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Eija Venelampi (ed.)

Radiation practices

Annual report 2019

THIS REPORT WAS PREPARED BY

Siiri-Maria Aallos-Ståhl
Elina Hallinen
Santtu Hellstén
Heli Hoilijoki
Sampsa Kaijaluoto
Antti Kallio
Anne Kiuru
Milla Korhonen
Venla Kuhmonen
Päivi Kurttio
Antti Latomäki
Maaret Lehtinen
Reetta Nylund
Pasi Orreveteläinen
Iisa Outola
Salla Rantanen
Teemu Siiskonen
Petri Sipilä
Antti Takkinen
Petra Tenkanen-Rautakoski
Tommi Toivonen
Reijo Visuri
Lasse Ylianttila

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Radiation practices

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Abstract

A total of 3 079 safety licences for the use of ionising radiation were current at the end of 2019. The use of radiation was controlled through regular inspections performed at places of use, regulatory control queries, control test packages sent by post to dental X-ray facilities, and maintenance of the Dose Register. The Radiation and Nuclear Safety Authority (STUK) conducted 217 inspections of safety-licensed practices in 2019. The inspections resulted in 123 repair orders issued.

A total of 15 700 occupationally exposed workers were subject to individual monitoring in 2019. Nearly 75 000 dose entries were recorded in the Dose Register maintained by STUK. In 2019, regulatory control of the use of non-ionising radiation (NIR) focused on laser equipment, sunbeds, radio appliances and cosmetic NIR applications. Thirty-one cases of sales or import of dangerous laser devices were found through regulatory control. Eleven on-site inspections of show lasers were conducted. Municipal health protection authorities submitted the details of the inspections of 23 sunbed facilities to STUK for evaluation and decision. In addition to this, 17 sunbed facilities were surveyed on the basis of STUK's own monitoring. In metrological activities, national metrological standards were maintained for the calibration of radiation meters used in radiotherapy, radiation protection and X-ray imaging, and the calibration of 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 RF radiation. This research also developed the regulatory control of nuclear medicine.

There were 52 radiation safety deviations related to radiation use in 2019. Of these events, 23 concerned the use of radiation in industry and research, 24 the use of radiation in health care, three the use of radiation in veterinary practices and two the use of non-ionising radiation. In addition, 1 862 events and near misses with an estimated minor significance for safety were reported for health care, and five radiation safety deviations were compiled together and reported for industry and research.

In 2019, nearly 11 000 radon measurements at nearly 2 500 workplaces were recorded in the national radon database. At conventional workplaces, the radon concentration exceeded the reference level 300 Bq/m^3 at approximately 20 per cent of the measured workplaces.

In 2019, 92 individuals were granted the right to act as radiation safety expert in the field of industrial and research expertise, and 54 persons were granted the right to act as radiation safety expert in the field of nuclear energy. During the six-month transition period, the applications were initially processed by the Advisory Board on Radiation Safety and subsequently by STUK.

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Management review

The Department of Radiation Practices Regulation (STO) of STUK functions as a regulatory authority on the use of ionising and non-ionising radiation, conducts research in support of regulatory control, and maintains metrological standards for ionising radiation.

Radiation practices are reasonably safe in Finland. Undertakings (parties running a radiation practice) take radiation safety quite seriously, they invest in its development, and the personnel using radiation is competent.

However, issues affecting radiation safety occur regularly. For example, metal recycling plants are repeatedly supplied with radiation sources which, when molten, pose a risk to the safety of workers and also entail considerable costs. It is worth noting that some of the sources found originate in Finland, which means that this is not simply a problem imported to Finland from abroad. Recurring events highlight the importance of supervising sources throughout their life cycle.

STUK has also increasingly had to resort to coercive measures and even to the assistance of the police in supervising radiation practices. The reason for this was, for example, neglecting the authorities' requests for specification or other requirements despite reminders. STUK has also been notified of the unauthorised use of radiation. The irregularities naturally concern a very small number of undertakings, but the developments must be monitored.
The undertakings are fully responsible for their own radiation practices.

In 2019, STUK's most important task was to implement the revised Radiation Act. New legislation issues included features such as the qualification and obligation to use a radiation safety expert, the repeated processing of orphan sources, i.e. in practice, large-scale scrap metal operations requires safety licence, and the requirement to furnish a security for all high-activity sealed sources and other radiation sources involving significant disposal costs. New requirements were introduced for the use of non-ionising radiation in beauty care, but more flexible regulation was also adopted. For the first time, the authorisation to issue STUK regulations was also included in the Radiation Act.

The aim of the new legislation, as well as the STUK strategy, is to emphasise the responsibility of the undertaking. This has changed the operating practices of STUK in many matters, and the practices are still taking shape after the legislative reform. However, STUK still wishes to remain a service-oriented and cooperative authority.

The structure of the code is different now, and the traditional ST Guides have been abandoned. However, the need for guidance material has been identified. STUK began to develop a radiation legislation guidelines service for these needs in 2019, in which all the relevant levels of legislation can be easily viewed at once and where examples can be found to illustrate the significance of the regulations. The service is likely to be published in autumn 2020 under the name Sammio. At the same time, major work is being launched to renew the data processing systems for STUK regulatory control. In the next few years, a system

supporting digitalisation and electronic services will be developed to replace the current regulatory control system for the use of radiation, which is at the end of its life cycle. For the undertakings this will manifest as smooth transactions and faster processing times.

In order to ensure the reliability of radiation practice measurements, STUK maintains metrological standards for the quantities of ionising radiation. The task is statutory and important. Metrological standards and the reliability of measurements play a key role in radiation safety work in the fields of health care, industry and research as well as in the maintenance of STUK's preparedness for accidents. STUK offers calibration and irradiation services for measuring instruments. As in previous years, the demand for services has remained high. At the same time, the metrological standard laboratory has already begun to fully prepare for STUK's move to new premises in a few years' time.

In summer, it is good to remember to protect yourself from the UV radiation of the sun. Each year, almost 2 000 Finns fall ill and more than 200 die of skin melanoma caused by UV exposure. The majority of these diseases could be avoided by remembering the basics of covering up, i.e. staying in the shade, wearing proper clothing, using sunscreen and wearing sunglasses. In 2019, STUK invested significantly more in education aimed at combating the harmful effects of UV radiation, and the work is to continue.

1 General

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

"Radiation practice" refers to use of radiation and to any activity or circumstances in which human 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 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

The principal key figures for the use of radiation and other practices causing exposure to radiation are shown in Figures 1–4.

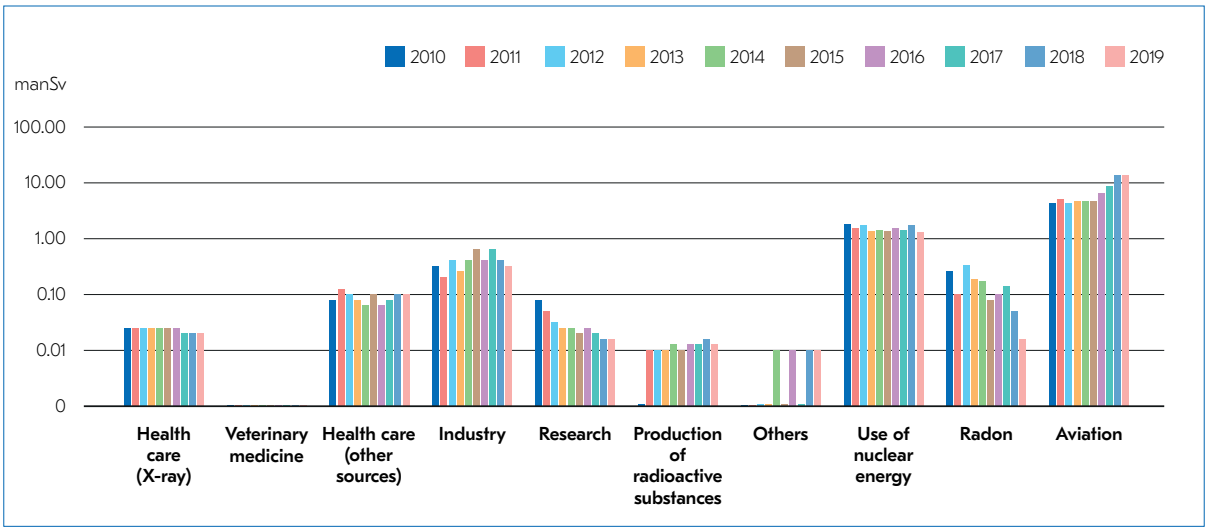


FIGURE 1. Collective effective doses (manSv) of workers subject to individual monitoring by occupational category, 2010–2019. In addition to the occupational categories specified in the graph, a few people subject to individual monitoring work in the following fields: manufacturing of radioactive materials, 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).

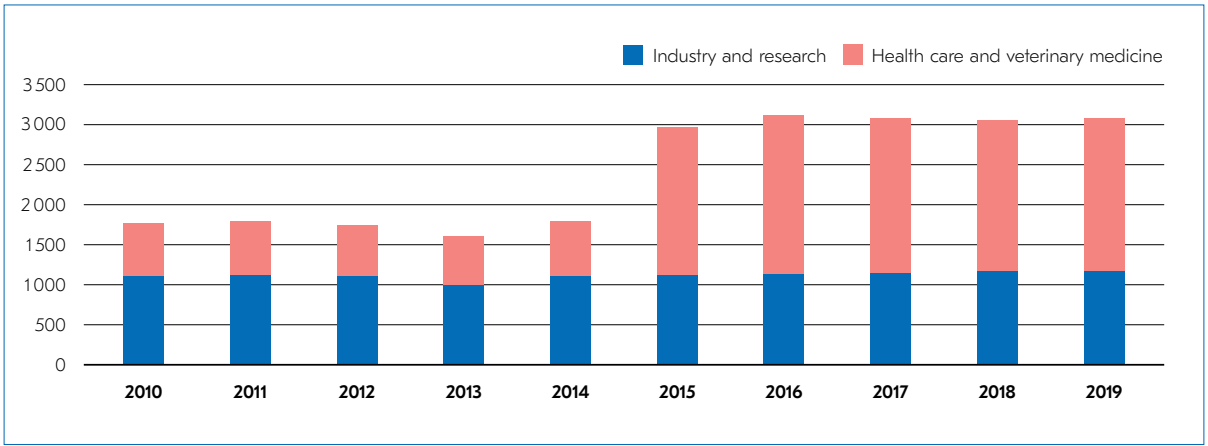


FIGURE 2. Number of safety licences in 2010—2019. The increase in health care licences in 2015 is due to the dental X-ray practices being changed from registered activities to activities that are subject to a licence.

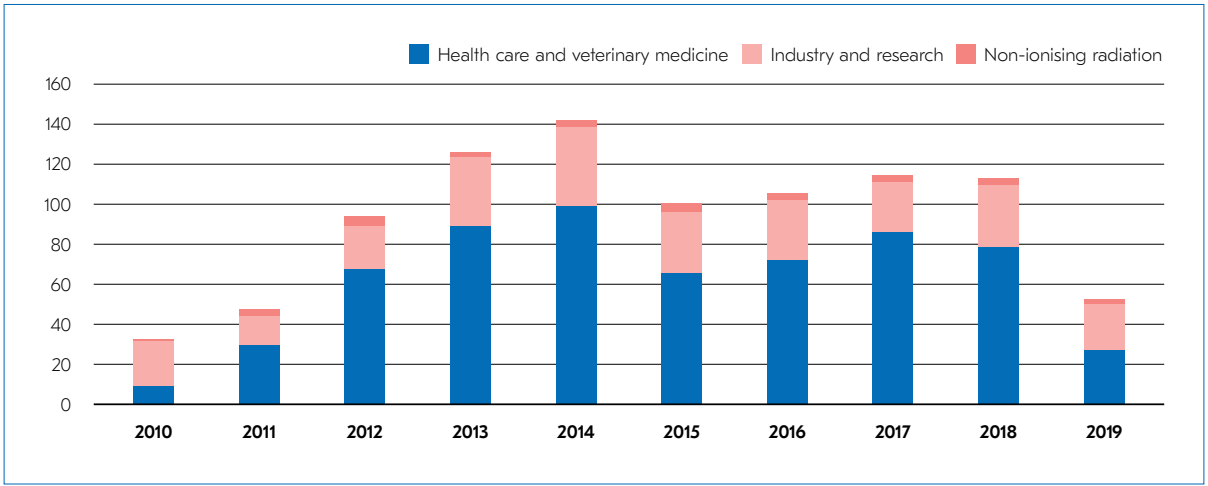


FIGURE 3. Numbers of non-delayed radiation safety deviations (previously *abnormal events*) in 2010—2019. From 2019 onwards, some of the radiation safety deviations which previously had to be reported immediately could be reported annually.

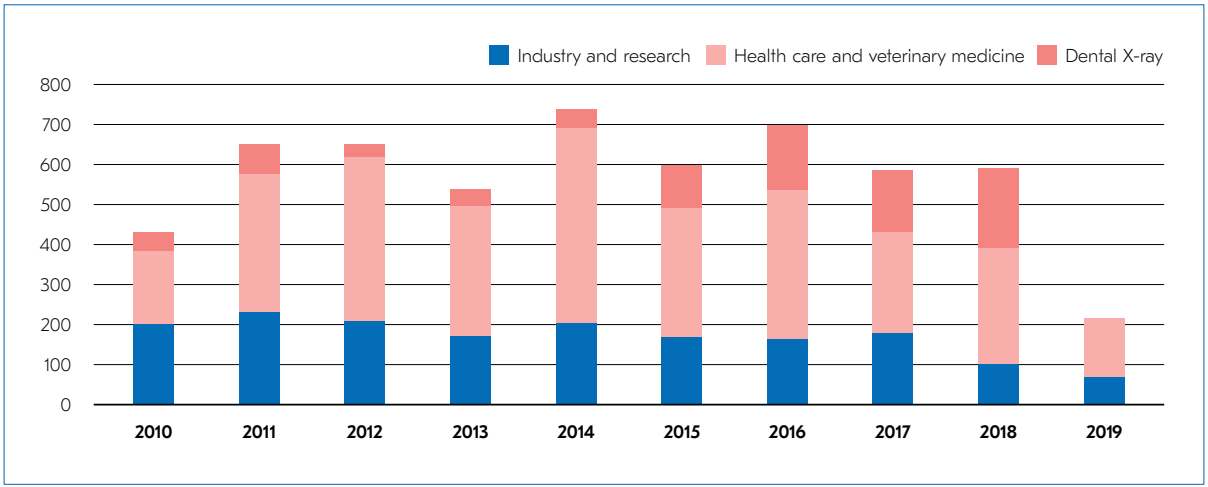


FIGURE 4. Numbers of on-site inspections in 2010—2019. As of 2019, dental x-ray inspections will be included in the chapter "Health care and veterinary medicine".

2 Regulatory control of the use of ionising radiation

In 2019, a lot of time in regulatory control was spent on taking into account the changes brought about by the Radiation Act (859/2018), which entered into force at the end of 2018, and the decrees issued under the Act. The latest STUK regulations entered into force in July 2019, and most of the legislation was only applicable from then on. Particularly in the early part of the year, the data processing system used for regulatory control did not support the changes brought about by the legislative reform, and in part the situation continued throughout the year.

After the amendment to the radiation legislation, no new application practices existed, which caused uncertainty and increased the need for communication. The reform of the radiation legislation was thus a major theme in the training events organised by the STUK in 2019, and during the Sädeturvapäivät radiation safety days in the autumn, where the issue was discussed in all areas of the use of radiation in health care. In addition, STUK organised meetings on legislative reform with organisations, training organisations and other stakeholders.

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

Safety licences

At the end of 2019, there were 1 614 current safety licences for the use of radiation in health care and 288 licences concerning veterinary practices (see also Figure 2). A total of 696 licensing decisions and 202 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 20.2 days. Table 1 of Appendix 1 shows the numerical distribution of the practices referred to in these licences.

Operational changes

At the beginning of the year, licensing decisions were made to add practices using non-medical imaging exposure to health care safety licences. This activity was subject to a separate licence in connection with the amendment of radiation legislation. On the basis of the transitional provision, it was possible to add it to the safety licence free of charge until mid-June. Another new issue requiring a licensing decision is the confirmation of the safety assessment for radiation practices. 27 of these decisions were made during the year, which is relatively few,

considering that there are over 1 900 safety licences. The transition period for the safety assessment of radiation practices will end in mid-June 2020.

Radiation appliances, sources and laboratories

Table 2 of Annex 1 provides detailed information on the numbers of sources and appliances and radionuclide laboratories used in health care and veterinary radiation at the end of 2019.

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.

Safety licences

At the end of 2019, there were 1 177 current safety licences for the use of radiation in industry and research (see also Figure 2). A total of 428 licensing decisions (new licences, amendments to existing licenses or terminations of licences) were issued during the year. The average time for processing safety licence applications and notifications was 30.4 days. Table 3 of Appendix 1 shows the numerical distribution of the radiation practices referred to in these licences.

Radiation appliances and laboratories

Figure 5 shows the number of appliances containing radioactive materials used in industry and research in the last ten years. The number has remained nearly unchanged for a long time. However, a slight decrease can be detected.

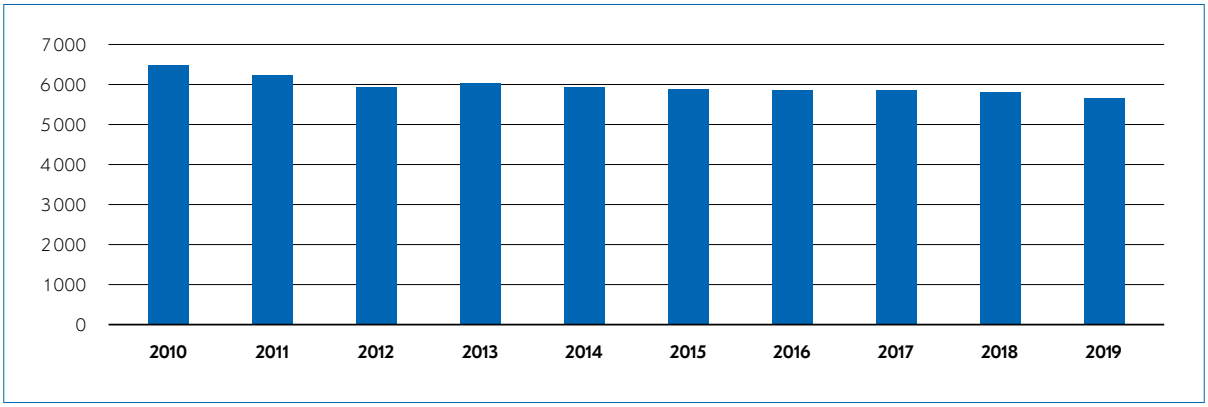


FIGURE 5. Appliances containing radioactive materials, 2010—2019.

Figure 6 shows the number of X-ray appliances in the last ten years. The number has increased steadily in ten years. Appliances containing radioactive materials have, to some extent, been replaced by X-ray appliances, in addition to which new scanning and analysis device applications have been introduced.

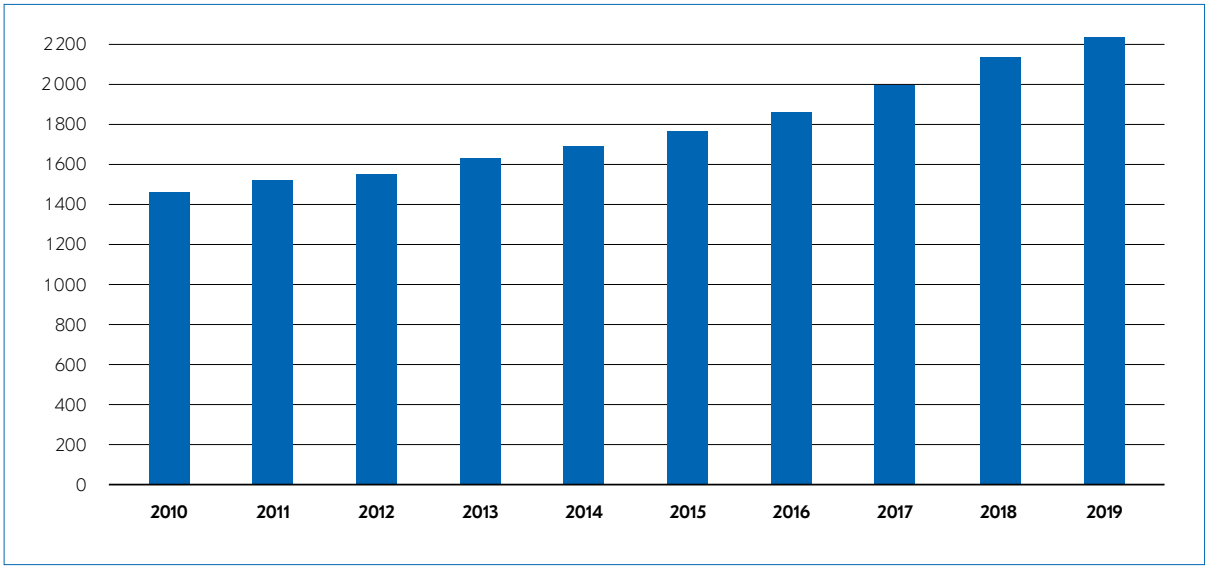


FIGURE 6. Number of X-ray appliances, 2010–2019.

Table 4 in Appendix 1 shows details of the numbers of radiation appliances as well as radionuclide laboratories in industry and research at the end of 2019.

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

The number of sealed sources which are used in industry and research and which are 40 years old or older in 2019–2023, are shown in 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 demonstrating its compliance. The transition period ends on 15 December 2023.

2.3 Inspections of licensed radiation practices

Health care, dental care and veterinary practices

In 2019, a total of 146 inspections were conducted on the use of radiation in health care and veterinary practices. Of these, 7 were inspections on veterinary practices. These inspections resulted in 14 repair orders issued to the undertakings. In terms of the last regulations, the radiation legislation as a whole was not completed until the beginning of July 2019. Due to this, at the beginning of the year, only individual inspections of the commissioning of equipment were carried out, as some of the requirements for the operations were not yet in force. The

operational inspections focused on larger entities than previously, and the themes of the inspections were the impacts of the legislative reform on the responsibilities of organisations using radiation and the implementation of the prerequisites for a justification assessment in practical work. The inspections will continue to focus on these themes in 2020.

Dental X-ray practices

Approximately 1 300 undertakings were engaged in dental X-ray practices in 2019. Patient radiation exposure from dental X-ray imaging was measured in 230 intra-oral X-ray appliances using testing equipment sent by post (altogether 400 test packages were sent). The average dose was 0.99 mGy. The dose refers to the dose on the surface of the cheek (Entrance Surface Dose, ESD) when imaging a tooth. The reference level of 2.5 mGy was exceeded in six appliances.

The inspections of dental X-ray practices focused on the operations of major 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.

As regards dental X-ray practices in particular, several cases have emerged during the year in which the designated radiation safety officer is no longer available for the task, but STUK has not been notified of the replacement of the radiation safety officer. In this case, the activities are carried out without a designated responsible person, which causes uncertainty and requires clarification work.

X-ray practices

The number of radiological examinations and procedures performed on adult and paediatric patients in 2018 was collected and reported during the year. The data were collected in accordance with the classification of the Association of Finnish Local and Regional Authorities for radiological research and measures.

6.0 million X-ray examinations and procedures were carried out in Finland in 2018. The number of radiological examinations has been monitored since 1984, and during this period the total number of non-dental X-rays has decreased by approximately one fifth. In recent years, X-ray procedures, CT and dental examinations have increased. On the other hand, conventional X-ray and contrast medium examinations have decreased. In 2018, the combined relative share of conventional X-ray and contrast medium examinations was 88.3% of all X-ray examinations, 9.5% of CT examinations, 0.9% of fluoroscopy or CT guided procedures, 0.7% of CBCT examinations and 0.6% of vascular contrast medium examinations. In addition, 1.1 million MRI and ultrasound examinations and procedures were reported, but the numbers of these examinations are not comprehensive.

In proportion to the population, 1 081 X-ray examinations and procedures were performed in Finland per one thousand inhabitants. Of these, 409 were dental X-ray examinations, 542 were conventional X-ray examinations, 103 were CT examinations and 6.9 were vascular contrast medium examinations.

In 2018, 7.5% of the total number of examinations performed were paediatric (0–16-year-olds). Children's examinations accounted for 6.3% of conventional X-ray and contrast medium

examinations, 10.8% of dental X-ray examinations, 1.1% of CT examinations and 0.8% of vascular contrast medium examinations.

In 2019, STUK conducted a survey on the use of mobile fluoroscopic X-ray equipment in health care emergency care units. Ten undertakings reported that they use the C-arm in the emergency unit mainly in connection with plaster cast operations in approximately 150 procedures a year. Some of the respondents indicated that they also engage in primary diagnostics and control scans using a fluoroscopy device. On average, approximately 50 health care professionals had been trained in emergency units for the use of the device. As regards medical exposure responsibilities, the procedures mainly met the requirements of the Radiation Act. One unit's response stated that medical caretakers, nurses or practical nurses use an X-ray unit independently, without the presence of a person responsible for medical exposure in the procedure room, in violation of the Radiation Act. A request was sent to the undertaking concerned to change the operating method to comply with the law by the deadline.

In addition, STUK conducted a hospital district-level survey on the personnel resources of radiological units. The report will be completed in 2020.

STUK also participated in the National Architecture for Radiological Imaging (Kvarkki) implementation project, i.e. the archiving project of the National Institute for Health and Welfare and KELA's image material, by issuing statements and consulting assistance for the project plans.

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

The suppliers of X-ray equipment notified of the health care X-ray equipment installed in 2019. In connection with the notifications, nine X-ray units were discovered for which a safety licence had not been applied before the operation was launched or whose use had not been notified rapidly enough after commissioning. In addition, 39 dental X-ray units were revealed for which an appropriate safety licence had not been applied for either possession or commissioning. In connection with the inspections, STUK was informed of a single dental X-ray unit for which no safety licence was issued. These undertakings were instructed to comply with the licence requirements.

Nuclear medicine

The majority of the inspections carried out on health care and veterinary units using unsealed sources were carried out during the latter half of 2019 after the legislative reform was completed. 10 inspections were carried out in the nuclear medicine units of health care, and one inspection was carried out in the unit providing radio-iodine treatments for cats. The audits focused on examining how and where unsealed sources are used in units and how the operation of the units meets the new legal requirements. In addition to the inspections, 11 nuclear medicine units visited in connection with the SUV-NEMA phantom research project.

STUK examined the number of nuclear medicine examinations and treatments conducted in Finland in 2018 and the radiation exposure to patients caused by the examinations. The data were collected in accordance with the classification of the Association of Finnish Local and

Regional Authorities for radiological research and measures. The information was obtained from all units that performed isotope studies or provided isotope treatments.

In 2018, 42 411 nuclear medicine examinations were conducted in Finland, and 2 571 nuclear medicine treatments were provided. The numbers and doses of nuclear medicine examinations and treatments have been mapped since 1975. At the beginning, the number of surveys was smaller, and since 1994 the survey has been carried out every three years. The total number of nuclear medicine examinations has remained almost the same for the last 15 years, but the number of examinations with PET radionuclides has increased on average by 13% each year. The numbers of PET examinations and the relative proportions of the total number of examinations were 1 930 (4.3%) in 2003 and 13 160 (31.0%) in 2018. The report will be published in 2020 in the STUK B series.

The numbers of nuclear medicine treatments have also increased and are now the largest in the survey history. The number of treatments is increased by treatments based on new radionuclides and pharmaceuticals (including Lu-177 DOTATE and Lu-177 PSMA), which are administered several times.

In 2019, there were two research projects in nuclear medicine. The Optimisation in Nuclear Medicine Imaging project examined optimisation practices regarding the activities of radiopharmaceuticals, imaging times and image quality. The research was conducted as a Webropol survey for all undertakings performing nuclear medicine imaging. The results were presented at the EANM'19 conference and the Sädeturvapäivät radiation safety days and will be published in the STUK B series report in 2020.

Another research project investigated the use of the NEMA IQ phantom as a tool for assessing national PET image quality. During the year, measurements were made on almost all PET devices used in imaging in Finland. Measurements are used to determine the variation of activity concentrations due to devices and reconstructions with different object sizes. This shows how different are the examinations performed on the patient, and the SUV value, depending on where in Finland the patient is imagined. Noise measurements provide information on whether a device and reconstruction combination causes a particularly inhomogeneous noise distribution in the images. In addition, the use of the Ge-68 phantom as a tool for the national PET image quality cycle is validated. The results of the research will be published in 2020.

Radiotherapy

Radiotherapy was provided in all five university hospitals, seven central hospitals and in one private clinic for approximately 16 500 patients. In 2019, STUK conducted five commissioning inspections of radiotherapy equipment, one commissioning inspection of a CT simulator and 20 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 0.5% 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, the multi-field plans calculated using the dose calculation system were compared with the corresponding measurement results. Inspections of dose calculation systems that affect patient doses were conducted on more than 400 radiotherapy beams. The calculation accuracy of the dose planning programmes of hospitals and the accuracy of the input data can be considered as very good. No deviations of over 3 per cent were detected.

The radiotherapy department of two university hospitals introduced a new type of radiotherapy device with a rotating rim, which also required more detailed inspection instructions.

STUK developed the regulatory control of magnetic resonance imaging devices used in radiotherapy planning, MRI simulators, in conjunction with experts from the HUS radiotherapy department. A phantom was acquired for controlling the MRI simulators, and inspection procedures were created. Setting the acceptance criteria requires additional measurements using the phantom.

During 2019, the first inspections were carried out on the boron neutron therapy device. 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; neutrons are produced in a particle accelerator. The device has been subjected to technical tests for use, and it has been used to measure radiation beam properties which must be known in detail when starting clinical patient tests. These are likely to begin at the end of 2020.

Use of radiation in industry and research

In the regulatory control of the use of radiation in industry and research, control projects concerning different functions were piloted. They are described in their own sections below. The control projects formed an inspection programme for industry and research. Regulatory control was also based on other methods (queries to undertakings, notifications from undertakings etc.) than inspections at places where radiation is used. The practice will be continued in 2020.

In 2019, 71 inspections were carried out at sites where radiation was used. In addition to these, more regulatory control was carried out through surveys and requests for specification. A request for a specification or a reminder was introduced as a new method, in case the undertaking did not comply with the time limits laid down for the application or notification.

In 2019, STUK submitted three requests for investigations to the police concerning a potential radiation violation. Possible violations concerned losing radioactive material and a failure to apply for a safety licence. During the year, one of these investigation requests led to an investigation, and it also became a decision of the District Court. The District Court imposed a fine on an entrepreneur for a radiation violation. Other investigation requests were still pending for investigation by the police at the end of the year.

Unsealed sources and particle accelerators

The control of unsealed sources and particle accelerators was targeted on risk-based grounds at category 1 unsealed source operations and the use of cyclotrons. There were a total of 10 safety licences for these operations at the beginning of the year, of which seven were inspected on-site during the year.

The themes of the inspections were the new requirements in the Radiation Act. In general, it can be said that issues related to radiation safety were in a good way. As a rule, only minor deficiencies were recorded in the inspection protocols. In a few cases, a report on the quality assurance programme was requested.

Several undertakings were still in the process of updating their own instructions to comply with the new legislation. This was emphasised particularly when the reform is considered more extensively from the perspective of a larger organisation (for example, the entire university).

VTT was granted a safety licence for the treatment and storage of radioactive waste related to the decommissioning of old laboratory facilities. In accordance with § 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 structures, the cleaning of surfaces and the treatment and storage of radioactive waste.

In 2019, STUK did not receive any safety assessments of safety licences granted for unsealed sources and cyclotrons.

Industrial radiography

During 2019, STUK carried out regulatory control on radiographic companies performing industrial radiography on risk-based grounds, with the primary focus being on companies whose operations had previously been found to be defective or who were known to engage in industrial radiography without a dedicated shielded enclosure. A total of twelve on-site inspections were carried out, four of which were unannounced, so-called surprise inspections, and one was a reactive inspection carried out after a suspected radiation safety deviation. Based on the findings of the reactive inspection carried out by STUK, STUK will pay more attention to the imaging arrangements of undertakings performing pipeline imaging in the future. The regulatory control will continue as project-based in 2020.

At the end of 2018, STUK sent a survey to radiography companies on the implementation of the obligations laid down in the new Radiation Act when using outside workers in industrial radiography. A summary of the replies was drafted in 2019. As a result of the conclusions of the survey, STUK will pay more attention to monitoring the state of health and radiation doses of radiation workers in the operational supervision of radiography companies.

Transportation of radioactive materials including high-activity sealed sources

The new requirement in the radiation legislation is that the transportation of high-activity sealed sources is subject to a licence. In 2019, STUK granted a total of five new safety licences for the transportation of high-activity sealed sources. One of the safety licences was granted for a fixed period in accordance with the licence application.

Based on the applications for safety licences and the observations of the inspection activities, the undertakings must pay attention to the maintenance and further development

of the management system, quality assurance programme, transport safety plan and radiation protection programme. During the life cycle of high-activity sealed sources, transportation is often a high-risk phase from the perspective of radiation safety and security arrangements.

As regards transportations requiring a safety licence, a notification procedure was introduced, for which the transition period was three months after the Act entered into force, i.e. until 15 March 2019. The carrier of a high-activity sealed source must notify STUK of each transportation operation before the transportation operation or before the arrival of the radiation source in Finland. In 2019, the STUK received 83 notifications. Based on the reports, the transport of gamma radiography equipment used in industrial radiography accounted for the largest share of the transport of radioactive materials subject to a safety licence in terms of quantity.

Activities involving the repeated handling or storing of orphan sources

As a new requirement, the Radiation Act requires a safety licence for operations in which orphan sources are repeatedly processed or stored. STUK examined the annual amount of recycled metal received or processed by the largest metal recycling companies and steel factories, as well as the origin of the recycled metal to be processed. In addition, radiation safety deviations involving orphan sources in previous years were verified for these companies. The purpose of the Radiation Act is to require a safety licence from companies where the processing of orphan sources may be expected to be continuous. Based on the survey, three companies, two of which are metal recycling companies and one of which is a steel plant, required a safety licence for handling and storing orphan sources. One of these companies was inspected already in 2019, and the rest will be inspected in 2020.

Security arrangements

In the supervision project on security arrangements, an inspection was carried out on ten industry and research safety licences for which the operations involve the processing of high-activity sealed sources.

Demands about the following deficiencies were made during the inspections:

- The undertaking had not prepared a security arrangement plan (3 cases)
- The security arrangement plan was not in accordance with the regulation (5 cases)
- Technical safety systems did not meet the requirements of the regulation (3 cases)
- Structural barriers did not meet the requirements of the regulation (2 cases)
- The storage of documents on security arrangements did not meet the requirements of the regulation (2 cases).

In connection with two inspections on security arrangements, no demands were made.

The guide for security arrangements of radiation sources, drafted to assist undertakings, was published in summer 2019. The guide is available on the STUK website (stuk.fi/julkaisut/oppaat).

Regulatory control of the trade in radiation sources

In 2019, STUK sent a surveillance questionnaire to 20 sealed source traders who, according to STUK's information, also store sealed sources. The survey examined, for instance, storage, the total activities of radioactive materials in the possession of operators at one time, the reception and handling of decommissioned radiation sources, and compliance with the obligations of radiation legislation. The survey did not reveal any significant shortcomings.

Inspections other than those related to control projects

During the year, a total of 15 inspections were carried out at sites which had not yet been inspected or for which a significant period of time had elapsed since the last inspection. The objects to be inspected were typically operators using X-ray equipment. As a general observation, the new requirements of the Radiation Act which entered into force at the end of 2018, such as the quality assurance programme and the management system, were often not taken into account in the practices. STUK presented the deficiencies in the inspection protocols and ensures that they are corrected.

High-activity sealed sources

According to § 22 of the 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 following the calendar year. All notifications for 2019 were submitted to STUK at the beginning of 2020. STUK compared the data to the licence register and ensured that the data from sealed sources matched. No deviations were discovered.

In 2019, nine high-activity sealed sources were removed from safety licences based on undertaking notifications.

Furnishing security

As a result of the reform of the Radiation Act, the values of the activity of a high-activity sealed source and the grounds for furnishing a security changed. At the same time, the obligation to furnish a security was extended to a larger number of undertakings than previously. In 2019, STUK provided undertakings a chance to be heard by sending hearing letters on furnishing of a security for practices involving high-activity sealed sources or practices where the combined activity of the radioactive material in possession at one time is higher per nuclide than the activity of the corresponding high-activity sealed source. For some undertakings, the hearing concerned both of the cases above.

In addition, STUK sent six requests for a specification on waste generated by the use and decommissioning of particle accelerators and the costs of waste management in order to determine the need for security. The need for security for undertakings who repeatedly handle or store orphan sources was also examined in connection with amendments to the safety licence. After the hearings, STUK made decisions on furnishing of a security and ensured that the security was set and that the required documents were submitted to STUK. In some respects, the project will continue in 2020.

2.4 Manufacture, import and export of radiation sources

The deliveries of sealed sources to and from Finland in 2019 are presented in Table 7 of Appendix 1, and the production volumes of radioactive materials (unsealed sources) in Finland in 2019 are presented in 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 35 800 of these devices were imported, with a combined activity of about 1.2 GBq.
- 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 as follows: Mo-99, Lu-177, I-131, I-123, Y-90, W-188, Br-82, P-32, F-18, Tl-201 and I-125.

At the beginning of 2020, STUK requested reports from all vendors of industry and research X-ray equipment operating in Finland (40 vendors) on appliances delivered in 2019 and their holders. According to the delivery information, it was initially found that one undertaking did not have a licence for the operation or possession of X-ray appliances. In addition, it was found that 20 licence holders had not reported their new X-ray appliances to STUK. STUK oversaw that the shortcomings detected were rectified 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 15 700 occupationally exposed workers were subject to individual monitoring in 2019, 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 were exposed to natural radiation, either radon or cosmic radiation (aviation), in their work. The numbers of workers are presented in Figure 7.

In 2019, 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. The distribution of collective worker doses across various sectors is shown in Figure 8.

Table 12 of Appendix 1 presents dosage data for 2019 for large groups of workers with significant exposure to radiation or groups which are large in number.

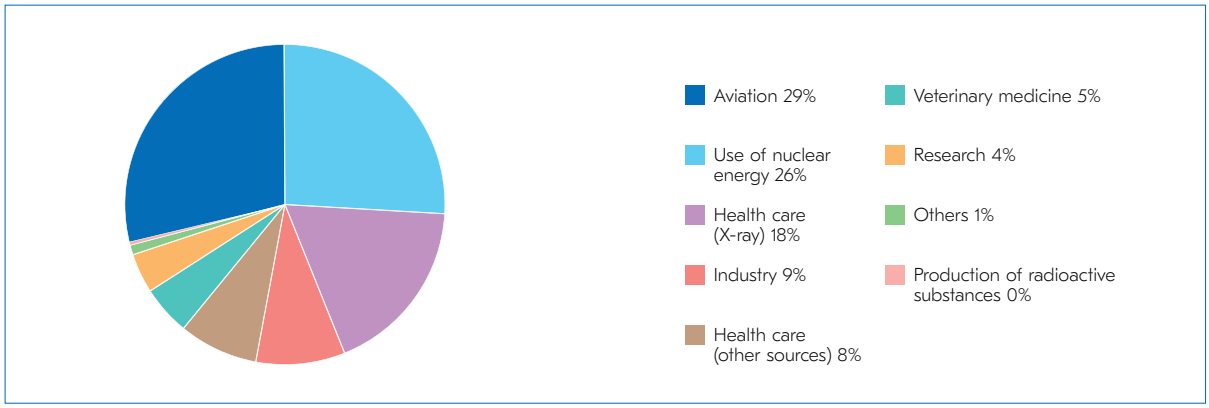
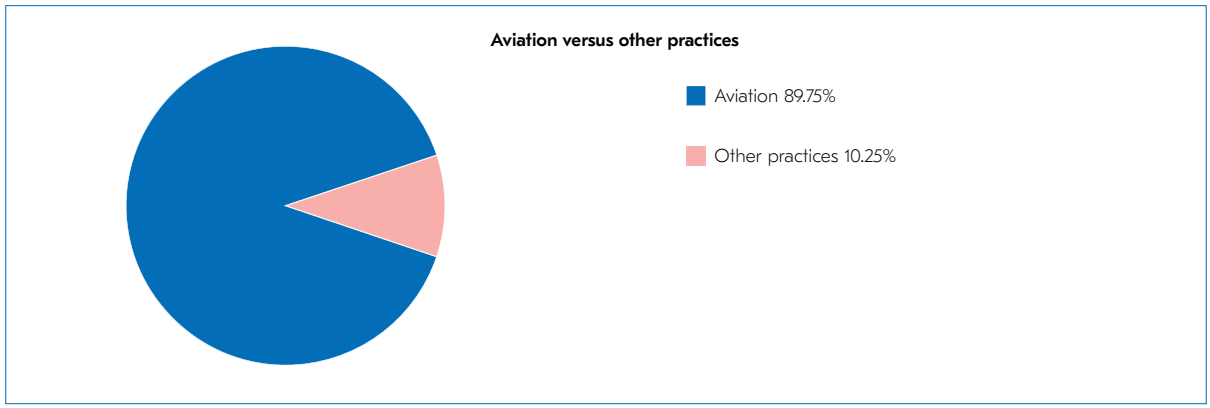


FIGURE 7. Numbers of workers subject to individual monitoring by sector in 2019. In addition to the occupational categories specified in the graph, a few people subject to individual monitoring work in the following fields: services, radon, installation/servicing/technical test operation and trade/import/export.



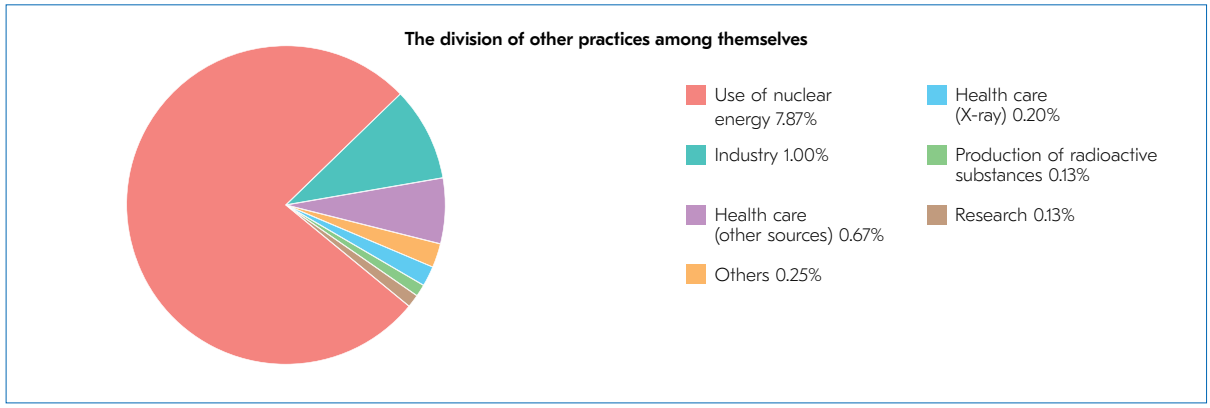


FIGURE 8. The distribution of collective effective doses for workers across various sectors in 2019. In addition to the occupational categories specified in the graph, a few people subject to individual monitoring work in the following fields: services, radon, installation/servicing/technical test operation and trade/import/export.

Use of radiation

Average worker radiation doses were of the same magnitude as in previous years. The workers' collective effective dose in connection with the use of radiation was approximately 0.33 manSv and decreased by approximately 6.0% compared to the previous year.

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 two largest doses (33.9 mSv and 23.0 mSv) were received by interventional radiologists. A cardiologist was exposed to the third largest dose (17.9 mSv). These doses correspond to the effective doses of approximately 1.1 mSv, 0.8 mSv and 0.6 mSv.
In health care X-ray operations, the workers' average dose was 0.3 mSv and the median effective dose was 0.0 mSv.

In the radiography practices of veterinary medicine, the three largest doses $H_p(10)$ were recorded for two veterinarians (7.4 and 5.0 mSv) and animal attendants (5.5 mSv). These doses $H_p(10)$ correspond to the effective doses of approximately 0.2 mSv. In veterinary medicine, the workers' average dose $H_p(10)$ was 0.1 mSv and the median effective dose was 0.0 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 $H_p(10)$ (3.2 mSv, 3.2 mSv and 3.1 mSv) caused by non-X-ray radiation were recorded for radiographers using several sources of radiation. In non-X-ray health care operations, the workers' average dose $H_p(10)$ was 0.1 mSv and the median effective dose was 0.0 mSv.

In the industrial sector, the largest doses $H_p(10)$ (9.4 mSv, 6.9 mSv and 4.6 mSv) were received by individuals carrying out tracer tests. In industry, the workers' average dose $H_p(10)$ was 0.1 mSv and the median effective dose was 0.0 mSv.

In the field of research, a laboratory worker using several different types of sources was exposed to the largest dose $H_p(10)$ (2.9 mSv). The second (1.8 mSv) and third (1.1 mSv) largest doses were received by a researcher and laboratory worker who used unsealed sources. In research, the workers' average dose $H_p(10)$was 0.0 mSv and the median effective dose was 0.0 mSv.

In the manufacture of radioactive substances, the two largest doses $H_p(10)$ (6.3 mSv and 4.0 mSv) were recorded for employees working in the production and delivery of radioisotopes. The third largest dose $H_p(10)$ (1.2 mSv) was recorded for an individual transporting radioisotopes. In the manufacturing of radioactive substances, the workers' average dose $H_p(10)$ was 0.7 mSv and the median effective dose was 0.2 mSv.

In some tasks, such as the handling of unsealed sources, workers are exposed to radiation unevenly. In such cases, the dose to the hands, for example, may be considerably high, even when the effective dose is relatively low. A specific annual dose limit of 500 mSv has been specified for skin, and workers use a so-called finger dosemeter to monitor radiation doses to the hands. In 2019, the dose to the hands did not exceed the annual dose limit for any worker. The three highest annual doses (137.3 mSv, 128.0 mSv and 124.6 mSv) were measured for laboratory attendants/bioanalysts and a researcher using unsealed sources. In addition to these three cases, only one laboratory attendant/bioanalyst and one radiographer using

multiple radiation sources had an annual dose greater than 100 mSv. In the field of research and the manufacturing of radioactive substances, the highest doses to the skin of the hands have increased to some extent from the previous year, while the doses have slightly decreased in health care and industry. The collective dose to the skin of the hands has decreased in all sectors, with the exception of industry. In industry, the increase in the collective dose to the skin of the hands is partly explained by the increase in the number of workers using a finger dosemeter compared to the previous year. The average and median doses to the skin of the hands were 10.0 mSv and 0.0 mSv in health care, 2.0 mSv and 0.0 mSv in industry, 8.5 mSv and 0.0 mSv in research and 7.7 mSv and 2.6 mSv in the manufacturing of radioactive substances.

Use of nuclear energy

The workers' collective dose in connection with the use of nuclear energy was approximately 1.18 manSv in 2019. This dose was 50.3% lower than in the previous year. In the use of nuclear energy, the collective dose varies considerably each year depending on the length of annual maintenance of nuclear power plants and the maintenance work carried out in the plants. In 2019, the highest personal radiation dose (7.8 mSv) caused by radiation work at Finnish nuclear power plants was recorded for an employee who performed mechanical and machine maintenance work. A person performing similar work was also exposed to the third largest (6.8 mSv) dose in the nuclear energy sector. The second most exposed (7.5 mSv) was an employee who worked in cleaning. The average of the employees' doses $H_p(10)$ in the use of nuclear energy was 0.3 mSv and the median was 0.0 mSv.

Aviation

In 2019, the dose data of employees of three airline were recorded in the STUK Dose Register. None of the employees' effective doses exceeded the 6 mSv dose constraint. The highest personal annual dose for a cockpit personnel was 5.0 mSv and for a cabin crew 5.4 mSv. The average annual doses of cockpit personnel was 2.8 mSv and the median was 3.2 mSv. The average annual doses of cabin crew was 3.0 mSv and the median was 3.3 mSv. The average doses of flight crew in 2010–2019 are shown in Figure 9.

Compared to the previous year, the total number of cabin crew increased by 8.2%, but the collective dose for cabin crew only increased by 1.0%. The total number of cockpit personnel and the collective dose to the employees remained at the previous year's level. The number of employees subject to individual monitoring of radiation exposure and the collective dose of employees are presented in Appendix 1, Table 9.

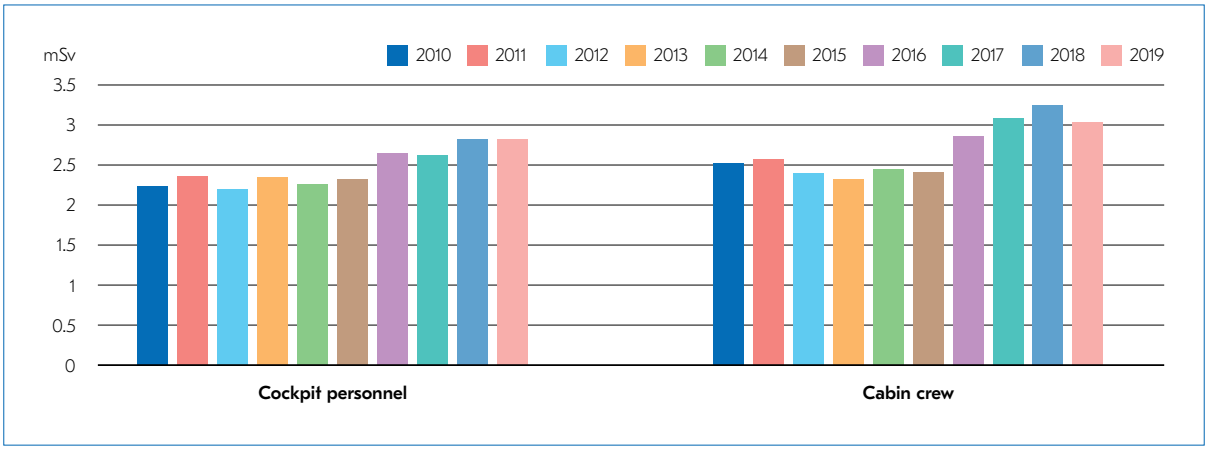


FIGURE 9. The average doses of flight crew in 2010–2019.

Changes over 10 years

The numbers of radiation workers subject to individual dose monitoring by sector for the last ten years (2010–2019) are presented in Appendix 1, Table 10. Collective employee doses by sector are shown in Figure 1 (chapter 1.1) and Table 11 of Appendix 1.

Radon at workplaces

Dose information of workers exposed to natural radiation at work is also recorded in the Dose Register.

In 2019, one workplace was under an obligation to organise radon exposure monitoring for its workers and any of its subcontractors' workers. This concerned a single employer. Workers from several companies (employers) may work at the same workplace. Altogether five 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 5.5 mSv and the median was 5.1 mSv. The largest effective dose was 8.7 mSv.

2.6 Approval decisions and verification of competence

Training organisations providing radiation protection training for radiation safety officers

Under § 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 for an approval from STUK to arrange such training and exams.

In 2019, approval decisions to arrange exams and training for radiation safety officers were issued to three training organisations. A total of three training organisations held valid approval decisions at the end of 2019. The small number of educational organisations granted approval in 2019 is due to a legislative amendment, according to which higher education institutions no longer need approval for their training from STUK. The approved training organisations are listed on STUK's website.

Parties engaged in aviation operations

In 2019, STUK inspected a single airline. The inspections on the other two airlines to monitor are due in 2020.

Approval decisions for dose measurements services and measurement methods

In 2019, STUK re-approved a dose measurement service which had already been approved before, and its six dose measurement methods. Among these dosimetry methods, the method of measuring eye doses did not have prior approval.

Approval decisions for radon measurements

Under § 64 of the Radiation Act, STUK approves radon measurements compliant with the requirements laid down in § 59 of the Radiation Act and the following regulations: STUK S/6/2018 and STUK S/3/2019.

Seven new approval decisions for a radon measurement method were issued in 2019. A list of organisations with approved measuring 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.

Qualification of radiation safety experts

As provided in the transitional provision of the Radiation Act, the Advisory Board on Radiation Safety issued a certificate attesting to the qualification of a radiation safety expert to the applicant who submitted an application within six months of the entry into force of the Radiation Act, if the eligibility requirements were met. The number of applications was 200, some of which concerned both fields of expertise: radiation practices in industry and research and the use of nuclear energy. 92 applicants were granted the right to act as a radiation safety expert in industry and research, and 54 in the use of nuclear energy.

At the end of the transition period, the applications for eligibility to act as a radiation safety expert were processed by STUK. In this case, a total of 21 applications were received, six of which were later withdrawn by the applicants. Based on the applications, STUK did not grant qualification certificates in 2019, but some of the applications were postponed to the following year.

2.7 Radioactive waste

STUK maintains a national storage facility for low-level radioactive waste. The amounts of the most significant types of waste kept in the storage facility at the end of 2019 are shown in Table 13 of Appendix 1. 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

The updated radiation legislation also changed the practices for reporting on radiation safety deviations (*previously abnormal events*) related to ionising radiation. Today, radiation safety deviations are divided into either those requiring immediate reporting or those reported annually in aggregated form.

The number of radiation safety deviations to be reported in Finland without delay in 2010–2019 is presented in Figure 3 (chapter 1.1), including radiation safety deviations occurring in the use of non-ionised radiation, which are described in more detail in chapter 4.7.

Radiation safety deviations to be reported without delay

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

1. radiation safety deviations, as a result of which the radiation safety of workers or the members of the public may be compromised at the site where radiation is used or in its surroundings
2. significant unintended medical exposure
3. the loss, the unauthorised use and possession of radiation sources which require a safety licence
4. the significant spread of a radioactive substance in indoor spaces or in the environment
5. other abnormal observations and information which may be of essential importance for radiation safety.

Regulation STUK S/2/2018 § 4 provides more detailed criteria for events that are considered significant unplanned medical exposure, which must be reported to STUK without delay.

In 2019, 52 radiation safety deviations occurred related to the use of ionising radiation which were to be reported without delay. Of these events, 23 concerned the use of radiation in industry and research, 24 the use of radiation in health care, three the use of radiation in veterinary practices and two the use of non-ionising radiation.

Radiation safety deviations to be reported in an aggregated manner

Radiation Act § 131 stipulates that the undertaking must notify STUK in an aggregated manner of the other radiation safety deviations related to radiation operations which do not require notification without delay. In practice, these radiation safety deviations notified in an aggregated manner have previously only been deviations concerning unplanned medical exposure, but with the current legislation, this applies to all undertakings, including industry

and research. These radiation safety deviations must be reported to STUK annually by 1 February at the latest.

A notification of unplanned medical exposure shall include the information set out in Table 1 of Appendix 1 to regulation STUK S/2/2018. An aggregated notification on unplanned medical exposure differs from the notification submitted without delay in that it indicates only the number of radiation safety deviations in each event category. No format has been defined for a notification on other radiation safety deviations which are less important in terms of safety.

Radiation safety deviations to be reported without delay in health care

The following are radiation safety deviations in the use of radiation in health care, grouped according to the use of radiation. An example of typical or significant events has been shown.

Radiation safety deviations in X-ray practices

There were 11 deviations reported without delay in health care X-ray practices, while 42 incidents were reported in 2018. The change in notification volumes is largely explained by the revised notification criteria in regulation STUK S/2/2018, which concern significant unplanned medical exposure. Many radiation safety deviations concerning unplanned medical exposure in X-ray operations, which have been reported on immediately in previous years, must now be reported on annually in an aggregated form.

In five events, the extra exposure to the patient or to the wrong patient was at least 10 mSv. In three cases, the event involved the exposure of employees.

The largest single exposure was received by an embryo, caused by a CT scan of the abdomen of a pregnant woman unaware of her condition. According to a subsequent assessment, the pregnancy was very early at the time of the examination (week 2 + 6). The estimated exposure of the womb was approximately 27 mSv.

In two separate cases, a body CT examination was performed on a patient due to a confusion of referrals, even though another type of imaging examination was planned. These examinations resulted in additional effective doses of 16 and 21 mSv. In both cases, it was possible to utilise the results of the examination, partly replacing other examinations designed for the patients in question.

Example case:
Maintenance was performed on the hospital's conventional X-ray unit, in which the key for the collimator assembly remained in an incorrect position. As a result, the automatic filter selection of the device did not function, and imaging took place without additional filtering for five days. According to the undertaking's report, the responsibility for ensuring the operating condition of the device was delegated to the maintenance-man of the device in accordance with the maintenance agreement. Based on this case, the undertaking will pay more attention to clearer definitions of these responsibilities in the future. 124 patients were subjected to additional exposure due to the case. Typically, the excess dose was 10–30% compared to normal exposure in connection with an examination. In individual examinations, the excess was more than 50%.

Radiation safety deviations in nuclear medicine units

The nuclear medicine units in health care reported eight radiation safety deviations. The number of notifications fell to a quarter compared to 2018, when 32 were made. The change in the number of notifications is explained by the new notification criteria laid down in regulation STUK S/2/2018 concerning significant unplanned medical exposure. Many radiation safety deviations concerning unplanned medical exposure in nuclear medicine operations, which have been reported on immediately in previous years, must now be reported on annually in an aggregated form.

In four radiation safety deviations, the patient was unnecessarily exposed, and three of the events were related to the exposure of an employee or a member of the public. Two of the notices made without delays were events which could have been notified annually in the aggregated notification.

The maximum additional exposure to the patient due to a radiation safety deviation was 24.3 mSv, due to a failed injection of a radiopharmaceutical. Radiation exposure to workers and members of the public, caused by radiation safety deviations in nuclear medicine, was small in 2019. According to estimates made by undertakings, the effective doses per event were no more than a few dozen microsieverts.

Example 1:
A confused patient had been brought to the imaging department with an already cannulated arm. The drip connected to cannula IV was removed, and the functionality of the cannula was tested with saline. The patient was then injected with the F-18 FDG radiopharmaceutical. The patient did not respond to the injection, so the injection was assumed to be successful. In connection with the PET scan, it was discovered that the radiopharmaceutical had remained in the arm, so the examination failed. The CT scan and radiopharmaceutical injection caused an exposure of 16.4 mSv and 7.9 mSv to the patient, i.e. a total exposure of 24.3 mSv. After the examination, it was discovered that a bruise had occurred at the injection site of the arm. The undertaking estimates that due to the confused state of the patient, the nurses did not detect the failure of the injection. In the future, to prevent similar events, the injection site will be inspected to confirm that the radiopharmaceutical has entered the bloodstream.

Example 2:
The patient had received Lu-177 PSMA radiopharmaceutical therapy with an activity of 7 600 MBq. Approximately 2.5 hours later, urine from the patient's urinary stoma began to leak into the patient's hospital clothing and the floor of the isolation room and the associated toilet. As immediate measures, the patient was asked to change clothes, and the contaminated floors were washed with water and then with Oxivir.

After washing the floors, the dose rate from the floor was 10.3 µSv/h. Contaminated areas were marked on the floor with tape. The leaking from the patient's stoma was blocked when the patient's spouse was able to bring a new stoma plate and bag from the patient's home. At no time did contaminated urine come into contact with the skin or clothing of the medical staff. The physician on call was informed of the event. He informed the physicist of the nuclear medicine unit, and the physician informed the radiation safety officer and radiation safety expert of the event.

The patient room was measured with a contamination meter and the floor was washed with 80% ethanol. Despite repeated washing, at its highest, the surface activity remained locally at the level of 80 Bq/m^2 on the plastic floor of the patient room and at 200 Bq/m^2 in the rough area adjacent to the toilet seat. The dose rate in the room was 0.25 µSv/h. During the following three weeks, the bed ward staff was authorised to use the isolation room only for nuclear medicine patients. Through the dose rate measured from the waste generated in connection with the clean-up, the amount of cleaned contamination was estimated to be approximately 100 MBq.

Before the treatment, the principles of radiation isolation and the importance of self-initiative in the care of the urinary stoma had been discussed with the patient. It was estimated that the reason for the event was that this was the patient's first treatment, and the patient had not fully understood the importance of self-care. The patient also did not have personal stoma supplies, which were needed in connection with the leak. To prevent similar events, preparations for leaks and the independent cleaning of potential excretion contaminations are discussed with patients in more detail. The personnel managing the event were in radiation work category A, and the undertaking estimated their exposure as low.

Radiation safety deviations in radiotherapy

In 2019, radiotherapy units submitted five reports on radiation safety deviations to be reported without delay. The summaries of three cases are included below. In the first case, an additional target area was drawn as a site for pain relief treatment. In the second case, the planning scan for radiotherapy failed due to cannula detachment. As a result of the situation, a nurse was slightly exposed to radiation and the patient scan had to be repeated. In the third event, the source of the afterloading therapy device arrived at the hospital unexpectedly and without notification. The hospital did not receive advance notification from the equipment manufacturer or carrier.

Radiation safety deviations in health care and veterinary medicine reported in an aggregated manner

In 2019, a total of 68 parties submitted a notification to STUK on 1,862 minor radiation safety deviations in health care or veterinary medicine.

In X-ray and dental X-ray practices, a notification was received from 63 parties, who reported 942 events and 757 near misses. In addition, 10 sites where radiation is used indicated that there had been no radiation safety deviations during the previous year. In nuclear medicine, a notification was received for 12 safety licences, and a total of 136 events were reported.

In addition to nine pre-described categories and their subcategories, the health care radiation safety deviations reported in an aggregated manner were divided into other minor radiation safety events and near misses. In addition, a few nuclear medicine and radiotherapy units had created their own categories. Additional information was also reported for some of the events. In X-ray practices, more than half of the reported radiation safety deviations consisted of examinations or procedures which failed for various reasons. There were 41 scans of the wrong patient and four cases of unintended foetal exposure.

The distribution of events in health care X-ray practices and in nuclear medicine practices reported into the categories specified in regulation STUK S/2/2018 Appendix 1 is presented in Tables 1 and 2.

Radiation safety incidents in veterinary medicine

With regard to veterinary medicine, three radiation safety deviations were reported as well as two other radiation safety deviations in the form of aggregated notifications. The majority of the notifications concerned the presence of fingers or hands within the radiation beam during the imaging. In one case, the equipment supplier's representatives unexpectedly used an X-ray unit, which had arrived for a presentation, with wide open collimation towards a control room. They tried to establish why the device did not produce radiation earlier. The representatives of the equipment supplier were approximately one metre away from the tube in the direction of the radiation beam. The radiation beam was aligned horizontally. At the time of the scan, the personnel at the site where radiation was used were at a distance of more than two metres from the device. The reason for the event was the negligence of the equipment supplier's representatives. The exposure to two representatives of the equipment supplier was estimated to be an effective dose of less than 0.1 mSv, and to the personnel of the site an effective dose of less than 1 µSv (0.001 mSv).

TABLE 1. Radiation safety deviations in health care X-ray practices reported in an aggregated manner.

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	**14**
	Other reason	**0**
Wrong examination, procedure, or anatomical object in the referral, which has resulted in an incorrect examination or procedure	Human error	**29**
	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	**27**
	Other reason	**0**
Wrong examination or procedure performed, or wrong anatomical object scanned	Human error	**145**
	Other reason	**4**
Failed examination or procedure (other than injection of a radiopharmaceutical or contrast medium) or related additional exposure	Incorrect or incomplete operating instructions	**10**
	Human error	**151**
	Single hardware or system failure	**190**
	Systemic hardware or system failure	**23**
	Other reason	**102**
Injection of radiopharmaceutical or contrast medium failed	Human error	**24**
	Technical failure of device or equipment	**25**
	Other reason	**105**
Unnecessarily repeated examination	No information on a previous similar examination, or results of a previous examination unavailable	**31**
	Other reason	**10**
Unintended foetal exposure	Pregnancy at such an early stage that it could not be confirmed	**3**
	The possibility of pregnancy was not determined using a reliable method before the procedure or examination	**1**
	Other reason	**0**

Type of radiation safety deviation	Cause and factor contributing to the radiation safety deviation	Number of radiation safety deviations per year
Extra exposure of a support person	Human error	**1**
	Incorrect or incomplete operating instructions or non-compliance with the instructions	**7**
	Other reason	**1**
A near-miss situation occurring more than once for the same reason	Operational error	**672**
	System or device error	**26**
	Other reason	**59**
Other radiation safety incidents related to medical exposure	Other reason	**20**

TABLE 2. Radiation safety deviations in nuclear medicine reported in an aggregated manner.

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	**0**
	Other reason	**0**
Examination or procedure performed on the wrong person	The patient's identity was not verified by means of a reliable method before the examination or procedure	**0**
	Other reason	**0**
Wrong examination or procedure performed, or wrong anatomical object scanned	Human error	**3**
	Other reason	**7**
Failed examination or procedure (other than injection of a radiopharmaceutical or contrast medium) or related additional exposure	Incorrect or incomplete operating instructions	**6**
	Human error	**3**
	Single hardware or system failure	**5**
	Systemic hardware or system failure	**1**
	Other reason	**6**
Injection of radiopharmaceutical or contrast medium failed	Human error	**2**
	Technical failure of device or equipment	**9**
	Other reason	**3**
Unnecessarily repeated examination	No information on a previous similar examination, or results of a previous examination unavailable	**0**
	Other reason	**1**
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**

Type of radiation safety deviation	**Cause and factor contributing to the radiation safety deviation**	**Number of radiation safety deviations per year**
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	**0**
	System or device error	***58***
	Other reason	**1**
Other radiation safety incidents related to medical exposure	Other reason	**8**

Radiation safety deviations to be reported without delay in industry and research

In 2019, a total of 23 reports on radiation safety deviations to be reported without delay were submitted to STUK concerning the use of radiation in industry and research. The events involved features such as industrial radiography, the use of unsealed sources, the transport of radioactive materials and the discovery of radiation sources in the metal recycling process or otherwise.

Use of radiation in industry and research

Nine radiation safety deviations related to the use of radiation in industry and research were reported to STUK. In three cases, sealed source shutters had not been closed. In four cases, the deviations were related to damage to the sealed source shields or failure of the device. In one case, the undertaking had lost the radiation source but subsequently found it. Similarly, in one case, an individual was mistakenly exposed to a radiation beam.

Example 1:
Two sealed sources were in the company's warehouse waiting for installation and commissioning. The sources were contained in the appropriate shields in the transportation packaging. For an unknown reason, the packaging was placed on an incinerable waste storage and ended up in a bark crusher. After hearing some noise, the bark crusher operator stopped the device and detected the sealed sources in a broken transportation packaging. The source shields were damaged, but no surface contamination was detected by sweeping tests.

Example 2:
The radiation source shield was damaged in the heat, so the level switch shutter no longer functioned. Hot steam was released on the shield from a crack of an industrial process device. The lead had partially melted inside the shield. However, the radiation source remained intact inside the shield and did not cause contamination in the environment.

Example 3:
Before the maintenance work, the installer had closed the sealed source shutter and reported it to the control room. The person who carried out the safety tour incorrectly concluded that the source shutter was open. On these grounds, the shutter was turned open again, and employees on the site were informed of the continuation of their work. The installer had then started the maintenance work, in which he had to reach through the measuring frame. The radiation safety officer had subsequently performed radiation measurements to confirm a suspicion of a radiation safety deviation. Based on the measurements, the source shutter was found to have been open. The dose to the installer was estimated to be 0.9 µSv.

Industrial radiography

Three radiation safety deviations related to industrial radiography were reported to STUK. In these cases, there were shortcomings in the delimitation and markings of the scanning areas as well as suspicions of possible exposure to outsiders. However, according to the reports received, the exposure was small or there was no exposure at all. The doses ranged from 0.3 to 50 µSv.

Example:
The company carried out tube scans in the cellar of the housing cooperative. One of the corridors leading to the scanning area was not marked for the duration of the scans, when a resident of the housing cooperative was able to get close to the imaging area while the radiographic device was on. STUK requested that the company performing the tube scans and the individual who was close to the scanning area submit written reports on the event. Based on the reports, the exposure of the individual who entered the imaging site was exposed to approximately 50 µSv at most.

Use of unsealed sources

Five radiation safety deviations related to the use of unsealed sources were reported to STUK. In three cases, a radioactive substance was released into the air. In addition, in one case, workers were exposed due to contamination, and in another case, by radioactive waste.

Example
An employee accidentally removed a container of radioactive waste from a lead-protected cabinet and left it briefly in the material lock and then on the table in an adjacent room. There was radioactive rubbish in the waste container. The event resulted in an additional radiation exposure to the employee concerned and to the individual working in the adjacent room. Active waste was taken to a protected waste storage facility. To be on the safe side, the dosemeters were submitted immediately for a reading. No abnormal dose accumulation was detected in the dosemeters due to this event. Due to the event, the waste container practices for the protective cabinets were modified, working instructions on the handling of active waste were revised, and additional radiation protection training was organised for employees, for instance in connection with the handling of active waste generated by the practices.

Transportation of radioactive materials

Four of the radiation safety deviations reported to STUK in 2019 were related to the transportation of radioactive materials. In two cases, the transportation packaging was damaged, and in two cases the drivers were not adequately qualified to transport dangerous goods.

Example:
As the employee of the freight terminal reversed the truck, the radioactive material transportation packaging got stuck between the truck frame and the floor. The top packaging layer and filling material were damaged as the airtight inner packaging remained intact. The terminal worker did not exercise caution or take care in accordance with the work instructions and did not monitor their surroundings sufficiently when unloading. After the event, the undertaking checked the condition of the consignment, contacted the consignee and delivered the consignment according to the original schedule. In addition, the undertaking went through the case together with the terminal personnel and brought up the work instructions related to the case as a review with the personnel.

Radiation sources found

Two of the radiation safety deviations reported to STUK in 2019 were related to the radiation sources or radiative loads found in the metal recycling process.

Example:
The company received a metal load which triggered an alert at their radiation portal. The radiative piece found in the scrap load was isolated from the rest of the load. A STUK inspector visited the site to perform measurements, on the grounds of which the radiation source was identified as Ra-226. Later on, STUK inspectors took a radiative piece to STUK for further measures. Responsibility for the waste was transferred to the State once the waste had been handed over to STUK.

Radiation safety deviations to be reported in an aggregated manner in industry and research

For 2019, the undertakings in industry and research submitted to STUK a total of five notifications of radiation safety deviations to be reported in an aggregated manner. In addition, two notifications were submitted to STUK, stating that there were no radiation safety deviations during 2019. The notifications containing different deviations were submitted by undertakings whose activities include extensive use of unsealed sources. The submitted notifications included a list of approximately 90 smaller deviations, most of which were related to small-scale contamination cases, which did not need to be notified to STUK without delay. Some of the deviations were related, for example, to malfunctions in various devices or systems. The notifications also reported on cases where radiation safety observations had been made, but no radiation safety incident 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 natural radiation from the ground and soil and practices related to it.

3.1 Radon at conventional workplaces

Targeted monitoring of radon in workplaces was initiated or continued in several areas. The STUK website contains information on STUK's monitoring projects at workplaces.

Thanks to enhanced radon monitoring at workplaces, STUK has managed to find several areas in which radon concentrations have been high and the reference level is exceeded in a large number of workplaces. On the other hand, no workplaces have been found in Eastern Finland in workplaces constructed on permeable soil outside the areas in which measurement is mandatory and which would have measured radon concentrations higher than the reference level. In the radon project (KOURA) for schools, the monitoring continued. Health protection authorities reported to STUK 1 268 schools to be measured at the beginning of the project in autumn 2016. By the end of 2019, radon measurement results had been received from all but 49 schools.

The authorities responsible for occupational health and safety at the Regional State Administrative Agencies (AVI) reported approximately 85 workplaces to STUK that had not performed radon measurements despite requests. After a notification by Regional State Administrative Agencies, radon measurements were carried out at some of the workplaces. STUK took these workplaces under its supervision, sending each one a request for specification and an order to perform radon measurement.

The radon concentrations obtained by STUK and other parties measuring radon at the workplaces are recorded in the radon database. More radon measurements at workplaces were recorded than previously. In November 2019, a website (stukasiointi.stuk.fi) was launched, through which employers notify STUK of radon measurement results obtained by parties other than STUK. In 2019, the radon concentration of approximately 2 500 new workplaces were recorded in the national radon database.

At these workplaces, 11 437 radon concentrations from approximately 11 190 measuring points have been recorded in the radon database. The number of measurements is higher than that of the measuring points, because several measurements were performed at some measuring points. The number of workplaces performing measurements has clearly increased,

and one workplace is performing more comprehensive measuring compared with previous years (Figure 10).

In the radon database, the median for the radon concentrations at conventional workplaces was slightly lower than last year (Figure 11). Approximately 310 workplaces measured at least one radon concentration above the action level (400 Bq/m³). Of conventional workplaces measured using alpha track radon detectors, approximately 15% had a radon concentration exceeding 400 Bq/m³ (the action level until 15 December 2018), and approximately 20% had a radon concentration exceeding the current reference level of 300 Bq/m³.

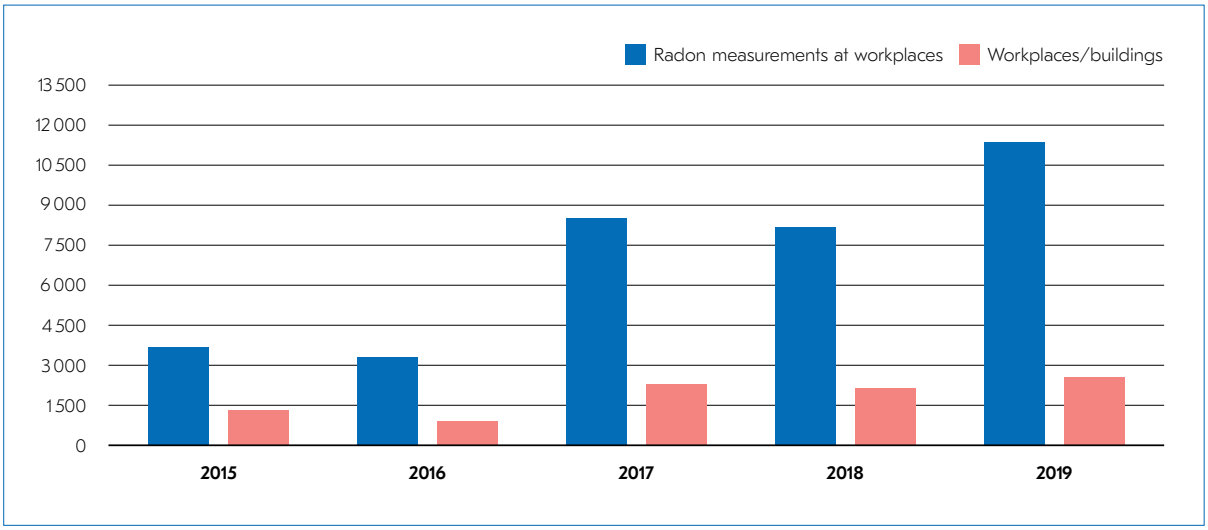


FIGURE 10. Number of workplace measurements/sites recorded in the national radon database, 2015–2019.

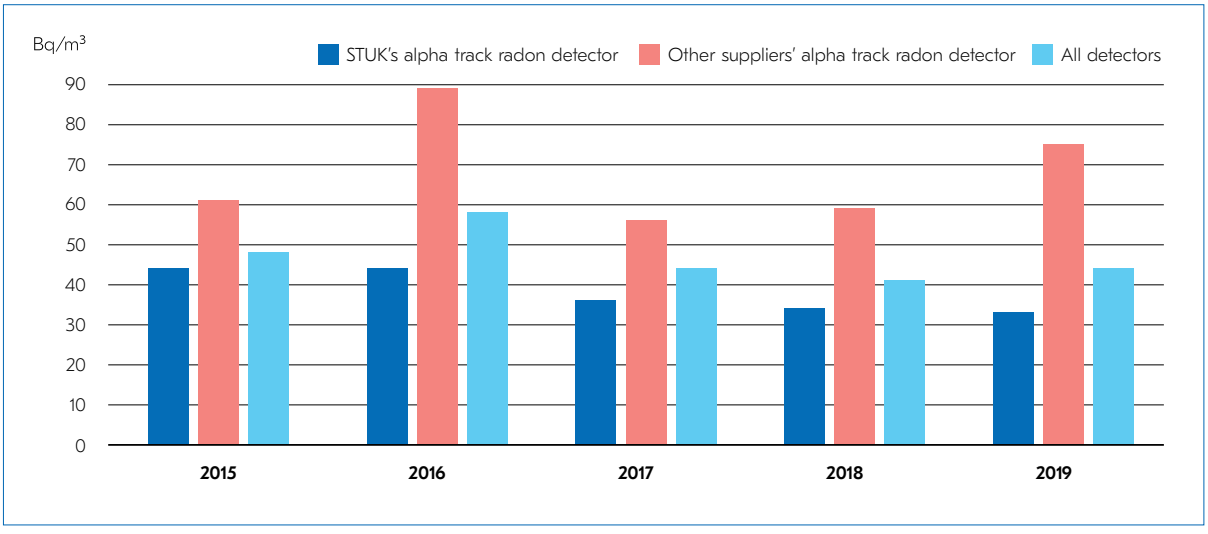


FIGURE 11. Median radon concentrations at conventional workplaces in different years were measured using alpha track radon detectors by STUK and other operators (UP), and in total, measured using the alpha track radon detectors of all suppliers.

3.2 Radon in underground mines and at excavation sites

Workplace radon concentrations were monitored at six mines and 16 underground excavation and construction sites. Radon concentration exceeded 300 Bq/m^3 at one mine and one excavation site. However, at the mine concerned, the working time was so short that the exposure reference level of 500 000 Bq·h/ (m^3·v) was not exceeded, and so STUK did not impose any requirements 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 twenty monitoring documents were drafted concerning the monitoring of the radioactive substances in construction materials.

Cooperation on the radioactivity of construction products was launched with TUKES. TUKES is responsible for regulatory control of the product information and CE markings of construction products. The new Radiation Act requires that construction products exceeding the screening level are marked for radioactivity and that instructions are provided to ensure that the reference level is not exceeded at the site.

3.4 Radioactivity of household water

STUK drafted a summary on the results of the monitoring measurements for the radioactivity of household water in 2016–2018. In addition, guidance was provided to municipal health protection authorities on the phone or by email in questions relating to the radioactivity of household water.

3.5 Regulatory control of other natural radiation

Fourteen new regulatory control issues were discussed in the monitoring of materials containing natural radioactive substances (NORM). In addition to these, a few statements were made. The monitoring practices will be developed and modified during 2020. Matters related to NORM monitoring are often long-term and complex, as the necessary investigations are slow and the industry does not have the necessary experience to carry out the studies required by the current radiation legislation. STUK often needs to request additional information and supplements.

One mine applied to STUK for a safety licence for radiation practices in 2019. The application was being processed at the end of the year. Two inspection visits were also made at this mine during the year.

One concentrating mill was visited together with STUK's Nuclear Waste Regulation and Safeguards Department (YMO). The concentrating mill requires a licence under the Nuclear Energy Act to produce nuclear material due to an intermediate product containing uranium. At the end of 2019, a report on radiation exposure was still unfinished.

In 2019, new communication material was created within the framework of the FINNORM project, for instance a press release for industry, a brochure for mining operators and an update of the STUK website. There has been communication on the amended Radiation Act and new regulations at the Industry and Research Radiation Safety Days, the Environment Board of Finnish Energy, the FEM conference and the ELY Centre's lecture series. The project has also surveyed the NORM activities in Finland and collected information on NORM sites from STUK. The information is intended to be used in the planned NORM monitoring database. STUK's Environmental Radiation Surveillance department (VALO) has co-developed an analysis package for NORM materials, which makes it easier for operators to order the right analysis.

STUK participated in the terrain review of the trial on the environmental licence for the mine and the EIA. The experience was educational in terms of the licensing of mining activities and the operation of the judiciary.

Four cases of waste disposal exceeding the clearance level were approved. The natural materials industry also submitted a number of relevant enquiries. The reports required of mining and other industries were still missing at the end of 2019. During 2020, the systematic submission of targeted requests for specifications will begin in connection with monitoring.

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4 Regulatory control of the use of non-ionising radiation

4.1 General

"Non-ionising radiation" refers to ultraviolet radiation, visible light, infra-red radiation, radiofrequency radiation, and low-frequency and static electric and magnetic fields. Coherent light, or laser radiation, is a special type of visible light. The use of non-ionising radiation requires a preliminary inspection only in certain special cases, such as 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 causes 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.

The work of the NIR Unit in regulatory control of the use of non-ionising radiation in 2010–2019 is shown in Tables 14–17 of Appendix 1. In 2019, STUK intervened a total of 31 times in the online auction of a dangerous laser pointer and once in the unlicensed use of a high-powered laser equipment. Similar to previous years, STUK received a 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.

Regulatory control of non-ionising radiation particularly focused on providers of sunbed services. Many shortcomings were still detected that affect safety. Regulatory control of radiation practices in the beauty care industry focused on powerful laser equipment and informing clients of the risks involved in the procedures as well as taking contraindications into account before the procedures.

The increased online trade with consumers ordering products directly from outside the EU poses a challenge to the regulatory control of consumer products. In addition, the prices of products such as high-powered laser equipment have decreased considerably as a result of the advancement of technology. In many product categories, traditional branded products

are accompanied by cheap non-branded models. STUK monitored the situation actively and noticed that dangerous laser pointers were frequently found again. Nearly half of the removal requests to online auctions were made to a single non-EU entrepreneur who repeatedly tried to sell overly strong laser pointers.

In addition to carrying out regulatory control, STUK promotes the reduction of the harmful effects of phenomena such as UV radiation through active communication. Concerns related to mobile phone base stations and wireless networks have been particularly apparent in citizens' inquiries and information requests 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 under 18-year-olds. Health inspectors inspect the facilities as part of the regulatory control pursuant to the Health Protection Act and submit a report on their findings to STUK for making decisions on potential measures. In addition, STUK carries out its own inspections where necessary.

The transition period for the amendment of the Radiation Act that prohibited self-service sunbed facilities ended already on 1 July 2015. In 2019, non-compliance with the requirement was still detected, and enhanced regulatory control was continued. Altogether 23 inspections of sunbed facilities were carried out by municipal health protection authorities. In addition to this, 17 sunbed facilities were surveyed on the basis of STUK's own monitoring (Appendix 1, Table 16). No deficiencies were detected in 32% of the facilities inspected. In 37% of the supervised facilities, the responsible person required by law was not present during all hours of use of the sunbed equipment. Deficiencies relating to operating and radiation safety instructions were detected in 63% of the facilities, problems related to timers in 13% and problems related to the availability of eye protectors in 11%.

4.3 Regulatory control of laser devices

The regulatory control of laser devices designed for private use is divided into market surveillance of traditional 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 31 laser devices. These cases were related to the selling of a laser device on a website for trade between consumers. In addition, the NIR Unit carried out a safety assessment of one laser pointer for another authority.

STUK received 73 notifications on the use of laser equipment in public shows. STUK inspected 11 of these performances on site. In the inspections, the safety arrangements and the pointing of the laser beams were mainly found to comply with the requirements. An accident occurred during the installation of one show, where a laser beam hit the eye of an

audio technician. There was no audience in the facility at the time. STUK is not a competent authority in terms of occupational accidents, so the matter was referred to the Regional State Administrative Agency for Southern Finland. Five fixed-term approvals were in force at the end of 2019. The approvals were granted while the previous Radiation Act was in force. Therefore, they may remain valid up to the end of 2020. Six licences which are valid until further notice were granted in 2019.

4.4 Regulatory control of devices producing electromagnetic fields

In 2019, STUK did not test wireless communications devices in connection with its market surveillance. Instead, STUK initiated a comparison measurement campaign in cooperation with the Swedish radiation protection authority (SSM). The exposure caused by ten mobile phones will be measured during the campaign. SSM carried out the measuring of mobile phones in 2018, and STUK will perform the measurements in 2019–2020. The results of the measurements will be posted on STUK's website.

Mobile phone base stations were monitored through preliminary safety analyses based on conctacts from citizens. All base stations were found to be safe and installed in a compliant manner.

4.5 Regulatory control of cosmetic NIR applications

The extensive campaign for the regulatory control of companies providing cosmetic treatments, initiated in 2016, continued in 2019. The regulatory control was targeted at strong laser devices and their use. STUK found out about them particularly through its own regulatory control and through complaints received. A total of 24 requests for specification were sent to undertakings in 2019, of which nine found the use of a laser device that was too powerful. One undertaking was given a decision on banning the use of two laser devices. In other cases, regulatory control resulted in the voluntary suspension of the use of laser devices or the initiation of a licence application process to act as a health care unit. In two cases, the laser device was reported to be inoperative at the time of the survey.

In other respects, regulatory control focused on the supervision of new obligations in the Radiation Act. These included the undertaking's obligation to inform the customer about 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 the start of the procedure. In spring 2019, STUK organised a press conference on the changes brought about by the new Radiation Act. For some of the new techniques, a transitional period of five years has been laid down before the limit values for exposure are implemented.

4.6 Other tasks

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

In addition to regulatory control, STUK's NIR unit replied to 602 citizen inquiries in 2019. Of these inquiries, 279 were made by telephone and 323 via email. In particular, these inquiries concerned radiation related to mobile phones, base stations and power lines as well as household electrical equipment and wiring. Many inquiries also concerned laser equipment and UV radiation.

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

In 2019, STUK received three notifications of events caused by non-ionising radiation that required immediate action. As a result of laser treatment performed by cosmetologist, a customer's cheek was permanently scarred. The complaint was related to a report which was already being drafted and which resulted in a ban on two laser devices.

In a radiation safety deviation, high-powered laser devices were used without permission in a nightclub. The use of lasers was discontinued immediately after the users were contacted by STUK. The operations were subsequently organised in such a way that an undertaking authorised to use high-powered laser devices managed the activities.

The numbers of radiation safety deviations in 2010–2019 are shown in Figure 3 (chapter 1.1; see also chapter 2.8 on radiation safety deviations in the use of ionising radiation).

5 Regulation work

The Radiation Act (859/2018) entered into force on 15 December 2018. Under the Act, one Government Decree, two Ministry of Social Affairs and Health Decrees and seven STUK regulations were also prepared. They also entered into force in 2018.

In 2019, STUK prepared six new regulations. One of these, the STUK regulation on the activity values of a high-activity sealed source, was repealed during the same year, as its contents were transferred to another regulation (the STUK regulation on the radiation safety of radiation sources during their use and the decommissioning of radiation sources and facilities where radiation is used). At the end of 2019, a total of 12 regulations issued under the Radiation Act were in force.

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.

Income from service activities has been used to finance radiation safety research. STUK has organised four internal funding applications (two in 2018 and two in 2019), for which a total of 29 applications have been received. With the help of funding, STUK has hired researchers, thesis authors and postgraduate students for the projects, reinforcing Finnish research cooperation.

The Finnish Consortium for Radiation Safety Research (Cores) continued its active operation. University cooperation has also been reinforced through the membership of the Helsinki Institute of Physics (HIP) and through joint participation in the applications and projects for Horizon 2020 and the Metrology Research Programme (EMPIR).

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).

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 to analyse the total dose caused by radiotherapy (incl. imaging) was prepared in collaboration between EURADOS and EFOMP. STUK participates in the computational determination of patient doses as well

as the development of risk-level calculation methods and coordinates the project. HUS is a domestic partner in the project.

STUK continued the project launched in 2017 to develop a measurement method for RF beauty care devices. The research has provided new data on the linking of RF radiation to the human body, which will improve the exposure value, and the safe use of the devices can be more accurately specified. The objective is to write a scientific article on the development of the measurement method in 2020. At the same time, the research data obtained is used on the IEC's ongoing standardisation project that will specify the highest acceptable exposures for RF treatment devices, among other things.

STUK assessed doses to the eye in a group of employees exposed to radiation in nuclear medicine. The assessments were carried out using thermoluminescence (TLD). Doses to the eye were also examined in interventional radiology and cardiology. At the same time, methods were developed for a reliable evaluation of the dose to the eye based on the available exposure parameters. The results will be published in 2020. The results are used for directing the regulatory control by the authorities.

STUK conducted a survey on the status of imaging optimisation in nuclear medicine. STUK also investigated methods suitable for assessing image quality in PET imaging and developed methods for monitoring MRI devices used in radiotherapy simulation. The results were presented at the autumn 2019 Sädeturvapäivät radiation safety days.

The four-year detector development project, funded by the Academy of Finland, continued in 2019. 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.

Demand for neutron measurement and irradiation has increased. STUK carried out simulations and measurements to analyse the suitability of its irradiation hall for the calibration of personal dosemeters with neutron radiation. The results were presented at two international conferences in summer 2019.

In 2019, two European metrology research programme projects were prepared to create a network-like consortium in the field of ionising radiation metrology. In the future, the networks will coordinate the research needs of metrology and cooperation between laboratories. The projects will be launched in summer 2020.

European Metrology Programme for Innovation and Research EMPIR

A three-year project on perfusion imaging dosimetry came to an end. STUK participated in the development of patient-specific CT dosimetry in co-operation with PTB from Germany and the University of Helsinki. The project has developed measurement and computational methods for the determination of patient doses for CT scans. The results will be utilised in the EURADOS project mentioned above.

On the RTNORM project, STUK developed dosimetry for ionisation chambers used 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, continued. The objective is to improve the accuracy of radon calibrations across Europe.

7 International cooperation

International cooperation

Industry and research

STUK participated in the work of the Nordic Non-medical Group on Industrial Radiation (previously NORGIR). STUK also participated in the activities of HERCA (Heads of European Radiological Protection Competent Authorities) in the Research and Industrial Sources and Practices (WG RISP) working group, which, among other things,

- collected data on requirements related to the maintenance of radiation devices
- collected data on requirements and good practices related to orphan sources
- updated government lists of justified operations in Europe
- several surveys were launched, the results of which will be published during 2020.

As regards the transportation of radioactive materials, STUK was actively involved in the work of the IAEA, for instance in the TRANSSC Committee and in practical European cooperation at EACA (European Association of Competent Authorities).

Health care and veterinary medicine

STUK participated in the work of the Nordic Working Group on Medical Applications (NGMA). The Group's annual meeting in August 2019 discussed, among other things, the Nordic joint inspection carried out for the equipment manufacturer and the ongoing Nordic reference level project. STUK participated in the activities of HERCA in the Medical Applications and Veterinary Applications working groups. In addition, STUK participated in a joint European campaign for referring physicians led by HERCA and aimed at reducing unnecessary exposure in connection with medical examinations.

Participation in the work of international organisations and commissions

Representatives of the Department of Radiation Practices Regulation are involved in a number of international organisations and commissions dealing with the 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, UNSCEAR.

Participation in meetings of international working groups

In 2019, representatives from STUK participated in the meetings of the following international organisations and working groups:

- EURAMET (European Association of National Metrology Institutes) annual meeting of contact persons
- Meeting of the Nordic Dosimetry Group
- Meeting of the group on the use of radiation in Nordic health care sector (Nordic group for medical applications)
- HERCA (Heads of the European Radiological Protection Competent Authorities) and its working groups
- The annual meeting of EURADOS (European Radiation Dosimetry Group) and its working groups
- The Nordic Non-medical Group
- EACA meeting (European Association of Competent Authorities on the transport of radioactive material)
- ICNIRP (International Commission on Non-Ionizing Radiation Protection)
- NACP (Radiation Physics Committee)
- Nordic Ozone Group (incl. UV matters)
- Nordic-NIR UV subgroup
- WHO EMF-project and InterSun Programme; international advisory group
- IEC TC 61 MT 16 meeting (including sunbed standards)
- IEC PT 60335-2-115 online meetings (standardisation of beauty care appliances)
- IAEA: Transport Safety Standards Committee
- IAEA: Radiation Safety Standards Committee
- CERN: Knowledge Transfer for Medical Applications
- Meeting of Nordic radiation protection authorities in Stockholm on the implementation of EU-BSS.

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 and research of the use of ionising and non-ionising radiation, and with standardisation activities in the field of radiation. These include the Advisory Committee on Metrology, the Radiation Safety Conference Committee, the Education Committee of Medical Physicists, Eurolab-Finland, SESKO and the Finnish Advisory Committee for Clinical Audit (KLIARY) funded by the Ministry of Social Affairs and Health and appointed by the National Institute for Health and Welfare, the Screening Committee, 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, the cooperation day for ADR trainers and the Dangerous Goods Transportation Day.

Participation in meetings of Finnish working groups

In 2019, 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
- The Screening Committee of the Ministry of Social Affairs and Health and its subordinate working group preparing the decree amendment
- 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 Radiation Safety Committee of the Finnish Defence Forces (NIR matters)
- 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.

Finnish conferences arranged by STUK

STUK organised the 13th Industry and Research Radiation Safety Days in Tampere in October 2019. The event presented the changes brought about by the revised Radiation Act, answered numerous questions from undertakings and shared good practices. Lecturers include representatives of both STUK and the undertakings. The lecture materials were made publicly available on the STUK website. In April, STUK organised a "training the trainers" event for organisations, providing radiation protection training in Helsinki.

In addition, STUK participated in the arrangements of the Sädeturvapäivät radiation safety days.

Other cooperation in Finland

A STUK representative served as a member and secretary on 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 the maintenance of the group's website. The activities of the group included preparing a recommendation concerning advanced clinical audits of small units performing X-ray examinations. The recommendation was published in January 2018. Some previously published recommendations were updated. Recommendations and more information about the group's activities are available on the group's website (www.kliininenauditointi.fi)..

9 Communication

In 2019, STUK received a number of radiation-related questions through its website 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:

- The fees charged by STUK for supervision will be simplified with the new regulation
- The Radiation and Nuclear Safety Authority's regulation on the activity values of a high-activity sealed source
- Tourism in the South increases the exposure of Finns to the harmful effects of UV radiation
- STUK carries out enhanced radon monitoring at workplaces
- Tornio steel mills found two radiation sources among recycled metal during the winter
- STUK will specify the radon measurement requirements for employers
- The Advisory Board for Radiation Safety with new members and tasks began its three-year term
- Young people are carefree about the risk of skin cancer caused by UV radiation
- High altitudes mean higher levels of radiation as evident from the radiation doses of flight crews. Cooperation has created top expertise in the field of radiation protection in the Nordic countries
- New regulations on radiation sources and radiation practices will enter into force
- An accident in connection with handling radioactive materials resulted in a production interruption and repairs at Tikkakoski
- Nordic radiation safety authorities urge people to avoid sunbeds due to the health risk
- Fines imposed due to an unauthorised X-ray unit
- European Radiation Safety Authorities remind doctors of the importance of radiation safety
- Radiation source missing – STUK urges recycled metal companies to pay attention
- Employers must notify STUK of the results of radon measurements
- Training for radon-related repairs in Helsinki on 5 February 2020.

Three newsletters were published in 2019 for radiation users in the health care sector and two newsletters 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 standards laboratory of radon has been utilized for radon meter calibration and research alike.

10.2 Meter and measurement comparisons

In 2019, STUK participated in three bilateral comparisons with IAEA. The comparisons were related to calibration of radiation protection meters and diagnostic meters. Air kerma was used in the comparisons, and the measurements were made using photon radiation and several different X-ray radiation qualities. In addition, a comparison of radiotherapy meters carried out as a Nordic cooperation project was published as a STUK TR report (STUK TR-31). In all measurement comparisons, STUK's results were excellent, which supports STUK's calibration activities well.

In addition, STUK participated in the dosimetry comparisons (RPLD comparison) arranged by the IAEA/WHO calibration laboratory network. STUK's results were well within the acceptable range; thus, the results efficiently support STUK's calibration activities (Figure 12).

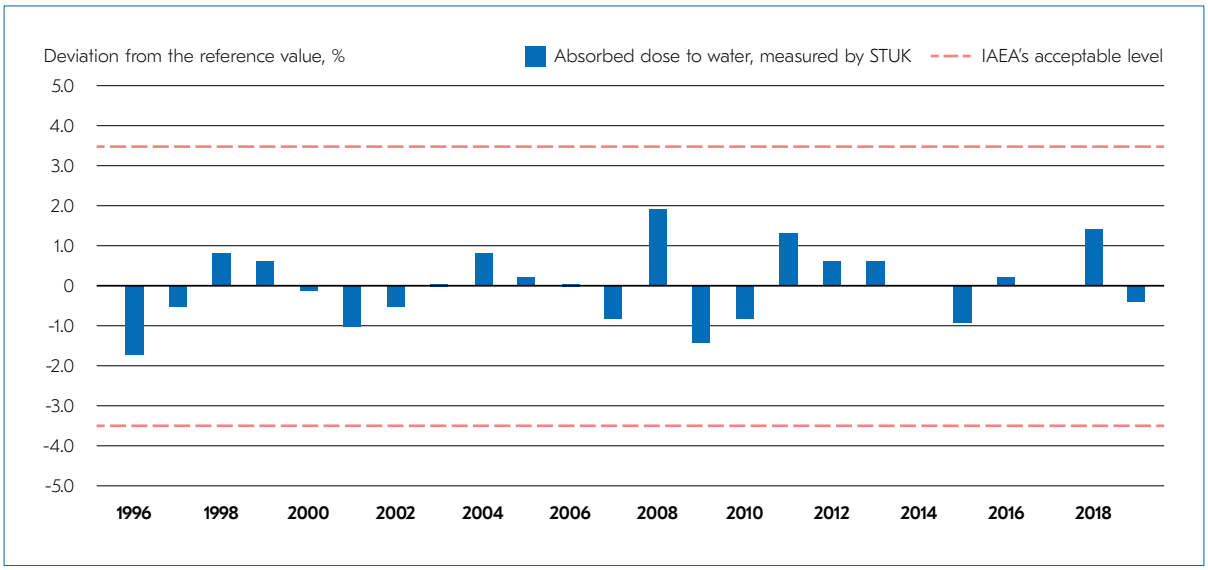

FIGURE 12. The results of IAEA dosimetry comparisons in which STUK has participated in 1996—2019.

11 Services

11.1 Calibration, testing and irradiation

STUK performed radiation meter calibrations and testing according to demand. The Dosimetry laboratory performed 436 radiation meter calibrations and irradiated 1,489 samples. Approximately 20% of the calibrations were performed on STUK's own instruments.

The standard laboratory of radon performed nearly 50 radon meter calibrations.

The Non-Ionising Radiation Surveillance Unit performed a total of five radiation meter calibrations and tests, along with four safety assessments and radiation measurements. The service output of the NIR Unit from 2010 to 2019 is shown in Table 15 of Appendix 1.

11.2 Other services

Altogether 48 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 2019.

Radiation practices	Number of practices
Health care and dental care	1 521
Radiotherapy	13
Nuclear medicine	25
Veterinary practices	288
Installation/servicing/manufacture	51
Other use of medical devices (research, education)	25
Non-medical exposure in health care	92

TABLE 2. Radiation sources and appliances and radionuclide laboratories in the use of radiation in health care and veterinary practices at the end of 2019.

Appliances/sources/laboratories	Number
X-ray diagnostic appliances (generators)*)	**1 430**
fixed conventional X-ray appliances	475
portable fluoroscopy appliances	295
portable conventional X-ray appliances	150
mammography appliances, of which	158
• screening mammography	68
• tomosynthesis	20
fixed fluoroscopy appliances, of which	110
• angiography	42
• fluoroscopy	23
• cardioangiography	52
CT-appliances, of which	141
• SPECT-CT	33
• PET-CT	18
CBCT appliances (other than dental imaging)	18

Appliances/sources/laboratories	**Number**
O-arm appliances	10
bone mineral density measurement appliances	70
other appliances	3
Dental X-ray appliances	**6 197**
intraoral X-ray appliances	5 409
panoramic tomography X-ray appliances	659
CBCT appliances	129
Radiotherapy appliances	**120**
accelerators	45
X-ray imaging appliances	55
automatic afterloading appliances	6
manual afterloading appliances	1
X-ray therapy appliances	1
radiotherapy simulators	12
Sealed sources/sealed source appliances)**	**408**
calibration and testing equipment	232
radiotherapy check sources	37
attenuation correction units	4
other sealed sources in health care	5
X-ray appliances in veterinary practices	**508**
conventional X-ray appliances	337
fluoroscopy appliances	2
intraoral X-ray appliances	155
CBCT appliances	4
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 2019.

Use of radiation	Number of practices
Use of X-ray appliances	723
Use of sealed sources	534
Installation/servicing/manufacture	173
Import and export of radiation sources or trade in them	115
Use of unsealed sources	64
Use of particle accelerators	18
Transport of high-activity sealed sources	4
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 2019

Appliances/laboratories	Number
Sealed source appliances	**5 654**
radiometric measuring instruments	4 840
calibration and testing devices	405
analysis devices	194
gamma radiography appliances	37
gamma irradiators	9
others	169
X-ray appliances	**2 234**
fluoroscopy appliances	971
analysis appliances	714
X-ray radiography appliances	372
measuring appliances	79
others	98
Particle accelerators	**28**
research	14
fluoroscopy	7
manufacturing of radioactive materials	7
Radionuclide laboratories	**88**
category 1	10
category 2	21
category 3	55
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 2019.

Radionuclide	Number of sources
Other than high-activity sealed sources	
Cs-137	4 019
Co-60	814
Am-241 (gamma sources)	303
Kr-85	300
Fe-55	101
Am-241 (AmBe neutron sources)	93
Ni-63	93
Sr-90	91
Pm-147	80
High-activity sealed sources	
Cs-137	26
Co-60	13
Am-241 (gamma sources)	10
Ir-192	9
Am-241 (AmBe neutron sources)	6
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)				
	2019	**2020**	**2021**	**2022**	**2023**
Cs-137	77	106	145	187	223
Co-60	27	32	36	46	49
Am-241 (gamma sources)	13	15	19	20	20
Am-241 (AmBe neutron sources)	10	10	10	11	12

TABLE 7. Deliveries of sealed sources to and from Finland in 2019.

Radionuclide	Deliveries to Finland		Deliveries from Finland	
	Activity (GBq)	Number	Activity (GBq)	Number
Ir-192	39 823	23	7 814	22
Kr-85	1 347	92	1 401	96
Am-241	384	543	2	345
Pm-147	380	39	20	9
Cs-137	132	105	<1	1
Fe-55	111	21	101	18
Ni-63	29	88	8	20
Gd-153	8	7	- *)	-
Sr-90	4	5	1	4
Se-75	3	1	199	1
Co-57	2	20	<1	1
I-125	2	6	-	-
Ge-68	1	16	-	-
Cf-252	1	1	-	-
Am-241/Be	-	-	171	1
Others total **)	< 1	14	-	-
Total	**42 227**	**981**	**9 717**	**518**

*) The symbol "-" indicates no deliveries from Finland.
**) Deliveries to Finland: Co-60, Ba-133, Cd-109, Gd-133, Na-22, Y-88, Eu-152 ja Ra-226.

TABLE 8. Manufacturing of radioactive substances (unsealed sources) in Finland in 2019.

Radionuclide	Activity (GBq)
F-18	273 324
C-11	34 870
O-15	33 678
Ga-68	41
Total	**341 913**

TABLE 9. Number of air crew members subject to individual monitoring of radiation exposure and collective dose (sum of effective doses) in 2010—2019.

Year	Number of workers		Collective dose (manSv)	
	Cockpit crew	Cabin crew	Cockpit crew	Cabin crew
2010	1 147	2 281	2.56	5.75
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

TABLE 10. Number of radiation workers subject to individual monitoring by sector in 2010—2019.

Year	Number of workers in each sector									
	Health care		Veteri-nary practices	Industry	Research and education	Production of radioactive materials	Radon	Others*)	Use of nuclear energy**)	Total***)
	Exposed to X-radiation	Exposed to other radiation sources								
2010	4 467	989	491	1 192	817	21	71	73	3 428	12 062
2011	4 320	1 050	550	1 209	742	22	21	79	3 631	11 659
2012	3 989	1 083	582	1 286	720	22	79	107	3 601	11 341
2013	3 953	1 147	636	1 329	727	20	36	125	3 780	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	4 598	11 050

*) 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 2010—2019.

Year	Collective dose (manSv)									
	Health care		Veterinary practices*)	Industry	Research and education	Production of radioactive materials	Radon	Others**)	Use of nuclear energy***)	Total
	Exposed to X-radiation*)	Exposed to other radiation sources								
2010	1.25	0.08	0.08	0.15	0.09	0.004	0.41	0.000	2.59	4.65
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

*) $H_p(10)$ 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 2019

Group	Number of workers	Total dose (Sv)	Average dose (mSv)		Highest dose (mSv)
			Workers whose dose exceeds recording level*)	All workers subject to individual monitoring	
Cardiologists and interventional cardiologists**)	211	0.34	2.4	1.6	17.9
Radiologists**)	231	0.20	3.1	0.9	14.4
Interventional radiologists**)	33	0.18	7.3	5.6	33.9
Consultant specialists**) ***)	246	0.05	1.0	0.2	7.6
Radiographers (other than X-radiation)	705	0.07	0.6	0.1	3.2
Animal attendants and assistants**)	511	0.06	0.8	0.1	5.5
Veterinarians**)	292	0.04	1.2	0.1	7.4
Industrial material inspection technicians****)	582	0.10	0.6	0.2	3.9
Industrial tracer testing technicians	25	0.04	3.0	1.7	9.4
Nuclear power plant workers					
• mechanical work and machine maintenance	809	0.40	1.2	0.5	7.8
• cleaning	259	0.13	1.2	0.5	7.5
• radiation protection personnel	107	0.10	1.4	0.9	6.8
• material inspection	226	0.10	0.9	0.4	5.1

*) 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 2019). 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 2010—2019.

Year	Regulatory inspections	Decisions	Statements	Prohibitions of dangerous laser equipment sold on the internet	Total
2010	55	3	9	31	98
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

TABLE 15. Service work of the NIR Unit in 2010—2019.

Year	Calibrations and tests	Safety assessments and radiation measurements	Total
2010	36	13	49
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

TABLE 16. Inspections of sunbed facilities in 2010—2019. In addition to STUK's own inspections in 2012—2019, 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
2010	16
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)

TABLE 17. SAR tests of mobile phones and other wireless devices in 2010—2019.

Year	Number of tests
2010	10
2011	5
2012	15
2013	11
2014	10
2015	14
2016	11
2017	0
2018	0
2019	0

Appendix 2
Publications in 2019

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 2019:

Scientific articles by STUK employees

International Commission on Radiological Protection: Lecomte JF, Shaw P, Liland A, Markkanen M, Egidi P, Andresz S, Mrdakovic-Popic J, Liu F, da Costa Lauria D, Okyar HB, Haridasan PP, Mundigl S. Radiological protection from naturally occurring radioactive material (NORM) in industrial processes. ICRP Publication 142. Annals of the ICRP 2019; 48 (4). https://www.icrp.org/publication.asp?id=ICRP%20Publication%20142

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Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

Laippatie 4, 00880 Helsinki
Tel. (09) 759 881
fax (09) 759 88 500
www.stuk.fi