulator and 36 periodic inspections.

The comparative measurements between STUK and hospitals revealed that the treatment dose accuracy at hospitals was very good: the average difference was below 0.4 % in all radiation 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, plans with multiple fields calculated using the treatment planning system were compared with the corresponding measurement results. Inspections of dose calculation systems that affect patient doses were conducted on more than 500 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 per cent were detected.

In connection with regulatory control, a study was conducted on the accuracy of the patient dose calculation in the small photon radiation fields of linear accelerators used in radiotherapy. The study was based on 1,500 dose measurements taken in connection with periodic and commissioning inspections in 2015–2019. With a few exceptions, the difference between the dose calculated by the hospital's dose planning system and the dose determined by STUK was within ± 3%. A STUK-B series report on this study was published in early 2021.

In 2020, the fixed-term safety licence for the installation and trial use of a boron-neutron therapy device was extended until the end of 2022. The travel restrictions imposed because of the COVID-19 pandemic have delayed the installation of the device slightly. The device will be used for the administration of treatments similar to those administered using the FIR-1 reactor in Otaniemi, Espoo. However, a nuclear reactor will not be needed to produce radiation; the neutrons will be produced in a particle accelerator. The device has been subjected to technical tests to check its operation and radiation beam properties have been measured. These properties must be known in detail when starting clinical patient tests. These tests are likely to begin at the end of 2021.

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 operations also included the processing of safety assessments, which created a heavy workload.

In 2020, four inspections were carried out at sites where radiation was used. 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. A total of 92 written requests were sent out due to other shortcomings observed in operations.

In 2020, STUK submitted two requests for investigations to the police concerning potential radiation violations. The potential violations concerned handing over radioactive material to an undertaking which did not have a safety licence and the transport of a high-level sealed source without a safety licence.

Unsealed sources and treatment of radioactive waste

In late 2019, a safety licence was granted for the decommissioning of VTT's laboratory facilities in Espoo and the treatment and storage of the resulting radioactive waste. Pursuant to section 83 of the Radiation Act, the licence covers the disposal or transfer of research samples for further use, the removal of radioactive materials, contaminated equipment and buildings, and the treatment and storage of radioactive waste. An on-site inspection of the safety licence was conducted in early 2020. The main focus of the inspection was on the requirements of the new Radiation Act and quality assurance measures.

Transportation of radioactive materials including high-activity sealed sources

A safety licence is required to transport high-activity sealed sources by road and rail. No applications for new safety licences for transport were submitted to STUK in 2020. 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 2020, the STUK received 83 notifications.

Own-check survey addressed to industry and research

STUK addressed an own-check survey to 137 industrial and research undertakings in December 2020. In early 2021, the survey was sent to a further 12 undertakings. Its purpose was to emphasise the undertakings' responsibility for their activities and to carry out risk-based supervision of undertakings that have radiation workers and that are likely to fall within the occupational radiation exposure category 1 or 2. The purpose of the survey was to determine if undertakings have addressed the amended radiation legislation in their activities. The survey responses enable STUK to target its supervision by carrying out additional investigations and inspections if necessary. A supervision report is drawn up based on the survey responses and observations made during inspections.

Security arrangements

A STUK project was launched to collect all industrial and research operators' plans for security arrangements that were not archived at STUK. As set out in regulation STUK S/3/2018, the plan for security arrangements applies to security levels A and B. In practice, this means that the undertaking uses high-activity sealed sources or mains-powered mobile industrial imaging equipment.

In 2020, STUK received a total of 17 plans for security arrangements, of which six were submitted on separate request, while the remaining 11 were obtained in connection with licence services and similar.

Section 11 of regulation STUK S/3/2018 lays down the minimum requirements for the contents of a plan for security arrangements.

Of all plans for security arrangements in industry and research

- 51% are compliant with the regulation
- 28% have not been inspected or processed since the current regulation entered into force
- 21% are not fully compliant with regulations.

On future inspections and in connection with licence matters, attention will be paid to keeping the plans for security arrangements up to date.

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 2020, see Table 7 in Appendix 1, and for the production volumes of radioactive materials (unsealed sources) in Finland in 2020, 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 value.
- Smoke detectors and fire alarm system ion detectors containing americium (Am-241). Approximately 27 200 of these devices were imported, with a combined activity of about 900 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 Finland 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, Tl-201, I-125 and Sm-153.

At the beginning of 2021, STUK requested reports from all vendors of industry and research X-ray equipment operating in Finland (40 vendors) on appliances delivered in 2020 and their holders. According to the delivery information, it was initially found that three undertakings did not have a licence for the operation or possession of X-ray appliances. In addition, it was found that some eight licence holders had not reported their new X-ray appliances to STUK, and four had not submitted appropriate notification of leasing X-ray appliances. By its oversight, STUK ensured that the detected deficiencies were remedied and that safety licence applications for the use of all the aforementioned appliances were submitted, or that the appliances were appropriately incorporated into an existing safety licence.

2.5 Radiation doses to workers

A total of 14 700 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.

In 2020, there were no cases of the 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.

Table 12 of Appendix 1 shows dosage data for 2020 concerning groups of workers with significant exposure to radiation or groups which are large in number.

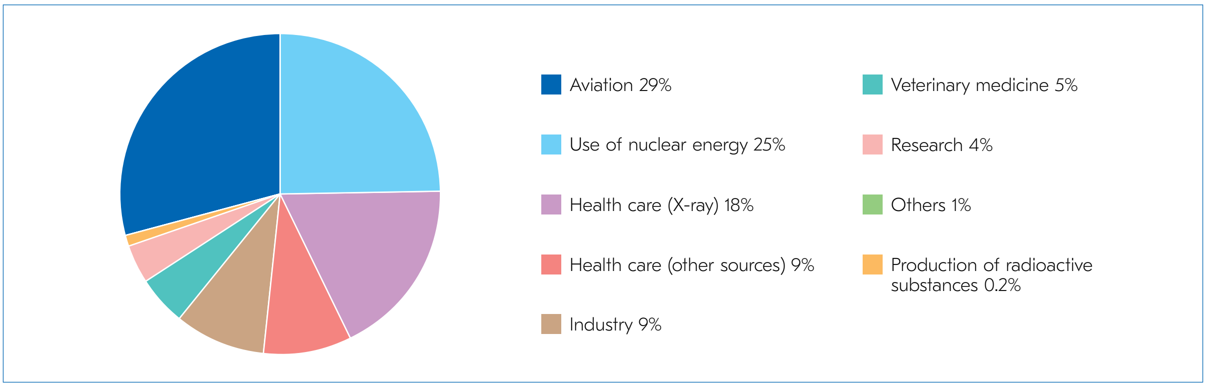

FIGURE 7. Numbers of workers subject to individual monitoring by sector in 2020. In addition to the occupational categories specified in the graph, a few people subject to individual monitoring work in the following fields: services, radon, installation/servicing/technical test operation and trade/import/export.

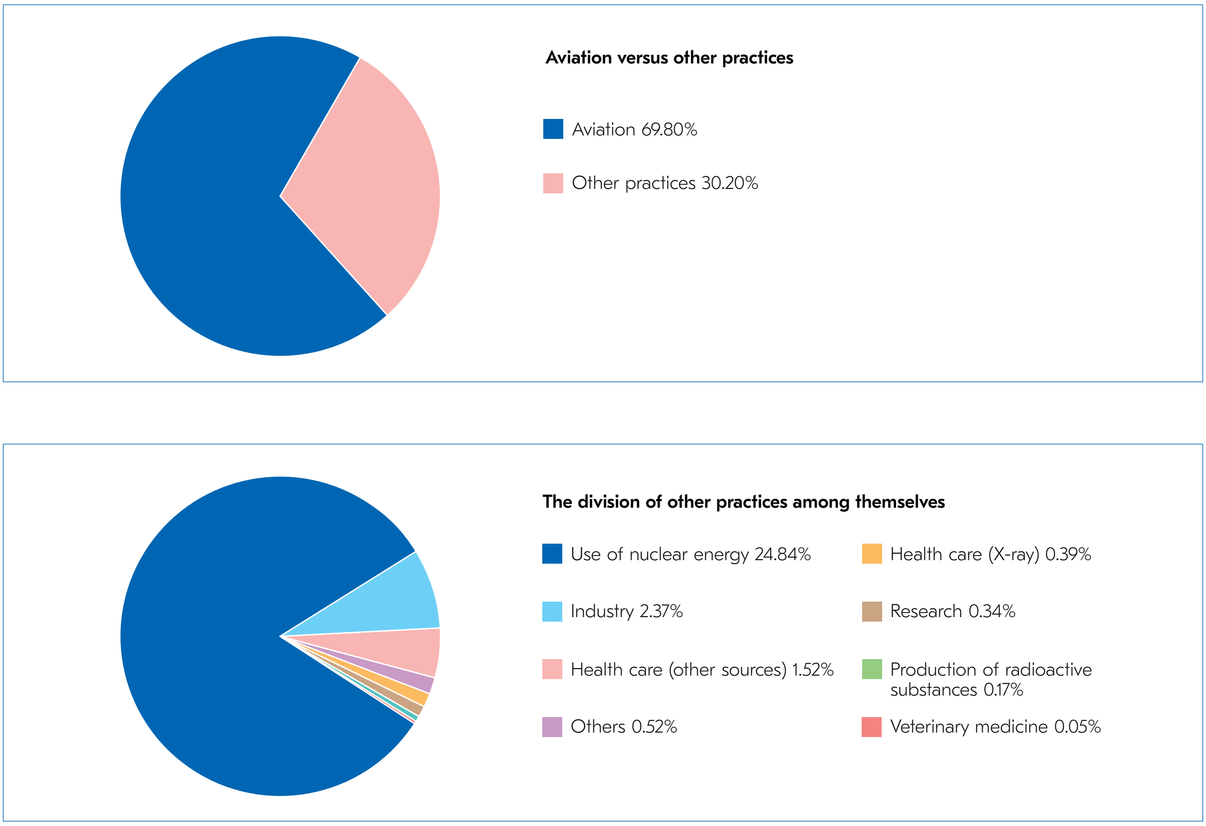

FIGURE 8. Distribution of collective effective doses for workers across various sectors in 2020. In addition to the occupational categories specified in the graph, a few people subject to individual monitoring work in the following fields: services, radon, installation/servicing/technical test operation and trade/import/export.

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 health care and veterinary X-ray practices, and the average doses in other fields of health care and industry have also decreased slightly. There have been major annual fluctuations in the average effective dose in the manufacture of radioactive materials, and in 2020, the dose was almost halved compared to 2019. The collective effective dose of workers involved in the use of radiation was about 0.30 manSv and decreased by about 10% 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) 0.07 mSv, industry 0.11 mSv, research 0.04 mSv and manufacturing of radioactive materials 0.37 mSv. The median effective doses in all sectors were almost without exception zero, excluding the manufacture of radioactive materials, in which workers' median effective dose was 0.2 mSv in 2020. 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) 0.026 mSv, veterinary medicine 0.018 mSv, health care (other sources) 0.35 mSv, industry 0.36 mSv, research 0.19 mSv and manufacture of radioactive materials 0.41 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.

In health care radiography, the four largest doses $H_p(10)$ (38.4 mSv, 19.5 mSv, 15.3 mSv and 13.1 mSv) were received by interventional radiologists. A cardiologist was exposed to the fifth highest dose (10.1 mSv). These doses $H_p(10)$ correspond to effective doses of approx. 1.3 mSv, 0.8 mSv, 0.5 mSv, 0.4 mSv and 0.3 mSv. In the radiography practices of veterinary medicine, the three largest doses $H_p(10)$ were recorded for two veterinarians (4.5 mSv and 3.9 mSv) and an animal attendant (4.3 mSv). These doses $H_p(10)$ correspond to effective doses of approximately 0.15 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 $H_p(10)$ (4.0 mSv, 3.4 mSv and 2.9 mSv) caused by other radiation sources were recorded for radiographers using several sources of radiation.

In the field of industry, the largest doses $H_p(10)$ (8.8 mSv, 5.4 mSv and 4.9 mSv) were received by individuals carrying out tracer tests.

In the field of research, a researcher using unsealed sources was exposed to the largest dose $H_p(10)$ (2.6 mSv). The second and third largest doses $H_p(10)$ (2.4 mSv and 2.2 mSv) were received by a laboratory worker who handled unsealed sources and a researcher who was exposed to radiation from an accelerator.

In the manufacture of radioactive materials, the two largest doses $H_p(10)$ (4.6 mSv and 1.0 mSv) were recorded for an employee working under the title 'other' and an employee working in the production and delivery of radioisotopes.

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 2020, the dose to the hands did not exceed the annual dose limit for any worker. The three highest doses to the hands (167.7 mSv, 139.4 mSv and 131.5 mSv) were measured for a radiographer, laboratory attendant/bioanalyst and a researcher using unsealed sources. In addition to these three, only two laboratory attendants/bioanalysts using multiple sources or unsealed sources were exposed to annual doses exceeding 100 mSv.

In recent years, there has been a declining trend in collective doses to the skin of the hands in health care, research and manufacturing of radioactive materials. In all sectors, the sum of doses to the hands was lower than in 2019. The average doses to the skin of the hands were 9.3 mSv in health care, 0.9 mSv in industry, 7.8 mSv in research and 4.9 mSv in the manufacture of radioactive materials.

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 health care. In industry, the largest doses to the hands have remained low in 2016–2020 compared to 2012–2015. In the field of research, the largest doses to the hands have remained at a lower level in 2013–2020 than before. In the manufacture of radioactive materials, 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 1.47 manSv in 2020. This dose was 24.6% higher 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 2020, the highest individual radiation dose (11.7 mSv) resulting from radiation work at Finnish nuclear power plants was recorded for an employee who carried out insulation work. Nine workers received a dose in excess of 10 mSv, all of whom were mainly carrying out insulation work. The average of the employees' doses $H_p(10)$ in the use of nuclear energy was 0.4 mSv. The median dose of all employees was 0.0 mSv and the median dose of those who exceeded the recording level was 0.63 mSv.

Aviation

In 2020, 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 4.17 mSv and for cabin crews 2.66 mSv. The average annual doses of cockpit personnel was 1.12 mSv and the median was 0.99 mSv. The average annual doses of cabin crews was 0.87 mSv and the median was 0.86 mSv. For the average doses of flight crews in 2011–2020, see Figure 9.

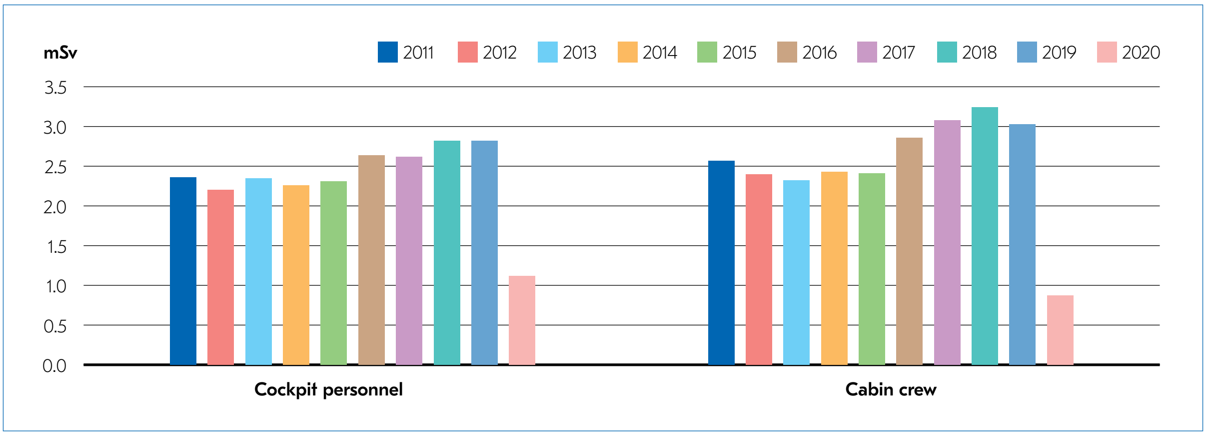

FIGURE 9. Average doses of flight crews in 2011–2020.

Compared to the previous year, the total number of cabin crew members decreased by 6.7%, and their collective dose was reduced by as much as 73.1%. Similarly, while the total number of cockpit personnel only decreased by 1.3%, the employees' collective dose went down by 60.6%. This considerable reduction in the collective doses of cabin and cockpit crews in 2020 compared to 2019 is explained by the major drop in flight numbers resulting from the COVID-19 pandemic. 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 (2011–2020), see Appendix 1, Table 10. For collective employee doses by sector, see Figure 1 (section 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.

No new workplace was under obligation to organise radon exposure monitoring for its workers in 2020. Exposure monitoring continued in one workplace. 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 5.23 mSv, while the median was 5.42 mSv. The largest effective dose was 6.61 mSv.

2.6 Approval decisions and verification of competence

Training organisations 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 organisations other than institutions of higher education . Training organisations that arrange training and competence exams for radiation safety officers must apply to STUK for approval to arrange such training and exams.

In 2020, decisions to grant approval for arranging exams and training for radiation safety officers were issued to two training organisations. Four training organisations held valid approval decisions at the end of 2020. The small number of educational organisations granted approval in 2020 is due to a legislative amendment under which institutions of higher education no longer need approval for their training from STUK. The approved training organisations are listed on STUK's website.

Approval decisions for dose measurement services and methods

In 2020, STUK re-approved a dose measurement service which had already been approved before, and its three dose measurement methods. The approved methods are based on determining the effective dose and the equivalent dose of the thyroid gland resulting from an internal radiation exposure based on direct HPGe radiation detector measurements as well as determining the effective dose resulting from an internal radiation exposure by measuring urine. In addition, one measurement method for a previously approved dose measurement service was approved as a partial decision. This method is based on determining the dose caused by neutron radiation using the thermoluminescence method.

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/6/2018 and STUK S/3/2019.

Five new approval decisions for a radon measurement method were issued in 2020. A list of organisations with approved measurement methods, with appropriately calibrated radon measurement equipment, and which have given their consent to be published on the list is found on the STUK website.

Verification of competence of radiation safety experts

STUK received a total of 25 applications to verify the competence of radiation safety experts. In addition, a decision was made on eight applications received in 2019. One of the applications concerned an area of expertise in which STUK is not competent to make decisions, and one concerned an area which is not a separate area of expertise. The number of applications also includes those on which the Advisory Board on Radiation Safety had previously made a decision and which, after an appeal had been lodged with the Administrative Court, had been returned to STUK for re-processing. Nine applicants were granted the right to serve as a radiation safety expert in industry and research, and two in the use of nuclear energy. The processing of six applications was postponed till 2021.

2.7 Radioactive waste

STUK maintains a 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 2020, see Table 13 in Appendix 1. No new waste was delivered to the low-level waste facility in 2020, partly due to the pandemic. Since the beginning of 2017, some of the waste has been disposed at the 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. The 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 2011–2020, see Figure 3 (chapter 1.1), including radiation safety deviations occurring in the use of non-ionised radiation, a more detailed description of which is contained in chapter 4.7.

Radiation safety deviations to be reported 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 unauthorised use or holding of a radiation source subject to a safety licence
4. any significant spreading of a radioactive substance 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 events that are regarded as significant unplanned medical exposure, which must be reported to STUK without delay.

In 2020, 51 radiation safety deviations occurred related to the use of ionising radiation which were to be reported immediately. Of these deviations, 24 concerned the use of radiation in industry and research, 21 in health care and six in veterinary practices, and two the use of non-ionising 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 the 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

Ten deviations were reported immediately in health care X-ray practices, while this figure was 11 in 2019.

In six 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 patient who had a CT scan and who was exposed to an additional effective dose of approx. 20 to 30 mSv. The patient was supposed to undergo a triple-phase CT scan of their liver, in which unusual imaging software was to be used. The scan was taken by two radiographers who were in the process of learning to use the device. As they were modifying the scan program, the radiographers inadvertently also changed the image quality of the scan from satisfactory to excellent in places, which increased the radiation dose. The patient's large size and less than optimal positioning also contributed to the large dose. The CT scanner was new, and the staff had not finished their operator training. A shortage of radiographers also resulted in a rush.

Example case:
Workmen were putting up a scaffolding outside the CT room. During the construction period, the windows of the room had been covered with sheets of plywood, which also covered the radiation hazard sign visible from the window. Due to shortcomings in information flows, the radiographers did not realise what was happening, and the workmen did not know that they should have watched out for scatter radiation coming from the partly unprotected windows of the room. The situation was noticed after two days. At that time, accessing the scaffolding was prohibited until the radiation protection of the windows had been improved. Three outside workers of a building contractor were exposed to an effective dose of up to 0.3 mSv each.

Radiation safety deviations in nuclear medicine units

Nuclear medicine units reported nine radiation safety deviations. There has been little change year to year, as eight cases were reported in 2019. Five of the radiation safety deviations concerned unplanned medical exposure, three exposures to employees and one exposure to a foetus (public exposure). In a few radiation safety deviations, both the patient and the employee were unnecessarily exposed.

The largest additional exposure caused by a radiation safety deviation to a patient was 52 mSv resulting from a diagnostic I-131 examination which failed due to device failure. Radiation exposures to workers and members of the public caused by radiation safety deviations in nuclear medicine were low in 2020. According to estimates made by undertakings, the effective doses per deviation were no more than a few dozen microsieverts.

Example case 1:
A patient had received a 185 MBq dose of I-131 for a diagnostic examination on Wednesday. The patient was scheduled for a scan on Friday, but the scanner hard disk and the collimator changer had broken down during the night between Thursday and Friday. The scanner could not be repaired on Friday because the equipment manufacturer was unable to supply spare parts until the following day. The clinic did not have a spare device for I-131 scans, which is why the examination had to be rescheduled. The radioactive drug caused an exposure of 52 mSv to the patient. To prevent similar incidents, a plan was made to send the patient to another hospital for imaging. The recurrence of the incident could also be prevented by having a backup device.

Example case 2:
On Friday, a patient with a memory disorder had been given I-131 radioiodine therapy for hyperthyroidism. The activity level of the dose was 377 MBq. On Thursday of the following week, the patient's condition deteriorated and they were taken to the emergency clinic in an ambulance. When the patient was collected, a friend of theirs was present. The friend said that the patient had received some type of treatment but did not know the details. While the patient was transported in the ambulance, they were cared for by a paramedic who was pregnant. During the transport operation of 30 to 45 minutes, the paramedic mainly stayed within a distance of 1-1.5 m from the patient. At the hospital, the patient's dose

rate was measured, and a medical physicist estimated that the foetus had been exposed to approximately 6 μSv. The hospital is considering if instructions could be modified to prevent similar radiation safety deviations.

Example case 3:
A patient had come in for their fourth Ra-223 Xofigo treatment. The radiographer had drawn 5 ml of the radiopharmaceutical into a syringe and measured the syringe using the activity meter of the radiopharmacy room. The activity indicator reading was 3.9 MBq, which was the activity aimed for in the syringe. However, the volume of the radiopharmaceutical in the syringe was higher than it should have been going by the activity concentration of the product. The volume calculated on the basis of the nominal activity concentration was 4.2 ml. The radiographer measured the syringe with another activity meter, obtaining the same result. The radiographer discussed the matter with a medical physicist, but a decision was made to administer the dose to the patient. Investigations conducted after the dose had been administered showed that the IBC software, which controls the activity indicators, used the same adjustment value for both activity indicators. At some point, the adjustment value had changed from 600 set for Ra-223 to 656, which was the old value. As a result, one dose received by the patient was approx. 19% higher than others. No adverse health effects were found in the patient as a result of the deviation. To prevent similar events, the adjustment values of the activity indicators will be checked after software and device updates. Attention will also be paid to calibrations. During a procedure, activity will be checked using a third indicator that is not connected to the IBC software.

Radiation safety deviations in radiotherapy

In 2020, radiation therapy units submitted two reports on radiation safety deviations subject to the immediate reporting obligation. In the first case, the radiation source in gynaecological brachytherapy had moved in relation to the treatment object, and in the second case, the acceleration electrode was damaged.

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

A total of 92 parties (licence holders or undertakings) notified 1 541 minor radiation safety deviations or near misses in health care or veterinary medicine in 2020. While the number of notifiers increased slightly from the previous year, the number of cases changed little.

In X-ray and dental X-ray practices, notifications were received from 66 parties, who reported 987 incidents and 432 near misses. In addition, eight deviations or near misses associated with occupational exposure were reported. Eight licence holders also reported that they had not had any radiation safety deviations during the previous year.

In nuclear medicine, a notification was received for 15 safety licences, and a total of 104 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 16 incidents were included in nuclear medicine deviations.

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 31 cases, the wrong patient was scanned. Most cases of additional exposure to a support person, nine of which were notified, were reported in dental x-ray practices.

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.

Radiation safety deviations in veterinary medicine

Radiation safety deviations in veterinary medicine were notified by nine licence holders in total. They concerned six radiation safety deviations, in addition to which ten other radiation safety deviations were notified in summarized reports. The majority of the notifications concerned the presence of fingers or hands within the radiation beam during a scan. In two cases, an employee had entered the CT room during device calibration by oversight. In one case, a person was exposed to an effective dose of no more than 10 μSv, and in another, a pregnant employee was exposed to a dose clearly smaller than this.

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	**11**
	Other reason	**1**
Wrong examination, procedure, or anatomical object in the referral, which has resulted in an incorrect examination or procedure	Human error	**50**
	Other reason	**13**
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	**16**
	Other reason	**3**
Wrong examination or procedure performed, or wrong anatomical object scanned	Human error	**124**
	Other reason	**40**
Failed examination or procedure (other than injection of a radiopharmaceutical or contrast medium) or related additional exposure	Incorrect or incomplete operating instructions	**19**
	Human error	**230**
	Single hardware or system failure	**107**
	Systematic hardware or system failure	**12**
	Other reason	**137**
Injection of radiopharmaceutical or contrast medium failed	Human error	**25**
	Technical failure of device or equipment	**17**
	Other reason	**95**
Unnecessarily repeated examination	No information on a previous similar examination, or results of a previous examination unavailable	**21**
	Other reason	**30**

Type of radiation safety deviation	**Cause and factor contributing to the radiation safety deviation**	**Number of radiation safety deviations per year**
Unintended foetal exposure	Pregnancy at such an early stage that it could not be confirmed	**2**
	The possibility of pregnancy was not determined using a reliable method before the procedure or examination	**1**
	Other reason	**0**
Extra exposure of a support person	Human error	**0**
	Incorrect or incomplete operating instructions or non-compliance with the instructions	**1**
	Other reason	**8**
A near-miss situation occurring more than once for the same reason	Operational error	**329**
	System or device error	**25**
	Other reason	**78**
Other radiation safety incidents related to medical exposure	Other reason	**24**

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	1
	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	1
Wrong examination or procedure performed, or wrong anatomical object scanned	Human error	4
	Other reason	2
Failed examination or procedure (other than injection of a radiopharmaceutical or contrast medium) or related additional exposure	Incorrect or incomplete operating instructions	2
	Human error	16
	Single hardware or system failure	14
	Systematic hardware or system failure	0
	Other reason	5
Injection of radiopharmaceutical or contrast medium failed	Human error	9
	Technical failure of device or equipment	8
	Other reason	4
Unnecessarily repeated examination	No information on a previous similar examination, or results of a previous examination unavailable	0
	Other reason	0

Type of radiation safety deviation	Cause and factor contributing to the radiation safety deviation	Number of radiation safety deviations per year
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	**7**
	System or device error	**19**
	Other reason	**1**
Other radiation safety incidents related to medical exposure	Other reason	**12**

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

In 2020, a total of 24 reports of radiation safety deviations subject to the immediate reporting obligation were notified to STUK concerning the use of radiation in industry and research. For example, these incidents were related to the use of sealed and unsealed sources, transport of radioactive materials and discovery of radiation sources in the metal recycling process or otherwise.

Use of radiation in industry

Ten radiation safety deviations related to the use of radiation in industry were reported to STUK. In three cases, work had been carried out in the vicinity of a sealed source without closing the shutters. In two cases, radioactive Kr-85 gas had leaked from a sealed source. One case involved the disappearance of an X-ray tube from a shipment on its way to Sweden. There was also one case in which three X-ray units used for pipeline and material inspections were stolen from an undertaking's facilities. The remaining cases were associated with deficiencies in the storage of sealed sources and a fire at the site.

Example case 1:
A belt conveyor using a belt scale, which contained a radiation source, caught on fire. The fire was put out quickly. The extinguishing systems quickly brought the fire under control, and the fire brigade put it out fully. The shutter on the radiation source shield worked, and it was closed. Before starting to clear the site, a sweeping test was taken on the site, which was found to be clean.

Example case 2:
Before planned downtime in a factory, demolition work was carried out around a radiation source, during which its shutter remained open. The work took place behind the beam of the radiation source, and consequently there was no additional exposure. If the demolition work had started in the begining of the planned downtime, the source could have been closed, detached and removed before the work began.

Example case 3:
As an undertaking was moving premises, an old Troxler survey meter containing two sealed sources was found when the basement was cleared out. The device was packaged appropriately and had radiation hazard signs. The device labels indicated that it belonged to a company which the undertaking had bought out years ago. The basement had not been used for years, which explains why the device had not been discovered before. The Troxler meter was disposed of appropriately as it was not needed.

Industrial radiography

No radiation safety deviations in industrial radiography were reported to STUK in 2020.

Use of unsealed sources and radioactive waste

One radiation safety deviation, which involved the splashing of a radioactive solution when unsealed sources were used, and one related to radioactive waste were reported to STUK.

Example case:

Security guards reported abnormal radiation levels in the building's courtyard in the evening. At its highest, the dose rate was approximately 20 μSv/h. The guards were asked to keep people out of the area. As a closer examination of the situation was carried out in the morning, it turned out that in the courtyard in front of double doors leading to a room, the dose rate at the door on the left was approximately 20 μSv/h. A few metres further away, the dose rate dropped below 1 μSv/h. It was discovered that the radiation shielding door was open. The dose rate by the door was approximately 600 μSv/h. The door had also previously been open more or less permanently, without any significant rise in radiation levels being observed outside. The increase was caused by higher radiation levels in the room. Radioactive waste packaging had been stored behind the door. As an immediate measure, the door was closed. A measurement was taken outside to ensure that the radiation level dropped to a reading equal to background radiation.

Transportation of radioactive materials

Two of the radiation safety deviations reported to STUK in 2020 were related to the transportation of radioactive materials. In one case, the transport packaging of radioactive material was misplaced at the end of the transport. In the other case, the forks of a forklift hit the transport packaging of radioactive material at the freight terminal, punching a hole through the cardboard of the outer packaging. The primary packaging inside the cardboard box remained intact, and the shipment was delivered to the recipient.

Radiation sources found

Ten of the radiation safety deviations reported to STUK in 2020 were related to radiation sources or radiative loads found in the metal recycling process. In five cases, the sources were melted in the steel manufacturing process. In four cases, radiation sources were found in scrap loads. One case involved two items found at a recycling centre, one of which had a radiation hazard label and an indication of the owner. No more information was obtained about the person who had brought the items to the recycling centre. STUK contacted the owner identified by the label markings, and the owner collected the items from the recycling centre.

Example case 1:

A company received scrap metal from demolition sites in a container. The company had radiation portal monitors for checking incoming goods, and a raised radiation level was detected in the container. The measurement result was verified by a hand-held radiation meter, and radioactive nuclide Cs-137 was thus identified. A STUK inspector visited the site and went through the load together with the company's employees. The load was found to contain a radiation source containing Cs-137 nuclide. The STUK inspector took possession of the source and removed it from the company's facilities. The incident happened outside

Uusimaa, which was about to be isolated because of the prevailing pandemic situation. This made arrangements to ensure a smooth return journey necessary.

Example case 2:
Several radioactive sources were melted at a steel plant. An Am-241 source was melted in four cases and a Ba-133 source in one case. In addition, an Am-241 source was melted in 2019.

These radiation sources are extremely difficult to detect among recycled metal by measuring, as the level of gamma radiation energy emitted by them is so low that it is easily absorbed by the recycled metal surrounding the sources. The highly accurate measuring devices used at the plant have, however, made it possible to detect the sources once the recycled metal has been melted.

The melted sources of radiation originated from different batches of scrap metal coming from the Netherlands, Germany, Poland and the United Kingdom. These countries receive scrap metal from around the world, and there is no way of finding out the actual origin of the sources.

STUK also reported the cases in 2019 and 2020 to the IAEA. As these are recurring incidents, STUK assessed them as an exceptional safety deviation belonging to category one on the INES scale of international nuclear and radiological events.

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

For 2020, the undertakings in industry and research submitted to STUK a total of five notifications of radiation safety incidents to be reported in summarized form. In addition, one notification submitted to STUK stated that there were no radiation safety deviations in 2020. The notifications of different deviations were submitted by undertakings whose activities include extensive use of unsealed sources. The submitted notifications included a list of approximately 57 minor deviations, most of which were related to small-scale contamination cases that the undertakings were not under obligation to report to STUK immediately. For example, some of the deviations were related to malfunctions in various devices or systems. The notifications also reported on cases where radiation safety observations had been made but no radiation safety deviation had occurred. STUK asked for more information on a few individual cases, but there was no need for further action.

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 2020, there were almost 15 000 workplaces in the database. The target has been set for recording the radon concentrations of more than 1 200 new workplaces in the national Radon Database each year. This target has been exceeded by over 3.5 times. The radon database contains around 4 400 workplaces, at which more than 17 000 radon measurements were carried out in 2020.

Around 13% of conventional workplaces measured in 2020 had radon concentrations exceeding the reference level of 300 Bq/m^3. The median for radon concentrations at conventional workplaces recorded in the radon database was lower than in recent years. The levels of radon concentrations obtained with the alpha track radon detectors of other actors were similar to readings recorded with STUK's equipment. The probable reason for this is that radon concentrations lower than the reference level have increasingly been reported to the radon database recently.

Almost 200 monitoring documents in which a workplace is ordered to reduce its radon exposure or to carry out additional investigations were issued, which is less than in 2019. Monitoring documents were not sent to sites where the employer announced that they were taking measures to reduce radon exposure. In recent years, the number of workplaces with continuous radon monitoring has increased considerably. At the end of the year, 513 workplaces were 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 controls the implementation of these measures.

Very high radon concentrations in workplace air can be a problem at groundwater and artificial groundwater plants. By December 2020, 412 radon measurements in 199 water utility buildings had been carried out at groundwater treatment plants. In 243 measurements, radon concentrations in excess of the reference level were found. Extremely high radon concentrations ($\geq$ 1 500 Bq/m^3) were detected in 95 measurements, and concentrations of over

10 000 Bq/m³ in 12. STUK has issued water utilities with instructions for limiting employees' radon exposure. At the end of the year, 36 groundwater facilities where measurements had been carried out were being monitored (18%).

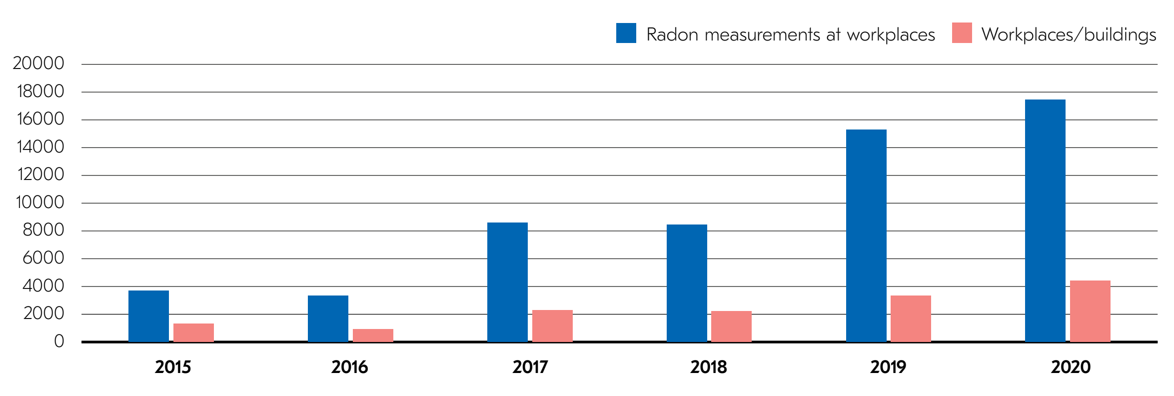

FIGURE 10. Number of workplace measurements/sites recorded in the national Radon Database in 2015–2020 by the end date of the measurement period.

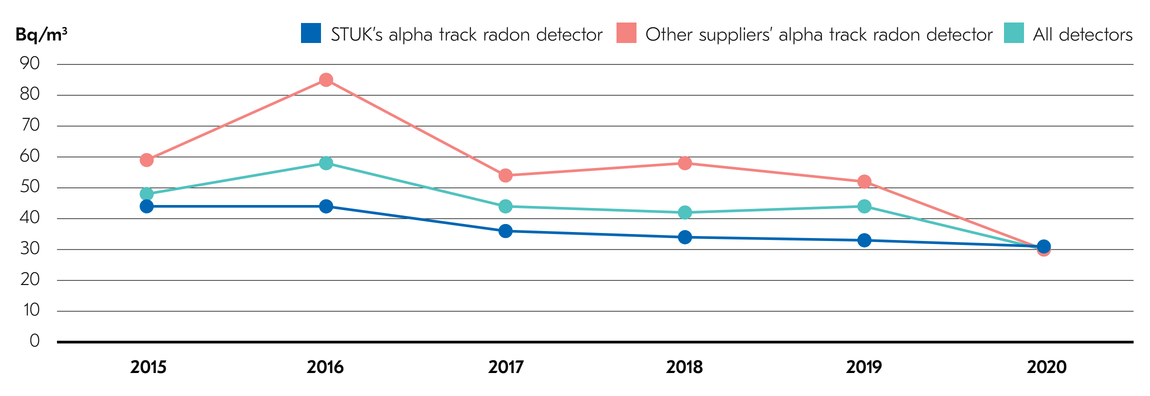

FIGURE 11. Median radon concentrations at conventional workplaces in different years measured using alpha track radon detectors by STUK and other operators (UP), and totals measured using the alpha track radon detectors of all suppliers.

3.2 Radon in underground mines and at excavation sites

Workplace radon concentrations were monitored at four mines and 17 underground excavation and construction sites. Radon measurements were incomplete at one mine, and radon concentrations higher than the reference level were measured at one mine and one excavation site. STUK issued them with a requirement to reduce radon exposure.

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 25 monitoring documents were drafted concerning the monitoring of radioactive materials in building supplies.

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

In NORM control, 30 new cases were initiated in 2020. NORM control cases mainly include notifications and reports on natural radiation exposure and some cases concerning waste. In addition, statements have been issued on EIA assessments and environmental permits, for example. At the end of the year, 23 reports were being processed, and decisions had been issued on four. In particular, the processing of reports submitted by power plants burning coal and peat as well as mining operators is pending. Based on current information, it can be estimated that there are approx. one hundred NORM undertakings with an obligation to report in Finland in total. This estimate does not include groundwater treatment plants.

STUK participated in remote inspections of the Terrafame mine. The processing of the safety licence for the Talvivaara mine, which was based on the old radiation legislation, has been dropped. The Talvivaara mine, similarly to other activities that involve exposure to natural radiation, has an obligation under the current legislation to investigate the natural radiation exposure. Any need for a safety licence will be determined on the basis of this report.

STUK was informed of 23 observations of natural radiation made by the Customs.

3.5 Regulatory control of cosmic radiation in aviation operations

Three airlines have a safety licence for aviation operations. A remote inspection of two of these undertakings was conducted for the first time in 2020. Remote inspections were found to be well suited to inspections of airlines.

4 Regulatory control of the use of non-ionising radiation

4.1 General

In this context, “non-ionising 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-ionising 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-Ionising Radiation (NIR) Surveillance Unit of STUK conducts market surveillance of devices and practices that cause public exposure to non-ionising 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 utilise non-ionising 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-ionising radiation in 2011–2020, see Tables 14 to 17 in Appendix 1. Two laser pointers were found to be too effective, and the sellers withdrew them from the market. One of them was discovered in connection with STUK’s regulatory control, and a RAPEX notification concerning it was submitted to the European Commission’s Safety Gate system of dangerous consumer goods. The other device was discovered thanks to a RAPEX notification made by France. In 2020, STUK intervened a total of 22 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.

The restrictive measures imposed on society because of the COVID-19 epidemic in spring 2020 had a particular impact on the supervision of laser performances as well as sunbed and beauty care facilities. Whereas there were practically no public shows for a time, it was unclear for some time how the restrictions would affect the activities of sunbed and beauty care undertakings. During this period, different remote supervision methods were tested, but experiences of them were not particularly good.

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 monitored the situation actively and noticed that dangerous laser pointers were frequently found again.

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 UV radiation devices

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 2020, non-compliance with the requirement was still discovered, and enhanced regulatory control was continued. Altogether 26 inspections of sunbed facilities were carried out by municipal health protection authorities. In addition to this, five sunbed facilities were surveyed on the basis of STUK's monitoring (Appendix 1, Table 16). No deficiencies were detected in 35% of the facilities inspected. In 23% 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 7%, operating instructions in 35%, device timers in 9% and the availability of eye protectors in 6% of the facilities.

Market surveillance of UV products focused on UV torches. Seven out of eight torches had deficiencies in the labelling. The seller of one torch withdrew it from the market, whereas the others corrected the warning labels to meet the requirements.

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 in the sale or use of 24 laser devices. Two laser pointers were found to be too powerful, and the sellers withdrew them from the market. One of the devices was discovered on the basis of STUK's regulatory control, and a RAPEX notification was submitted. The other device was discovered thanks to a RAPEX notification made by France. The remaining 22 cases were related to the sale of a laser device on a website for trade between consumers.

STUK received 35 notifications of the use of laser devices in public shows and inspected two of them on site. As a result of the restrictions brought in to control COVID-19 epidemic, the number of shows dropped dramatically from the previous year, and they tended to be 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 especially in autumn 2020. In roughly one case out of three, the notification to STUK was delayed. One undertaking was issued with a written request to rectify the matter, while another received a reprimand by e-mail. STUK also received reports stating that in two cases, the alignment of the laser beam and the placement of the laser equipment did not correspond to the notification. The era of fixed-term approvals ended at the end of 2020, after which only licences valid until further notice have been issued. Six licences valid until further notice were issued in 2020, and the total number of valid licences was 12.

4.4 Regulatory control of devices producing electromagnetic fields

In 2020, STUK tested ten mobile phones as part of a comparison measurement campaign conducted with the Swedish Radiation Safety Authority (SSM). SSM carried out measurements on mobile phones in 2018, while STUK performed its measurements in 2020. The results of the measurements will be posted on STUK's website in 2021.

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. A study of microwave drying of moisture and water damage in buildings found that microwave drying has been falling out of use in the 2010s. Only two companies provide this service today. The technique is little used by one of these companies, as microwaves are only used to dry four or five sites every year. According to the study, microwave drying is carried out safely following STUK's instructions, avoiding excessive microwave radiation exposure to employees or the public.

The radiation safety of wireless power transfer was examined by means of a literature review and surveys. In Finland, wireless power transfer is used to charge the batteries of low-voltage electrical devices, including mobile phones, electric toothbrushes, laptops, kitchen appliances and power tools. It is currently not used in higher voltage applications, such as charging electric car batteries. This minimises exposure to magnetic fields in wireless power transfers.

The radiation safety of amateur radio stations was examined by carrying out radiation measurements in the vicinity of different antennas. The measurement results indicate that public exposure in the local area to radiofrequency electric and magnetic fields generated by amateur radio stations is significantly lower than the limit value with transmitter power and modes of operation used in the stations' normal activities. Particular attention should be paid to the placement of antennas when high transmission power is used. The antennas must be installed at a sufficient height and far enough away from the nearest residential buildings, in places to which the public has no access. Radiofrequency electric and magnetic fields generated by amateur radio station antennas installed following amateur radio equipment manuals do not have health impacts on the public. A TR report was prepared on the study and published in Julkari.

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 2020. Regulatory control was targeted at strong laser devices and their use. In particular, STUK received information on them through its regulatory control and complaints received. A total of 24 requests for specification were sent to undertakings in 2020, and in seven of these cases, a laser device that was too powerful was found. The supervision led to voluntary suspension of the use of laser devices or to the initiation of a licence application process to operate as a health care unit, which is why no decisions to suspend activities had to be issued. 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 three cases, drafting more detailed care instructions was regarded sufficient as a corrective measure that justified the continued use of the devices. 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 from the end of 2023 onwards. In the regulatory control of these device types, efforts have been made to inform undertakings about the situation of their devices after the transition period. The IMPULSSI research project also developed a measurement system suitable for determining the properties of light impulse devices in 2020 to support their future regulatory control. The suitability of the system for on-site measurements was ensured by monitoring measurement visits to the premises of cooperative undertakings.

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. In addition, STUK gave a lecture on the requirements of the Radiation Act to students aiming for a specialist qualification in beauty care in 2020.

4.6 Other tasks

STUK received requests for a statement on power line projects and land use plans near power lines. Altogether 16 statements were issued on projects. Two statements were issued on other matters related to non-ionising radiation.

In addition to regulatory control, STUK's NIR unit replied to 816 inquiries from citizens in 2020, which is clearly the largest number ever recorded. Of these inquiries, 282 were made by telephone and 534 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 COVID-19 epidemic, UVC radiation and devices.

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

In 2020, STUK received three notifications of events caused by non-ionising radiation. STUK received four notifications of accidents that occurred in beauty care services. In the first case, a treatment provided with RF therapeutic equipment had caused pain and a skin reaction which continued on the day following the procedure. In the second case, a customer had noticed undesirable changes in their face following a procedure performed with an ultrasound device. The other two complaints were related to services offered in health care operating units that are not subject to STUK's regulatory control. The notable feature of these reports was, however, that damage had been caused using device types that are also widely used outside health care.

Complaints related to laser shows and sunbed facilities were also made to STUK. A complaint about two laser shows drew attention to the alignment of the laser beams and the placement of laser devices at the show (see chapter 4.3).

Two sunbed customers complained to STUK that the responsible person was not present when the sunbed was used (one of these incidents occurred at the turn of the year 2019–2020). The complaints concerned two facilities of the same service provider. STUK inspected these sites and insisted that in the future, the undertaking ensure that the responsible person is always present when the sunbed is available.

For the numbers of radiation safety deviations in 2010–2020, see Figure 3 (chapter 1.1; see also chapter 2.8 about radiation safety deviations in the use of ionising radiation).

5 Regulation work

During the year, STUK submitted proposals concerning needs for legislative amendments to the Ministry of Social Affairs and Health. The amendments would apply to the Radiation Act and the decrees issued by virtue of it. They are mainly based on experiences gathered in connection with regulatory control and the requirements of the Basic Safety Standards Directive. In addition, revisions of STUK regulations were drafted, three of which were circulated for comments in late 2020. One of them concerns ionising radiation, while the other two are related to non-ionising radiation.

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.

A further purpose of research related to the use of radiation is to increase knowledge and expertise in this field and to ensure reliable measurement of radiation. Research on ionising 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-ionising 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. 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.

STUK participated in the work of the EURADOS working groups 2 (Harmonisation 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 optimisation of exposure. A project aiming to analyse the total dose caused by radiotherapy (incl. imaging) was prepared 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 Finnish project partners were Helsinki University Hospital and Tampere University Hospital.

STUK continued a project launched in 2019 aiming to develop a measurement method for IPL (intense pulsed light) beauty care devices. The project applied this measurement method both to devices sold to households and those used by beauticians. The objective is to write a scientific article on the project, with an emphasis on the market surveillance of IPL devices in 2021.

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 doses to the eye based on the available exposure parameters and AI models. The results will be used for directing the regulatory control of the authorities.

The four-year detector development project funded by the Academy of Finland continued in 2020. The work is carried out in cooperation with the Helsinki Institute of Physics. The project develops position-sensitive detectors that identify the type of radiation. They are developed to respond to the needs of diagnostic radiation practices and radiotherapy dosimetry. The detectors can also measure the radiation energy spectrum.

STUK continued the RATPA project on radon concentrations at Finnish workplaces and employees' radon exposure, which began in 2018. The study has carried out measurements at 700 workplaces with at least one alpha track radon detector. Additionally, continuous radon measurements and gamma measurements have been carried out. The findings of one of the project's sub-objectives, or occupational health and safety officers' perceptions of radon matters in the workplace, were published as a STUK B report in 2020.

STUK continued the FINNORM project launched in 2019, which maps out industrial activities involving exposure to naturally occurring radioactive materials (NORMs) in Finland. The project has improved monitoring, informed the industry about the new radiation legislation and developed procedures for evaluating exposure. The project is underpinned by the amended radiation legislation and international recommendations related to NORMs, the rise of the circular economy, implementation of STUK's strategy related to risk-based control, and open questions related to NORMs in Finland. The project studied NORMs in mining and groundwater treatment plants. The findings of a thesis on mining activities, which was part of the project, was published in 2020. The other findings and the revised NORM guide will be published as the project is concluded in 2021.

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 Standards Directive (BSS), also at the levels of administration and practical control. Among other things, the project will examine reliable exposure assessment methods and radon measurements in different types of workplaces as part of radon control at workplaces. Special attention will be focused on temporal and local variations in radon concentrations and different types of environmental conditions. One of the aspects to be investigated is radon exposure in mobile work carried out at a variety of locations. The RiFaTuB case control study investigates a possible link of head area CT scans and radon in indoor air as well as other factors to brain tumour risk in children. A publication of the Eur Radiol Open journal reports that the number of CT scans on children has declined in the 2000s, especially in the head area, while the number of musculoskeletal system scans has even increased slightly.

STUK continued a project launched in late 2019 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 in buildings 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)

In 2020, two European metrology research programme projects were launched with the aim of creating a network-based consortium in the field of ionising radiation metrology. In the future, the networks will coordinate metrology research needs and cooperation between laboratories. STUK participates in both projects.

The RTNORM project, which focused on radiotherapy dosimetry, was concluded. The project developed accurate dosimetry for ionisation chambers for dose determination in radiotherapy. The project is related to the update of the IAEA protocol for dose measurement in radiotherapy (IAEA TRS 398).

The MetroRADON project launched in 2017 was concluded in 2020. Its aim was to develop accurate procedures for the traceable measurement and calibration of small radon concentrations. The project made possible the calibration of low radon activity concentrations, and a European network of calibration laboratories is now up and running. The impact of thoron (radon-220) on radon meters was investigated. Two reference calibrations of radon concentrations were organised in this project, in both of which STUK participated.

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 organisations and commissions dealing with regulatory control and the development of safety instructions and measuring methods relating to the use of ionising and non-ionising radiation, and in standardising activities in the field of radiation. These organisations 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 March 2020, remote meetings were introduced because of the pandemic, and some of the regular meetings were cancelled or postponed.

STUK representatives lead the nuclear medicine division of the HERCA Medical Applications working group. In this working group, the authorities of the HERCA countries have looked at the use of new nuclear therapies and the radiation safety issues related to them and prepared a summary, which HERCA approved for submission to a scientific journal.

Participation in the work of international organisations 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 2020, radiation practice experts from STUK participated in the meetings of the following international organisations 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
- The annual meeting of EURADOS (European Radiation Dosimetry Group) and its working groups
- EACA meeting (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), 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 (standardisation of beauty care devices)
- Nordic-NIR general meeting, chaired by STUK.

8 Cooperation in Finland

Participation in the work of Finnish organisations and commissions

Representatives of STUK are involved in many Finnish organisations and commissions that deal with the regulatory control of and research in the use of ionising and non-ionising radiation, and with standardisation activities in the field of radiation. They include the Advisory Body on Metrology, the Radiation Safety Day committee, the Education Committee of Medical Physicists, 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 National Institute for Health and Welfare, the authorities' radon working group and the Environmental Intolerance Network. 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 2020, representatives from STUK participated in, among other things, the meetings of the following Finnish organisations and working groups:

- Subordinate working groups of the Ministry of Social Affairs and Health for the comprehensive revision of radiation legislation
- Environmental Intolerance Network of the Ministry of Social Affairs and Health
- 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 the Customs
- Finnish network of metrological standard laboratories
- Advisory Board coordinating radiation safety expert training (STAKONE)
- Advisory Committee on Radiation Safety
- Advisory Board on Metrology.

Finnish conferences arranged by STUK

Several conferences planned for 2020 had to be cancelled due to the pandemic, including the Radiation Safety Days event, in the planning of which STUK participated actively. However, STUK was able to respond to some of the needs by means of webinars. Webinars were organised particularly in the field of nuclear medicine.

Other cooperation in Finland

A STUK representative served as a member and secretary of the Finnish Advisory Committee for Clinical Audit (KLIARY) appointed by the National Institute for Health and Welfare (THL) and funded by the Ministry of Social Affairs and Health (STM). The STUK representative was also responsible for maintaining the Committee's website. Among other things, the Committee prepared a recommendation on the use of cardiological radiation for clinical audits. Recommendations and more information about the Committee's activities are available on its website (www.kliininenauditointi.fi).

As a task assigned by the Ministry of Social Affairs and Health, STUK coordinates a preliminary study on the development of the referral guidelines referred to in the Radiation Act. Participants in this work are the Ministry of Social Affairs and Health, the Finnish Institute for Health and Welfare, STUK, hospital radiologists and a medical physicist. The working group submitted its final report to the Ministry of Social Affairs and Health (STUK-B 273).

STUK participated in inter-authority cooperation led by the Ministry of Social Affairs and Health. In 2020, joint workshops of Fimea, Tukes, Valvira and STUK were organised on own-checks and remote inspections. The participants in the workshops shared experiences of good methods by which the authorities can support own-checks and remote inspection practices.

A two-part webinar was organised for radiation safety experts in industry and research. The first day focused on the amended radiation legislation as well as on supplementary training for radiation safety experts and their role in radiation practices. The topic of the second day was the requirements for safety assessments and STUK's experiences of confirming safety assessments. For the presentations of the online seminar, visit STUK's website.

An undertaking organised a training day on the use of ionising radiation for its employees. STUK was invited to the event to talk about the requirements under the radiation legislation. In addition, STUK discussed the regulatory control of radiation use and instructions for preparing a safety assessment at the training event.

An undertaking operating in industry and research that uses X-ray equipment wished to organise an online training course relevant to its sector. The undertaking invited a STUK inspector to give a lecture on the new Radiation Act.

STUK has charged the fee indicated in STUK's service price list for lectures at events organised by undertakings and the time needed to prepare them. Inspectors working with industry and research can be invited to give lectures, and the hourly fees charged by the personnel members are available in STUK's service price list at https://www.stuk.fi/web/en/services.

9 Communication

In 2020, 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-ionising 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:

- A radiation source lost in Helsinki was found
- Fire alarms mixed up with scrap caused trouble for a scrap entrepreneur
- Orphan source collected safely in Imatra
- Radon is the greatest source of radiation exposure to Finns
- Shade, clothing and sun cream protect against UV radiation
- RadoNorm: A European research project on the risks of natural radiation and their management
- Sunbeds increase cancer risk also during the COVID-19 pandemic.

Three newsletters were published in 2020 for radiation users in the health care sector and three for users in industry.

10 Metrological activities

10.1 General

STUK serves as the national metrological laboratory for radiation dose quantities. STUK maintains national and other measurement standards to ensure the accuracy and traceability of radiation measurements 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 the field of radiation metrology, STUK is involved in the work of the Advisory Committee on Metrology and the European Association of National Metrology Institutes (EURAMET). 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 ionising radiation, and the NIR Unit for non-ionising radiation. Metrology of ionising radiation activity quantities is the responsibility of the Department of Environmental Radiation Surveillance (VALO) at STUK.

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 2020, STUK participated in a dosimetry comparison (RPLD comparison) 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 12).

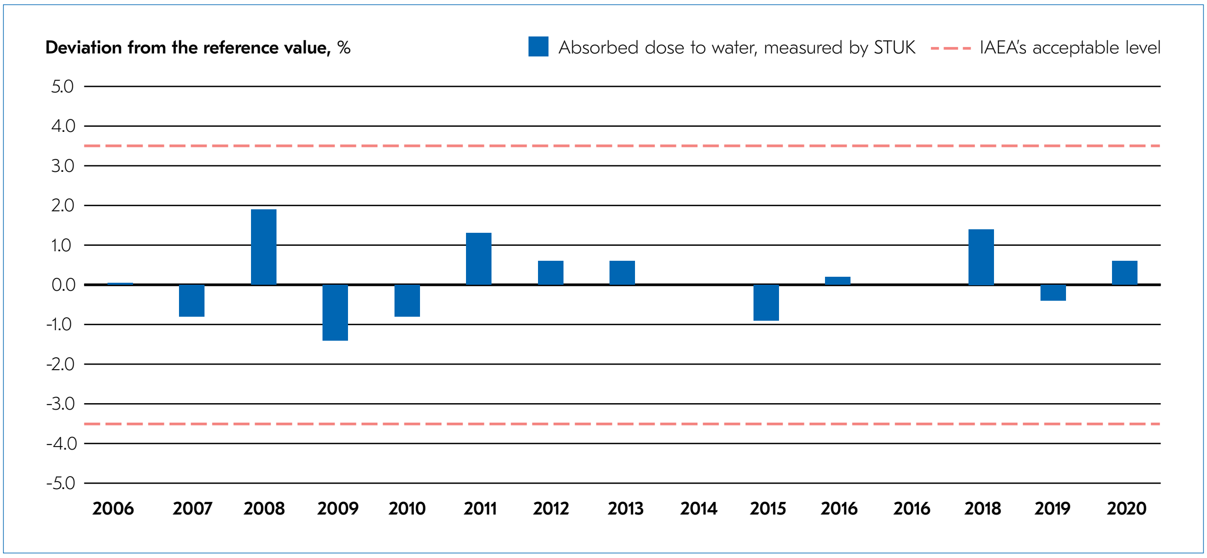

FIGURE 12. The results of IAEA dosimetry comparisons in which STUK has participated in 1996–2020.

11 Services

11.1 Calibration, testing and irradiation

STUK performed radiation meter calibrations and testing according to demand. The Dosimetry laboratory performed 478 radiation meter calibrations and irradiated 2,091 samples. Approximately 20% of the calibrations were performed on STUK's own instruments. For the trend in service output in 2011–2020, see Table 18 in Appendix 1.

The Radon metrology laboratory also produced three exposure certificates with a large number of exposures. In addition, two alpha track film calibration calculations were carried out, and the certificates associated with them were prepared. The number of radon meters calibrated was 47.

The Non-Ionising 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 2011 to 2020, see Table 15 in Appendix 1.

11.2 Other services

Altogether 58 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 2020.

Radiation practices	**Number of practices**
Health care and dental care	1 423
Radiotherapy	13
Nuclear medicine	25
Veterinary practices	298
Installation/servicing/manufacture	49
Other use of medical devices (research, education)	13
Non-medical exposure in healthcare	133

TABLE 2. Radiation sources and appliances and radionuclide laboratories in the use of radiation in health care and veterinary practices at the end of 2020.

Appliances/sources/laboratories	**Number**
X-ray diagnostic appliances (generators)*)	**1 1471**
fixed conventional X-ray appliances	480
portable fluoroscopy appliances	307
portable conventional X-ray appliances	161
mammography appliances, of which	171
• screening mammography	82
• tomosynthesis	25
fixed fluoroscopy appliances, of which	123
• angiography	40
• fluoroscopy	24
• cardioangiography	59
CT-appliances, of which	146
• SPECT-CT	36
• PET-CT	16
CBCT appliances (other than dental imaging)	18
O-arm appliances	12

Appliances/sources/laboratories	**Number**
bone mineral density measurement appliances	50
other appliances	3
Dental X-ray appliances	**6 213**
intraoral X-ray appliances	5 474
panoramic tomography X-ray appliances	642
CBCT appliances	143
Radiotherapy appliances	**125**
accelerators	50
X-ray imaging appliances	53
automatic afterloading appliances	6
manual afterloading appliances	1
radiotherapy simulators	15
Sealed sources/sealed source appliances)**	**276**
calibration and testing equipment	331
radiotherapy check sources	40
attenuation correction units	4
other sealed sources in health care	5
X-ray appliances in veterinary practices	**523**
conventional X-ray appliances	347
fluoroscopy appliances	2
intraoral X-ray appliances	178
CBCT appliances	5
CT appliances	10
Radionuclide laboratories	**36**
unsealed sources in laboratories, category 2	28
unsealed sources in laboratories, category 3	8

*) 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 2020.

Use of radiation	**Number of practices**
Use of X-ray appliances	706
Use of sealed sources	497
Installation/servicing/manufacture	150
Import and export of radiation sources or trade in them	112
Use of unsealed sources	61
Use of particle accelerators	19
Transport of high-activity sealed sources	3
Waste treatment (if not part of practices)	3
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 2020.

Appliances/laboratories	**Number**
Sealed source appliances	**5 614**
radiometric measuring instruments	4 823
calibration and testing devices	405
analysis devices	190
gamma radiography appliances	18
gamma irradiators	9
others	169
X-ray appliances	**2 202**
fluoroscopy appliances	960
analysis appliances	708
X-ray radiography appliances	361
measuring appliances	79
others	94
Particle accelerators	**27**
research	13
fluoroscopy	7
manufacturing of radioactive materials	7
Radionuclide laboratories	**87**
category 1	10
category 2	21
category 3	54
activities outside laboratories (tracer tests in industrial plants)	2

TABLE 5. Radionuclides most commonly used in sealed sources in industry and research at the end of 2020.

Radionuclide	Number of sources
Other than high-activity sealed sources	
Cs-137	3 963
Co-60	764
Kr-85	296
Am-241 (gamma sources)	273
Fe-55	95
Am-241 (AmBe neutron sources)	91
Sr-90	88
Pm-147	81
Ni-63	70
High-activity sealed sources	
Cs-137	26
Co-60	12
Ir-192	9
Am-241 (AmBe neutron sources)	6
Am-241 (gamma sources)	3
Pu-Be	1
Se-75	1

TABLE 6. The numbers of sealed sources which are used in industry and research 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)			
	2020	2021	2022	2023
Cs-137	84	121	161	194
Co-60	30	30	37	45
Am-241 (gamma sources)	14	17	19	19
Am-241 (AmBe neutron sources)	8	8	8	10

TABLE 7. Deliveries of sealed sources to and from Finland in 2020.

Radionuclide	Deliveries to Finland		Deliveries from Finland	
	Activity (GBq)	Number	Activity (GBq)	Number
Ir-192	42 036	13	1 419	13
Se-75	2 760	1	530	2
Kr-85	1 476	100	1 051	71
Fe-55	175	31	124	21
Cs-137	113	125	1	11
Pm-147	23	24	2	12
Gd-153	11	21	-	-
Co-57	7	50	-	-
Sr-90	6	8	4	2
Ni-63	6	53	5	32
Co-60	5	16	< 1	2
Po-210	2	5	-	-
Ge-68	1	24	-	-
Am-241	1	204	2	396
Na-22	1	3	-	-
Others total **)	< 1	66	< 1	22
Total	**46 624**	**744**	**3 139**	**584**

*) The symbol "-" indicates no deliveries from Finland.

**) Deliveries to Finland: I-125, Ba-133, H-3, C-14, Eu-152, Ra-226, I-129, Tc-99, Pu-242.

Deliveries from Finland: Eu-152, Ba-133, H-3, C-14.

TABLE 8. Manufacturing of radioactive substances (unsealed sources) in Finland in 2020.

Radionuclide	Activity (GBq)
F-18	254 809
O-15	36 183
C-11	30 802
Ga-68	11
Total	**321 804**

TABLE 9. Number of air crew members subject to individual monitoring of radiation exposure and collective dose (sum of effective doses) in 2011–2020.

Year	Number of workers		Collective dose (manSv)	
	Cockpit crew	Cabin crew	Cockpit crew	Cabin crew
2011	1 208	2 423	2.85	6.23
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

TABLE 10. Number of radiation workers subject to individual monitoring by sector in 2011–2020.

Year	Number of workers in each sector									
	Health care		Veter-inary practices	Industry	Research and education	Manufacturing of radioactive materials	Radon	Others *)	Use of nuclear energy **)	Total ***)
	Exposed to X-radiation	Exposed to other radiation sources								
2011	4 320	1 050	550	1 209	742	22	21	79	3 830	11 659
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

*) 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 workers subject to individual monitoring by sector in 2011–2020.

Year	Collective dose (manSv)									
	Health care		Veterinary practices *)	Industry	Research and education	Manufacturing of radioactive materials	Radon	Others *)	Use of nuclear energy **)	Total ***)
	Exposed to X-radiation *)	Exposed to other radiation sources								
2011	1.33	0.11	0.09	0.13	0.07	0.007	0.10	0.001	1.83	3.67
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

*) $H_p(10)$ 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 2020.

Group	**Number of workers**	**Collective dose (manSv)**	**Average dose (mSv)**		**Highest dose (mSv)**
			Workers whose dose exceeds recording level*)	**All workers subject to individual monitoring**	
Cardiologists and interventional cardiologists**)	213	0.25	1.88	1.18	10.07
Radiologists**)	229	0.19	2.83	0.81	9.99
Interventional radiologists**)	32	0.16	6.44	5.03	38.44
Consultant specialists**) ***)	245	0.04	0.79	0.15	4.59
Radiographers (other than X-radiation)	686	0.07	0.67	0.11	4.01
Animal attendants and assistants**)	496	0.05	0.87	0.11	4.31
Veterinarians**)	276	0.03	1.01	0.12	4.46
Industrial material inspection technicians ****)	592	0.10	0.59	0.17	4.77
Industrial tracer testing technicians	25	0.03	2.86	1.43	8.79
Nuclear power plant workers					
• mechanical work and machine maintenance	781	0.50	1.41	0.65	7.55
• cleaning	206	0.18	1.76	0.88	7.75
• insulation work	56	0.15	8.25	2.65	11.66
• material inspection	257	0.15	0.92	0.59	5.92
• radiation protection personnel	103	0.14	1.63	1.33	8.92

*) 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 2020). 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	2 082
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	2.5 kg

TABLE 14. Work of the NIR Unit in regulatory control of the use of non-ionizing radiation in 2011–2020.

Year	Regulatory inspections	Decisions	Statements	Prohibitions of dangerous laser equipment sold on the internet	Total
2011	56	6	3	42	107
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

TABLE 15. Service work of the NIR Unit in 2011–2020.

Year	Calibrations and tests	Safety assessments and radiation measurements	Total
2011	4	10	14
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

TABLE 16. Inspections of sunbed facilities in 2011–2020. 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
2011	7
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)

TABLE 17. SAR tests of mobile phones and other wireless devices in 2011–2020.

Year	Number of tests
2011	5
2012	15
2013	11
2014	10
2015	14
2016	11
2017	0
2018	0
2019	0
2020	10

TABLE 18. Service work pertaining to ionising radiation in dosimetry laboratory in 2011–2020.

Year	Calibrations and tests, Number of meters	Number of irradiations	PCXMC-licences
2011	317	235	59
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

Appendix 2
Publications in 2020

The electronic publication archive Julkari (julkari.fi) features STUK's serial publications in PDF format. Julkari also serves as a publication register. For this reason, only metadata is available for some publications.

The following publications concerning safe use of radiation were completed in 2020:

Scientific articles by STUK employees

Abuhamed J, Nikkilä A, Lohi O, Auvinen A. Trends of computed tomography use among children in Finland. European Journal of Radiology Open 2020; Volume 7, 100290, pp. 1-7.
DOI: https://doi.org/10.1016/j.ejro.2020.100290

Bly Ritva. Radiation protection issues in radionuclide therapy – workers (medical staff), third persons, waste management. p 37-48. In book: Developments in nuclear medicine – New radioisotopes in use and associated challenges. Radiation Protection No 194. EU scientific seminar held in Luxembourg on 13 November 2019. Luxembourg: European Commission: 2020.
DOI: https://doi.org/10.2833/905722

Bly Ritva, Järvinen Hannu, Kaijaluoto Sampsa, Ruonala Verneri. Contemporary collective effective dose to the population from x-ray and nuclear medicine examinations – changes over last 10 years in Finland. Radiation Protection Dosimetry 2020; 189 (3): 318-322.
DOI: https://doi.org/10.1093/rpd/ncaa045

Kojo K, Kurttio P. Indoor Radon Measurements in Finnish Daycare Centers and Schools – Enforcement of the Radiation Act. Int. J. Environ. Res. Public Health 2020; 17: 2877.
DOI: https://doi.org/10.3390/ijerph17082877

Lindgren Jussi, Liukkonen Jukka. The Heisenberg uncertainty principle as an endogenous equilibrium property of stochastic optimal control systems in quantum mechanics. Symmetry 2020; 12 (9): 1533. DOI: https://doi.org/10.3390/sym12091533

Lindholm C, Pekkarinen A, Sipilä O, Manninen A-L, Lehtinen M, Siiskonen T. Estimation of Hp(3) among staff members in two nuclear medicine units in Finland. Radiation Protection Dosimetry 2020; 190 (2): 176-184. DOI: https://doi.org/10.1093/rpd/ncaa096

Madekivi V, Boström P, Karlsson A, Aaltonen R, Salminen E. Can a machine-learning model improve the prediction of nodal stage after a positive sentinel lymph node biopsy in breast cancer? Acta Oncologica 2020. DOI: https://doi.org/10.1080/0284186X.2020.1736332

Tikkanen J, Zink K, Pimpinella M, Teles P, Borbinha J, Ojala J, Siiskonen T, Gomà C, Pinto M. Calculated beam quality correction factors for ionization chambers in MV photon beams. Physics in Medicine & Biology 2020; 65 075003: 15pp.
DOI: https://doi.org/10.1088/1361-6560/ab7107

STUK's own serial publications

Helasvuo Timo (ed.). Kuvantamisessa henkilöön kohdistettu muu kuin lääketieteellinen altistus vuonna 2017. Terveydenhuollon valvontaraportti. (Non-medical imaging examinations performed in 2017. Supervision report in health care.) STUK-B 250. Helsinki; Radiation and Nuclear Safety Authority: 2020. http://www.julkari.fi/handle/10024/139367

Helasvuo Timo. Radiologian henkilöstöresurssit 2019. Valtakunnallinen selvitys julkisen terveydenhuollon radiologisten yksiköiden henkilöstöresursseista. Terveydenhuollon valvontaraportti. (Human resources in radiology departments 2019. Nationwide assessment of human resources in radiology departments in public healthcare. Supervision report in health care.) STUK-B 257. Helsinki; Radiation and Nuclear Safety Authority: 2020.
http://www.julkari.fi/handle/10024/140246

Kaijaluoto Sampsa, Liukkonen Jukka. Isotooppitutkimukset ja -hoidot Suomessa vuonna 2018. Terveydenhuollon valvontaraportti. (Nuclear medicine examinations and therapeutic treatments in Finland in 2018. Supervison report in health care.) STUK-B 252. Helsinki; Radiation and Nuclear Safety Authority: 2020. http://www.julkari.fi/handle/10024/139991

Kojo Katja, Vahtola Johanna, Kurttio Päivi. Radonkysely työsuojeluhenkilöille. (Radon survey for occupational health and safety officers.) STUK-B 261. Helsinki; Radiation and Nuclear Safety Authority: 2020. https://www.julkari.fi/handle/10024/140616

Liukkonen Jukka. Optimointi isotooppikuvantamisessa. Terveydenhuollon valvontaraportti. (Optimization in Nuclear Medicine Imaging, Supervison report in health care.) STUK-B 251. Helsinki; Radiation and Nuclear Safety Authority: 2020.
http://www.julkari.fi/handle/10024/139515

Puranen Lauri. Radioamatööriasemien säteilyturvallisuus. (Radiation safety of amateur radio stations.) STUK-TR 33. Helsinki; Radiation and Nuclear Safety Authority: 2020. https://www.julkari.fi/handle/10024/140543

Siiskonen Teemu (ed.), Bly Ritva, Isaksson Risto, Kaijaluoto Sampsa, Kiuru Anne, Kojo Katja, Kurttio Päivi, Lahtinen Juhani, Lehtinen Maaret, Muikku Maarit, Peltonen, Tuomas, Ruonala Verneri, Torvela Tiina, Turtiainen Tuukka, Virtanen Sinikka. Suomalaisten keskimääräinen efektiivinen annos vuonna 2018. (Average effective dose of Finns in 2018.) STUK-A263. Helsinki; Radiation and Nuclear Safety Authority: 2020. http://www.julkari.fi/handle/10024/139611

Siiskonen Teemu (ed.), Bly Ritva, Isaksson Risto, Kaijaluoto Sampsa, Kiuru Anne, Kojo Katja, Kurttio Päivi, Lahtinen Juhani, Lehtinen Maaret, Muikku Maarit, Peltonen, Tuomas, Ruonala Verneri, Torvela Tiina, Turtiainen Tuukka, Virtanen Sinikka. Den genomsnittliga effektiva dosen hos finländarna 2018. STUK-A264. Helsinki; Radiation and Nuclear Safety Authority: 2020. https://www.julkari.fi/handle/10024/140841

Venelampi Eija (ed.), Aallos-Ståhl Siiri-Maria, Hallinen Elina, Hellstén Santtu, Hoilijoki Heli, Kaijaluoto Sampsa, Kallio Antti, Kiuru Anne, Korhonen Milla, Kuhmonen Venla, Kurttio Päivi, Latomäki Antti, Lehtinen Maaret, Nylund Reetta, Orreveteläinen Pasi, Outola Iisa, Rantanen Salla, Siiskonen Teemu, Sipilä Petri, Takkinen Antti, Tenkanen-Rautakoski Petra, Toivonen Tommi, Visuri Reijo, Ylianttila Lasse. Säteilyn käyttö ja muu säteilylle altistava toiminta. Vuosiraportti 2019. (Radiation practices. Annual report 2019.) STUK-B 247. Helsinki; Radiation and Nuclear Safety Authority: 2020. https://www.julkari.fi/handle/10024/140238

Venelampi Eija (ed.), Aallos-Ståhl Siiri-Maria, Hallinen Elina, Hellstén Santtu, Hoilijoki Heli, Kaijaluoto Sampsa, Kallio Antti, Kiuru Anne, Korhonen Milla, Kuhmonen Venla, Kurttio Päivi, Latomäki Antti, Lehtinen Maaret, Nylund Reetta, Orreveteläinen Pasi, Outola Iisa, Rantanen Salla, Siiskonen Teemu, Sipilä Petri, Takkinen Antti, Tenkanen-Rautakoski Petra, Toivonen Tommi, Visuri Reijo, Ylianttila Lasse. Radiation practices. Annual report 2019. STUK-B 258. Helsinki; Radiation and Nuclear Safety Authority: 2020. https://www.julkari.fi/handle/10024/140550

STUK brochures/Other publications

Turtiainen T. Lakisääteiset työpaikkojen radonmittaukset. (Statutory radon measurements at workplaces.) Finnsafe 2/2020: s. 24.

Wassholm Sebastian. När olyckan är framme – en fallstudie om Strålsäkerhetscentralens roll i Finlands krisberedskap inför en strålrisksituation. (In the Event of an Accident - A case study on the Radiation and Nuclear Safety Authority's role in Finnish emergency preparedness when dealing with a radiation risk situation). Master's thesis. Faculty of Social Sciences, Business and Economics, Public Administration. Åbo Akademi University 3 July 2020. https://www.doria.fi/handle/10024/177831

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