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RADIATION PRACTICES

Annual Report 2003

Erkki Rantanen (ed.)

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Abstract

A total of 1811 safety licences for the use of radiation were current at the end of 2003. There were 1962 responsible parties engaged in licence-exempt dental X-ray practices, made notifiable to STUK. Regulatory control of the use of radiation was carried out through regular inspections performed at places of use, postal control, guidance, maintenance of a Dose Register and research intended to support the regulatory control.

A total of 10 900 workers engaged in radiation work were subject to individual monitoring in 2003. 135 000 dose entries were made in the register maintained by STUK. In no case did the individual dose of any worker exceed the dose limits stipulated in the Radiation Decree.

Regulatory control of natural radiation concentrated on radon at workplaces and exposure of aircrews to cosmic radiation. At the end of 2003, 90 workplaces including a total of 141 work areas were subject to ongoing radon monitoring. A total of 2485 pilots and cabin crew members were monitored for exposure to cosmic radiation.

Metrological activities continued with calibration and development work as in previous years. The DOS Laboratory of STO joined the international MRA agreement on the “self declaration principle”.

Regulatory control of the use of non-ionizing radiation focused particularly on mobile phones and sunbeds. Mobile phone market control began by measuring the radiation produced by a range of 12 mobile phones of varying type. Spot check inspections were conducted at tanning facilities and a report was completed on radiation safety improvements at such establishments. A method of measurement based on commercial CCD spectroradiometers was developed for spectral measurements of UV phototherapy appliances and sunbeds. The said method is also suitable for measurements at places of use. A new type of magnetometer, which measures peak values over a wide frequency band weighted according to exposure limits, was developed for measuring low frequency magnetic fields.

In 2003, STUK investigated 15 abnormal incidents involving the use of radiation. Eight of these incidents concerned the use of radiation in industry, research and education, six involved medical uses of radiation and one concerned the use of non-ionizing radiation. None of these incidents resulted in serious consequences.

Contents

1 Background

The expression “use of radiation” refers to the use of radiation appliances and radioactive substances in health care, industry, research and education, and to import, export and production of and trading in radiation appliances and radioactive substances. The expression “radiation practices” refers to the use of radiation and also to any activity or circumstances in which human exposure to natural radiation causes or is liable to cause detriment to health.

The regulatory body for the safety of the use of radiation and other practices causing exposure to radiation is the Radiation and Nuclear Safety Authority (STUK) pursuant to the Radiation Act (592/1991). The regulatory control also applies to the use of non-ionizing radiation insofar as the said use is not controlled by other public authorities. The regulatory control the safety of the use of radiation and of other practices causing exposure to radiation is the responsibility of the Department of Radiation Practices Regulation (STO) and the Laboratory of Non-Ionizing Radiation Surveillance (the NIR Laboratory) at STUK.

This annual report covers events involving the use of ionizing and non-ionizing radiation and other practices causing exposure to radiation, and to the regulatory control of these events in 2003. The report also includes statistics for 2003 gathered by STO and the NIR Laboratory, and details of the metrological and research activities, regulation work, Finnish and international co-operation, and the information activities and services of these units. Abnormal incidents involving the use of radiation are explained in the report as example events, so that similar incidents can be avoided in future.

2 Regulatory Control of the Use of Ionizing Radiation

2.1 Background

Under section 16 of the Radiation Act, a safety licence is required for the use of radiation. This license is granted by STUK on application. An amended licence must be requested in the event of any change in operations that is significant from the point of view of radiation safety. Such changes include, for example, a change in place of use, commissioning of new radiation appliances or a change in the radiation safety officer responsible for the safety of the use of radiation. STO maintains a safety licence register of all licences granted and of the radiation sources referred to in the said licences.

Under section 17 of the Radiation Act, STUK may exempt the use of radiation from the safety licence if it is possible to ascertain with sufficient reliability that use of radiation will not cause damage or danger to health. On certain conditions the use of dental X-ray appliances in general dental surgeries is exempt from safety licensing. Appliances and practices that are exempt from licensing must be notified to STUK for registration. STUK maintains a dental X-ray appliance register of notified appliances.

Through its on-site inspections at places of the use of radiation STUK supervises compliance with radiation legislation and the terms stipulated in safety licences, and ensures that practices are otherwise carried out in a safe and acceptable manner. Inspections usually cover the entire scope of the practice. Cases in which a separate, more restricted inspection may be made include, inter alia, occasions when a partial change of the pactice occurs, for example when commissioning a new place of the use of radiation or radiation appliance. The first inspection of radiation sources and their use generally occurs when the practice begins. Periodic inspections are thereafter conducted at intervals of between 2 and 5 years, depending on the nature of the practice.

Under the Radiation Act, the party running a radiation practice (hereafter the responsible party) must arrange radiation exposure monitoring of persons engaged in radiation work. This monitoring must be individual for category A workers. For reasons of expediency, individual monitoring is also often arranged for persons engaged in category B. Pursuant to section 34 of the Radiation Act (amendment 1142/1998), STUK maintains a Dose Register of the radiation exposure of workers engaged in radiation work.

STUK also maintains a national storage facility for solid low-level radioactive waste pending final disposal. This storage facility forms part of the final disposal facility for intermediate- and low-level power plant waste at the Olkiluoto nuclear power plant of Teollisuuden Voima Oy.

According to section 17 of the Radiation Decree (1512/1991), STUK is to be notified of any abnormal event pertaining to the use of radiation that is substantially detrimental to safety at the place where the radiation is used or in its environs. Any disappearance, theft or other loss of a radiation source such that it ceases to be in the possession of the licensee must likewise be notified. Any other abnormal observation or information of essential significance for the radiation safety of workers, other persons or the environment must also be notified.

2.2 Use of Radiation in Health Care

Safety licences

11 new safety licences for the use of radiation in health care were granted in 2003. 207 applications for amendments to existing licences were also processed. 66 of these applications concerned a change of the radiation safety officer, and 141 concerned a change in the practice such as commissioning of new equipment or a change in the place of use. 151 decisions were also made to cancel a licence or part thereof due to discontinuation of the practice or decommissioning of a radiation source (decommissioning of e.g. dental X-ray appliances in licence-exempt dental X-ray practices are also included in this figure).

706 safety licences for the use of radiation in health care were current at the end of 2003. The number of radiation practices referred to in these licences is shown in Table I.

Licence-exempt dental X-ray practices

The use of dental X-ray appliances has been exempted from safety licensing by decision no. 202/310/99 of STUK on the following conditions:

1. The appliance must have a CE marking (Directive 93/42/EEC) in accordance with the Medical Devices Act (1505/1994).
2. The shielding at the place of use of the appliance must comply with the requirements of Guide ST 3.1.
3. A dentist or physician must direct the use of the appliance and take responsibility for safety in such use.

If the use of a dental X-ray appliance fails to comply with the conditions set out in the decision of STUK, then a safety licence must be obtained for the said use. Compliance with the conditions is investigated at the time of registering appliances that are notified to STUK.

A total of 1962 responsible parties engaged in notifiable licence-exempt dental X-ray practices in 2003.

For the regulatory control of dental X-ray appliances a total of 1514 test packages were sent by post to responsible parties.

Radiation Appliances

Table II shows details of the radiation appliances and radionuclide laboratories in health care listed in the safety licence register and in the register of dental X-ray appliances at the end of 2003 (the Table also includes appliances used in veterinary medicine). 6986 radiation appliances and 77 radionuclide laboratories were entered in the registers. Most of these appliances were dental X-ray appliances. While the number of radiation appliances remained roughly the same as in the preceding year, there was a fall of about 11 per cent in the number of radionuclide laboratories.

X-ray diagnostics

Inspections of X-ray diagnostics conducted by STUK revealed no serious inadequacies in safety arrangements and no hazard situations were notified in 2003. Broadly speaking, the safety standard of X-ray diagnostics may be considered to be relatively good, even though considerable differences in patient doses of as much as many tenfolds continued to be found between various places of use. It is usually possible to reduce these higher doses without compromising the purpose of the procedure. This will require greater safety awareness in modes of practice and optimization of diagnostic methods.

The introduction of reference levels was monitored at periodic inspections of radiation practices. Inspections of the use of radiation focused particularly on CT appliances, and the doses induced by these appliances and image quality were investigated. The aim was to study implementation of the principle of optimization in the use of CT appliances and to use the findings to prepare a plan for improving optimization.

Inspections of fluoroscopy appliances

8 fluoroscopy appliances (about 1.5 per cent of all appliances) were inspected during 2003. In all of the appliances inspected the air kerma rate and fluoroscopic image quality were adequate when assessed according to the critical limits set out in Guide ST 3.3.

Investigations of patient doses and image quality

For several years inspections conducted by STUK have involved an investigation of patient radiation doses and examination image quality in lumbar spine AP and chest PA imaging. An X-ray image of a phantom has been taken using the imaging techniques available at the X-ray facilities inspected, and the radiation dose at the phantom surface has been measured at the same time. Measurements of this kind were made at about 10 per cent of X-ray facilities in 2003.

Table III shows the doses measured in the course of inspections conducted between 1999 and 2003. The Table also shows the reference levels issued by STUK and the levels recommended by the European Union expert group (for the reference levels see the Radiation Practices Annual Report 2000, STUK-B-STO 44). The average doses fell below the STUK reference levels for the examinations in question. The dose distributions obtained in measurements taken in 2003 are shown in Figures 1 and 2.

The European Union expert group has also issued recommendations for X-ray image quality. However, these recommendations apply to clinical X-ray images. There are no international reference values for technical image quality. The national situation may be assessed by comparing the results of image quality measurements made in various years.

The results of image quality measurements made by STUK between 1999 and 2003 are shown in Table IV. These measurements were made using the phantoms and measurement methods set out in Guide ST 3.5. No substantial changes in image quality may be discerned on the basis of these findings.

Regulatory control of dental X-ray appliances

Dental X-ray appliances are subject to control measurement at intervals of 3–5 years using a test package sent by post. The measurements provide data on radiation doses and other aspects of dental X-ray appliances. These control measurements are described in greater detail in the Radiation Practices Annual Report 1995 (STUK-B-STO 33).

The radiation doses produced by 1317 dental X-ray appliances were measured in 2003. The doses correspond to the dose administered at the surface of the cheek in imaging of a molar tooth. The distribution of measured doses is shown in Figure 3. The average dose was 2.6 mGy and the range was 0.7–21.4 mGy in conventional dental X-ray imaging appliances. The recommended[*)] reference level of the IAEA (International Atomic Energy Agency) for dental X-ray images is 7 mGy (Entrance Surface Dose). The corresponding reference level imposed by STUK is 5 mGy. 2 per cent of the appliances measured exceeded the 5 mGy reference level. A dose of 5 mGy in dental imaging corresponds to an effective dose of about 7 μSv.

The dose-area-products from a total of 272 panoramic X-ray appliances were measured between 1995 and 2003. Figure 4 shows the distribution of dose-area-products of the appliances that were in use in December 2003 (a total of 210 appliances). The average dose using conventional imaging appliances was 91.8 mGy·cm^2 and the range was 46–217 mGy·cm^2, while the corresponding average dose with digital imaging appliances was 88.1 mGy·cm^2 and the range was 60–131 mGy·cm^2. The corresponding reference level for dose-area-product imposed by STUK is 120 mGy·cm^2.

[*)] International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. Safety Series No. 115, Schedule III, p. 279, International Atomic Energy Agency (IAEA), Vienna 1996.

Table I. Number of radiation practices referred to in safety licences for the health care sector at the end of 2003.

Use of radiation	Number of practices
X-ray examination	449
Dental X-ray examination*)	10
Veterinary X-ray examination	185
Use of unsealed sources	52
Use of sealed sources	21
Radiotherapy	13
Other uses of radiation	17

*) Licence granted for dental X-ray appliances that are nevertheless mainly used for purposes other than dental X-ray practices.

Table II. Number of radiation appliances and radionuclide laboratories used in health care and veterinary medicine at the end of 2003.

Appliances/laboratories	Number
X-ray diagnostic appliances (generators)*)	**1604**
X-ray tubes	1841
• mammography (not screening)	103
• screening mammography	103
• computed tomography	73
• angiography (not DSA)	22
• digital subtraction angiography (DSA)	83
• bone density measurement	68
Dental X-ray appliances	**5008**
• conventional dental X-ray appliances	4365
• panoramic X-ray appliances	643
Radiotherapy appliances	**84**
• accelerators	28
• afterloading appliances	12
• X-ray therapy appliances or radiographic appliances	19
• radiotherapy simulators	8
• BNCT equipment	1
• other appliances	16
Appliances containing radioactive substances	**75**
• blood irradiation appliances	7
• calibration sources and other appliances	68
Veterinary X-ray appliances	**215**
Radionuclide laboratories	**77**
• B-type laboratories	18
• C-type laboratories	55
• other laboratories	4

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

Table III. Radiation doses measured on the surface of a phantom in lumbar spine AP and chest PA imaging in 1999–2003.

Year	Dose*) (mGy) Average (range)	
	Lumbar spine AP	**Chest PA**
1999	5.4 (1.1–11)	0.13 (0.03–0.33)
2000	5.9 (0.7–23)	0.13 (0.04–0.44)
2001	5.8 (1.1–21)	0.13 (0.04–0.37)
2002	5.6 (1.5–19)	0.13 (0.04–0.40)
2003	5.2 (1.0–25)	0.10 (0.03–0.25)
EU reference level **)	10	0.3
STUK reference level	8	0.2

*) Dose on the surface of a phantom (Entrance Surface Dose).
**) Normal sized, 70 kilogram patient.

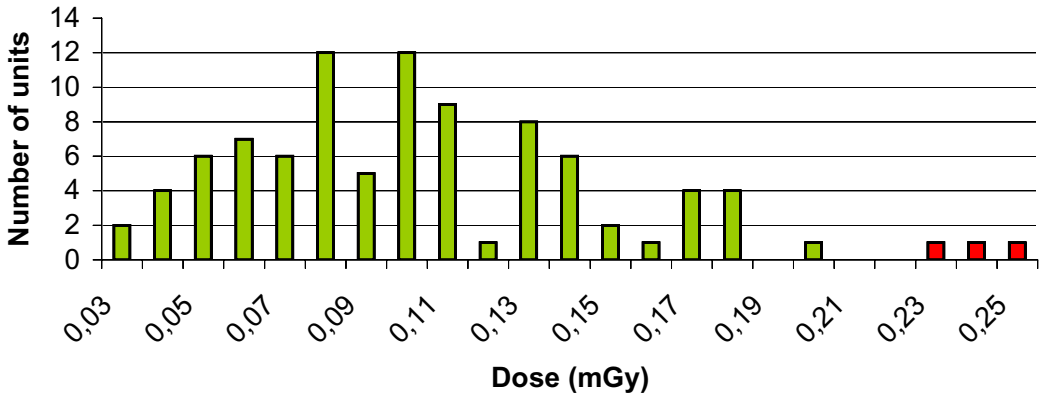

Figure 1. Dose distribution for chest imaging measurements in 2003.

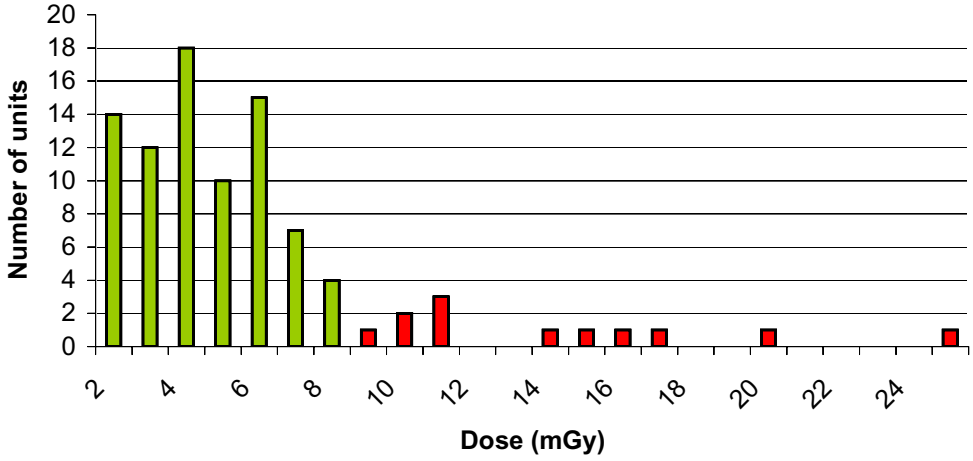

Figure 2. Dose distribution for lumbar spine imaging measurements in 2003.

Table IV. Image quality in lumbar spine AP and chest PA imaging in 1999–2003.

Year	Optical density (OD) Average (range)		Contrast (OD) Average (range)		Spatial resolution (line pairs·mm^{-1}) Average (range)	
	Lumbar spine AP	Chest PA	Lumbar spine AP	Chest PA	Lumbar spine AP	Chest PA
1999	1.26 (0.66–1.97)	1.64 (1.06–2.33)	0.25 (0.06–0.47)	0.30 (0.13–0.54)	2.0 (0.8–3.1)	3.7 (1.4–5.0)
2000	1.22 (0.58–1.88)	1.67 (0.60–2.26)	0.22 (0.08–0.39)	0.30 (0.08–0.52)	2.2 (0.9–4.3)	3.9 (1.8–5.0)
2001	1.24 (0.71–2.37)	1.76 (0.75–2.69)	0.22 (0.07–0.51)	0.30 (0.15–0.62)	2.0 (1.0–3.4)	3.7 (1.6–5.0)
2002	1.34 (0.82–2.13)	1.76 (0.77–2.40)	0.23 (0.08–0.45)	0.30 (0.10–0.78)	2.1 (1.0–5.0)	4.0 (1.8–5.0)
2003	1.25 (0.77–2.10)	1.70 (1.01–2.30)	0.23 (0.08–0.46)	0.30 (0.14–0.53)	2.1 (1.2–3.7)	4.2 (2.8–5.0)

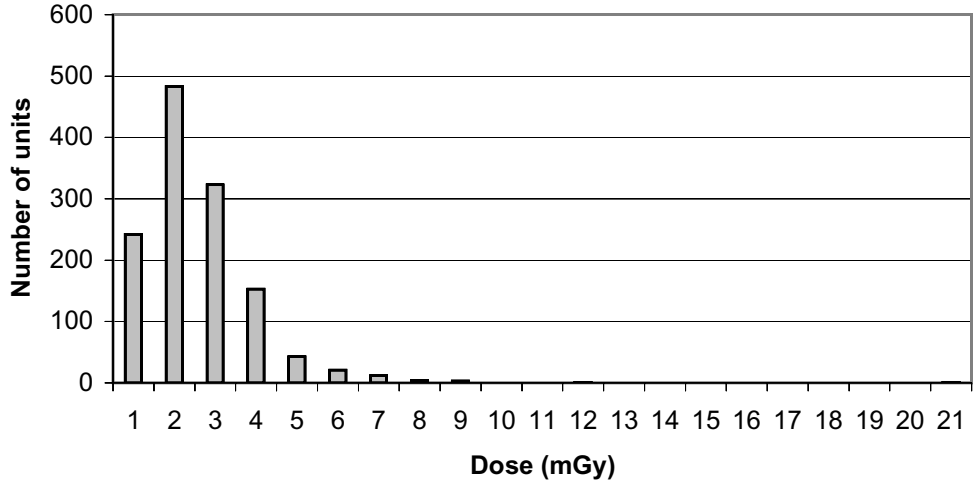

Figure 3. Dose distribution for dental X-ray measurements in 2003.

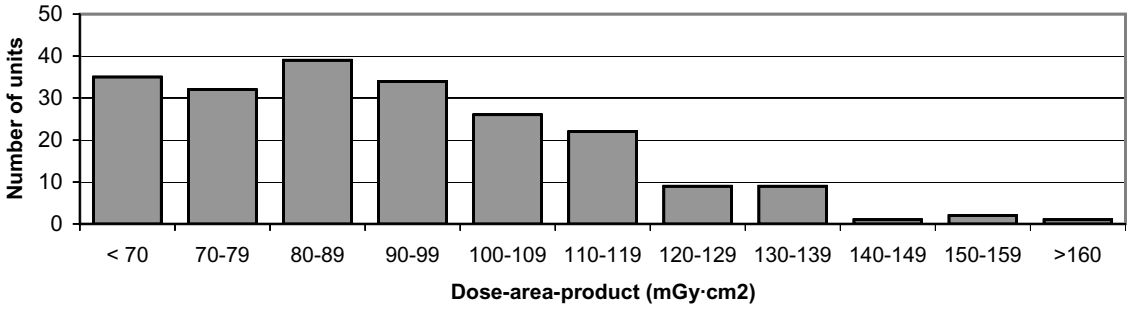

Figure 4. Distribution of dose-area-product in panoramic X-ray appliance measurements between 1995 and 2003.

Mammography

Mammography appliances have formed an inspection project at STUK in the 2000s. The distribution of doses from mammography appliances inspected in 2002–2003 is shown in Figure 5 (the dose was measured on the surface of a Plexiglas phantom of thickness 4.5 cm). The average dose was 6.6 mGy. The reference level imposed by STUK is 10 mGy.

The findings from the mammography appliances studied in 2002–2003 were published in the report series of STO (STUK-B-STO 52).

Radiotherapy

The aim of radiotherapy is to destroy a localized tumour while minimizing damage to healthy tissue. For this to succeed, the radiation must be applied to a specified target volume with the greatest possible accuracy and at the correct dose. According to international recommendations, including those of the ICRU (International Commission on Radiation Units and Measurements), the average uncertainty in therapeutic dose should not exceed 5 per cent. In the regulatory control of the proper implementation of the principle of justification and optimization, the main concern therefore focuses on the factors that govern the accuracy of the radiotherapy dose administered to the patient, i.e. on the correct magnitude of the dose and its correct targeting in the patient. To ensure good accuracy of radiotherapy doses, radiotherapy units are required to prepare quality assurance programmes for the use of therapy appliances.

A new calibration and measurement method based on the absorbed dose to water was introduced nationwide during 2003 for use in external radiotherapy. This method complies with international practice in accordance with the dosimetry guidelines of the WHO (World Health Organization) and the IAEA. Correct application of the method was ensured in practice by conducting inspections of every external radiotherapy facility. Comparison measurements were also made at Umeå University Hospital in Sweden. The comparison showed that dosimetry practices in Umeå and in Finland are highly congruent.

31 inspections of radiotherapy departments were made, five of which concerned the commissioning of a new accelerator. The inspections and associated measurements give cause to consider that a good standard of radiation safety of health care staff and patients has continued in radiotherapy. Inspections and comparison measurements of radiotherapy appliances (therapy appliances and radiotherapy simulators) also indicate that the procedures applied and appliance features governing the accuracy of the therapeutic dose generally comply with the requirements prescribed for them. Five remarks were recorded in respect of inadequacies in safety systems, radiotherapy appliances or quality control methods. The action level for photon radiation (1 per cent) and the level for electron radiation (2 per cent) were not exceeded in comparison measurements of the dose produced by therapy appliances.

Nuclear medicine

Inspections were conducted at seven isotope laboratories. No significant deficiencies or abnormalities were observed. The introduction of reference levels was monitored at periodic inspections. A more extensive report on reference levels and quality assurance will be prepared in 2004.

2.3 Use of Radiation in Industry, Research and Education

Safety licences

45 new safety licences for the use of radiation in industry, research and education were granted in 2003. 197 applications for amendments to existing licences were also processed. 72 of these applications concerned a change of the radiation safety officer, and 125 concerned a change in the practice such as commissioning of new equipment or a change in the place of use. 71 decisions were also made to cancel a licence or part thereof due to discontinuation of the practice or decommissioning of a radiation source.

1105 safety licences for the use of radiation in industry, research and education were current at the end of 2003. The number of radiation practices referred to in these licences is shown in Table V.

Radiation appliances and sources

Table VI shows details of radiation appliances and sources and of radionuclide laboratories in industry, research and education entered in the safety licence register at the end of 2003. 7152 radiation appliances and 180 radionuclide laboratories were entered in the register. While the number of radiation appliances remained roughly the same as in the preceding year, there was an increase of about 3 per cent in the number of radionuclide laboratories. Most of the appliances were of a type containing sealed sources for use in industry. Small sources falling below the exemption values (e.g. calibration sources for use in laboratories) and radiation sources held in stock by importers were not registered by type of source.

Table VII shows details of sealed sources and the radionuclides used therein.

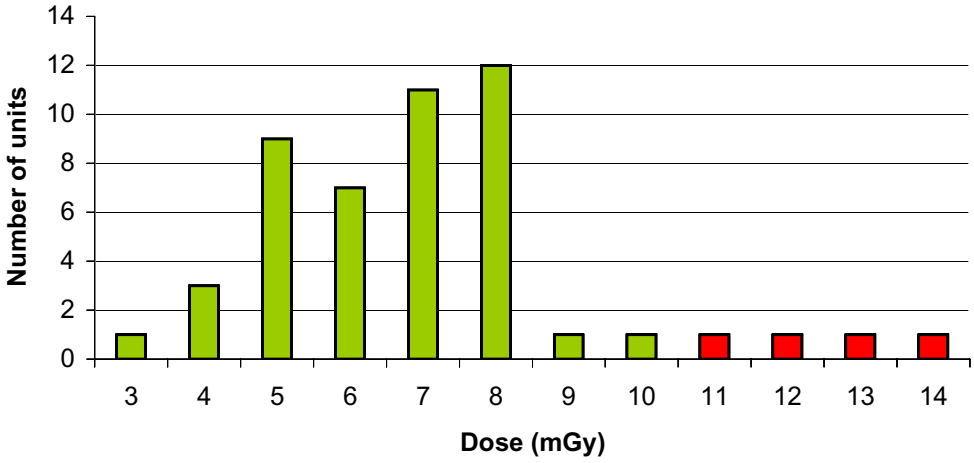

Figure 5. Dose distribution from mammography appliance measurements in 2002–2003.

Table V. Number of radiation practices referred to in current safety licences for the use of radiation in industry, research and education at the end of 2003.

Use of radiation	Number of practices
Use of sealed sources (excluding gamma radiography)	642
Use of unsealed sources	142
Import, export and trade	140
Installation, test operation and servicing	135
Use of X-radiation (excluding radiography)	199
X-ray radiography	83
Gamma radiography	8
Manufacture of radioactive substances	5
Other uses of radiation	18

Table VI. Number of radiation appliances and sources, and radionuclide laboratories in industry, research and education at the end of 2003.

Appliances/laboratories	**Number**
Appliances containing radioactive substances	**6278**
• level switches	2330
• continuous level gauges	1034
• density gauges	992
• basis weight meters	678
• weight scales	547
• moisture and density gauges	134
• fluorescence analyzers	132
• thickness gauges	74
• radiography appliances	22
• other appliances	335
X-ray appliances and accelerators	**874**
• radiography appliances	324
• fluoroscopic appliances	249
• diffraction and fluorescence analyzers	184
• thickness gauges	38
• ash meters	17
• particle accelerators	16
• other X-ray appliances	18
• other analytical appliances	28
Radionuclide laboratories	**180**
• A-type laboratories	2
• B-type laboratories	33
• C-type laboratories	127
• other laboratories	18

Table VII. Radionuclides most commonly used in sealed sources in industry, research and education, and number and activities of sources at the end of 2003.

Radionuclide	Number of radiation sources	Total activity (GBq)
Activity < 400 GBq		
Cs-137	3771	10 157
Co-60	1475	1541
Kr-85	402	5186
Am-241 (gamma sources)	346	2474
Pm-147	177	4326
Fe-55	153	433
Am-241 (AmBe neutron sources)	123	1090
Sr-90	78	209
Cd-109	65	37
Cm-244	27	125
Activity > 400 GBq		
Cs-137	27	666 230
Ir-192	14	53 940
Co-60	7	130 715
H-3	1	3700

2.4 Import, Production and Export of Radioactive Substances

STUK gathers data for regulatory purposes annually from the importers and manufacturers of radioactive substances on trade in and production of such substances. Data on radioactive substances brought to Finland from within the European Union are also received directly from the consignors, pursuant to Council Regulation (Euratom) No. 1493/93[*)]. The information on radionuclides imported to, produced in and exported from Finland in 2003 is shown in Tables VIII–X. The figures in the Tables are based on data gathered from licensees engaged in import, production and export. The import and export statistics exclude radioactive substances imported and exported by responsible parties within the European Union for their own use. The statistics also exclude radioactive substances supplied to other countries via Finland.

5132 sealed sources were imported and 3291 sealed sources were exported (Table VIII). Sealed sources are mainly used in industrial measurement and research appliances. Tritium (^{3}H) is also used in bearing instruments and the iodine isotope ^{125}I is used in radiotherapy.

The smoke detectors and ionization detectors used in fire alarm systems and containing americium (^{241}Am) are excluded from Table VIII. A total of 287 836 such appliances were imported with a combined activity of about 9 GBq.

The total activity of imported unsealed sources was 61 976 GBq and the total activity of exported unsealed sources was 14 890 GBq (Table IX). Unsealed sources are used in nuclear medicine and in indicator tests for industry and research.

A total of 47 562 GBq in short-lived radioactive substances for use as unsealed sources were produced in Finland in 2003 (Table X). Short-lived isotopes manufactured in particle accelerators are mainly used for labelling pharmaceutical products.

[*)] The expression "shipment of radioactive substances " is used to denote the import, export and transit conveyances of radioactive substances between the Member States of the European Union. This chapter uses the terms "import" and "export" regardless of the country of origin or destination of a radioactive substance.

Table VIII. Imports and exports of sealed sources in 2003.

Radionuclide	Imports		Exports	
	Activity (GBq)	Number	Activity (GBq)	Number
Ir-192	48 179	26	8432	25
H-3	7652	3500	6408	2165
Pm-147	735	79	95	18
Kr-85	244	73	1009	72
Fe-55	163	116	177	82
I-125	149	880	-*)	-
Cs-137	121	114	11	20
Cd-109	41	85	36	74
Po-210	31	42	-	-
Co-60	16	68	< 1	2
Gd-153	11	38	5	10
Am-241	13	49	18	818
Sr-90	4	18	< 1	1
others total **)	10	44	6	4
Total	**57 371**	**5132**	**16 197**	**3291**

*) The "-" symbol indicates no imports/exports.

**) Imports, nuclides: Am-241 (AmBe neutron sources), Ba-133, Co-57, Eu-152, Ge-68 and Ni-63.
Exports, nuclides: Cm-244 and Ge-68.

Table IX. Imports and exports of unsealed sources in 2003.

Radionuclice	Activity (GBq)	
	Imports	Exports
Mo-99	51 966	12 534
I-131	7026	1692
Sm-153	1470	170
Ho-166	510	40
W-188	370	372
P-32	158	< 1
Tl-201	112	- *)
I-123	94	36
I-125	88	8
S-35	58	-
In-111	47	-
H-3	41	2
F-18	-	35
others total **)	36	1
Total	**61 976**	**14 890**

*) The "-" symbol indicates no imports/exports.

**) Imports, nuclides: Ba-133, C-14, Ca-45, Co-57, Cr-51, Cs-137, Cu-64, Eu-152, Fe-55, Fe-59, Ga-67, Ge-68, I-129, Na-22, P-33, Ra-226, Se-75, Sr-89 and Y-90.
Exports, nuclides: C-14, Cs-137, Cu-64, Eu-152 and I-129.

Table X. Manufacturing of radioactive substances (unsealed sources) in 2003.

Radionuclide	**Activity (GBq)**
O-15	31 400
F-18	7368
C-11	7193
Br-82	1532
Ar-41	56
Na-24	9
I-123	3
others total*)	1
Total	**47 562**

*) Nuclides: Cr-51, Cs-129, Cs-132, Cs-136, Cu-64, Ni-63 and Sm-153.

2.5 Individual Monitoring

Background

The Dose Register maintained by STUK records the radiation exposure data of workers subject to individual monitoring. The individual doses of workers are determined by approved dosimetric services. Data were provided for the Register in 2003 by nuclear power plants and by Doseco Oy – which also maintains the dosimetric service for the Olkiluoto nuclear power plant – by responsible parties and by the airlines Finnair Oyj and Oy Air Finland Ltd. Data are also recorded in the Register from Radiological Monitoring Documents for persons who have worked abroad and from reports received from the Swedish Dose Register.

The doses arising for workers from external radiation are measured using personal dosemeters. The measurement results are reported in terms of the quantity personal dose equivalent, either $H_p(10)$ or $H_p(0.07)$, which are (usually) sufficiently accurate approximations of the effective dose and the equivalent dose to the skin. If the personal dose equivalent is large, then the exposure circumstances are investigated and an assessment is made of the effective dose or the equivalent dose to the skin of the person concerned. The measurement results of $H_p(10)$ fail to correspond to the effective dose, when using individual protective appliances (use of X-radiation in health care and veterinary medicine), in which case the effective dose is reckoned from $H_p(10)$ by dividing the latter by a factor between 10 and 60. When using an individual protective appliance (e.g. a lead apron) the dosemeter is placed on top of the protection, as the dosemeter measurement then also indicates the exposure of any parts of the body that remain unprotected.

The doses arising for the worker from internal radiation are determined from secretion samples or from body activity measurements performed using whole body counting appliances. The worker's effective dose is reckoned from the measured activity and recorded in the Dose Register.

The smallest dose to be recorded in the Dose Register (recording level) for $H_p(10)$ for persons working in nuclear power plants is 0.1 mSv per month and for other workers 0.1 mSv per month or 0.3 mSv per quarter, depending on the duration of the measurement period. The corresponding recording level for $H_p(0.07)$ is either 2 mSv per month or 6 mSv per quarter.

Category A workers departing for radiation work within the territory of the European Union require a Radiation Passbook. This comprises a Radiological Monitoring Document procured from STUK (an extract from the Dose Register) and a certificate issued by the medical practitioner responsible for medical surveillance of the worker. The Radiological Monitoring Document must be submitted to the responsible party abroad, who records details of the duration of radiation work, of radiation exposure and of any medical inspections on the said document.

The document is returned to STUK after the overseas radiation work assignment ends so that the details can be recorded in the Dose Register.

Individual monitoring in 2003

10 900 workers were subject to individual monitoring at 1160 workplaces. A total of 135 000 dose entries were made. 32 per cent of worker employment relationships were classified in category A and 67 per cent were classified in category B. No classification was notified in 1 per cent of cases.

In no case did the effective dose of a worker exceed the annual dose limit of 50 mSv, or the value of 20 mSv which is the annual average of the five-year dose limit. Neither did the dose to a worker's hands exceed the annual dose limit of 500 mSv in any case. The total dose was 9 per cent lower in the use of radiation and 42 per cent smaller in the use of nuclear energy than the corresponding figures for the previous year. The total doses in the use of nuclear energy vary considerably each year depending on the duration of annual servicing and the duties performed in servicing work.

The largest $H_p(10)$ arising from X-radiation in health care was 35 mSv recorded for a radiologist. This corresponds to an effective dose of 0.6–3.5 mSv. Besides X-ray equipment, other radiation sources are used in health care, and the $H_p(10)$ values measured for the users of such appliances are approximations of the effective dose. The largest effective dose in health care was 4 mSv. The largest dose to the fingers was 203 mSv, recorded in the case of a laboratory technologist using unsealed sources.

The largest $H_p(10)$ in veterinary medicine was 14.9 mSv, recorded in the case of an animal attendant. This corresponds to an effective dose of 0.3–1.5 mSv. Besides X-ray appliances, only a few people (2–6) in veterinary medicine use other radiation sources (unsealed sources) each year. The largest effective dose for users of such unsealed sources in 2003 was 0.1 mSv.

The largest $H_p(10)$ measured in industry was 10 mSv, and was due to more than one radiation source. The largest radiation doses in industry are generally caused by unsealed sources and the use of industrial X-ray appliances. Some industrial radiographers working in industry also work at nuclear power plants. The radiation doses that they sustain while working at nuclear power plants are reckoned together with the dose for persons working in material testing (see Table XIII).

The largest $H_p(10)$ sustained in research and education was 13 mSv recorded for a person who had used unsealed sources. Most of the total dose arising in research work was sustained by only a few people. The doses arising for other persons were minor or fell below the recording level.

The total dose sustained by workers at Finnish nuclear power plants was 2.0 Sv. 1.6 Sv of this total dose was recorded for outside workers and the remaining 0.4 Sv was sustained by the permanent staff of the power plants. 904 persons subject to individual monitoring worked permanently at Finnish nuclear power plants, of whom 424 sustained doses exceeding the recording level. There were 1864 outside workers, of whom 1127 sustained doses exceeding the recording level. The largest $H_p(10)$ was 19 mSv, and was sustained by a person working in mechanical and servicing duties. The person concerned sustained some of this radiation exposure at a Swedish nuclear power plant.

Effective doses exceeding 0.1 mSv and arising from internal radiation exposure occurred in the case of nine nuclear power plant workers and one person working in research. The combined dose sustained by these workers from internal exposure was 2.2 mSv.

The number of workers subject to individual monitoring in 2003 is shown in Table XI and the combined doses of workers in various occupational categories are shown in Table XII. For comparison, the Tables also show the corresponding details for the years 1999 to 2002. Table XIII shows the doses in 2003 of persons sustaining high levels of exposure or of numerically large worker groups.

Documents and reports in 2003

STUK issued 38 Radialogical Monitoring Documents from the Dose Register. A total of 39 worker doses were investigated more thoroughly during the year and one investigation was made on the basis of earlier measurement data due to a suspected occupational disease.

Table XI. Number of workers subject to individual monitoring in 1999–2003.

Year	Number of workers in various occupational category						
	Health care		Veterinary medicine	Industry	Research and education	Use of nuclear energy	Total*)
	Exposed to X-rays	Exposed to other radiation sources					
1999	4435	990	278	1125	1378	2403	10 502
2000	4530	954	292	1032	1255	2826	10 757
2001	4576	919	288	1128	1362	2753	10 899
2002	4697	891	296	1180	1209	3055	11 190
2003	4741	906	305	1114	1109	2862	10 901

*) The figure shown in certain rows of this column is not necessarily the same as the sum of the figures in other columns of the corresponding row, as some health care staff are exposed to both X-rays and other forms of radiation, and there are workers in industry who also work in the use of nuclear energy.

Table XII. Total doses in various occupational categories (sums of $H_p(10)$ values) in 1999–2003.

Year	Total dose (Sv)						
	Health care		Veterinary medicine	Industry	Research and education	Use of nuclear energy	Total
	Exposed to X-rays	Exposed to other radiation sources					
1999	1.60	0.10	0.04	0.15	0.07	2.78	4.74
2000	1.63	0.11	0.07	0.22	0.10	4.40	6.53
2001	1.68	0.11	0.06	0.22	0.10	2.58	4.75
2002	1.69	0.13	0.07	0.24	0.09	4.12	6.36
2003	1.55	0.12	0.07	0.20	0.09	2.38	4.41

Table XIII. Data on certain occupational groups ($H_p(10)$ values) in 2003.

Group	Number of workers	Total dose (Sv)	Average dose (mSv)		Largest dose (mSv)
			Workers whose doses exceed recording level	All workers subject to individual monitoring	
Cardiologists	148	0.53	4.5	3.6	25.2
Radiologists	592	0.48	2.3	0.8	34.6
Interventional radiologists	20	0.13	7.4	6.7	25.7
Surgeons	253	0.12	2.4	0.5	27.4
X-ray assistants	2546	0.12	0.6	0.0	3.1
Industrial radiographers	345	0.09	1.1	0.3	5.4
Researchers	864	0.04	1.4	0.0	9.6
Nuclear power plant workers					
• mechanical duties	711	0.70	1.4	1.0	14.4
• cleaning	233	0.29	2.1	1.2	12.7
• material testing	200	0.21	1.3	1.0	9.3
• insulation work	74	0.18	2.7	2.4	9.0
• radiation protection	65	0.11	1.9	1.7	8.5
• operating staff	238	0.09	0.7	0.4	4.0

*) The recording level is 0.1 mSv per month for persons working in nuclear power plants and 0.1 mSv per month or 0.3 mSv per quarter for other workers depending on the duration of the measurement period.

2.6 Radioactive Waste

159 waste packages had been transported to the national storage facility for low-level radioactive waste maintained by STUK by the end of 2003. The activities or masses of the principal wastes held in the storage facility are shown in Table XIV.

Before the waste is sent to the storage facility it is transported to an interim storage unit at the STUK's premises at Roihupelto in Helsinki. This interim storage unit received 39 batches of low-level waste in 2003, comprising a total of 111 packages. Table XV shows the activities or masses of the wastes consigned to STUK in 2003.

Table XIV. The principal low-level radioactive wastes in the Olkiluoto facility (December 2003).

Radionuclide	Acvivity (GBq) or mass
H-3	18 493
Co-60	248
Kr-85	1153
Sr-90	142
Cs-137	1960
Ra-226	230
U-238	442 kg
Pu-238	1647
Am-241	1003
Cm-244	83

Table XV. Low-level radioactive wastes received by STUK in 2003.

Radionuclide	Activity (GBq) or mass
H-3	4.0
Co-60	4.2
Ni-63	3.0
Kr-85	79
Sr-90	0.4
Cs-137	220
Pm-147	14
Ra-226	0.3
U-238	10 kg
Am-241	68
Cm-244	29
Pu-238	1.0

2.7 Abnormal Incidents

During 2003, STUK investigated 14 cases in which abnormal incidents or situations occurred or were suspected in the use of ionizing radiation. 8 of these cases concerned the use of radiation in industry and research and 6 involved the use of radiation in health care.

The case histories set out below indicate the abnormal incidents that were investigated and the reasons for them, together with the measures taken on account of each incident.

Incident 1

A dose rate of 2–3 $\mu Sv \cdot h^{-1}$ was measured on the surface of a metal cabinet supplied to a scrap processing facility. The cabinet had been sent to the facility from the Finnish Defence Forces. A gamma spectrometer measurement revealed the origin of the radiation to be a radium source (^{226}Ra). An examination of the contents of the cabinet indicated that the radiating element was an instrument panel. With the permission of STUK the scrap processing facility surrendered the instrument panel to the representatives of the Finnish Defence Forces.

Incident 2

A district heating station had been shut down and its gas generator was out of service. For some reason, the gas generator produced so much

residual heat that a tar/grease fire ignited at the top of the silo, but was rapidly extinguished. The level gauge in the silo containing a radiation source (^{60}Co, 3.7 GBq) was blackened in the fire. Measurements and observations indicated that the protective lead jacket of the gauge had survived the fire intact, but that its radiation hazard sign had been tarnished.

STUK ordered the installation of a new radiation hazard sign to replace the damaged sign.

Incident 3

Five ^{137}Cs radiation sources (0.74–22.2 GBq) were discovered in the defence shelter of an enterprise during a fire inspection. The enterprise had previously traded in level and density gauges containing radiation sources, and had stored radiation sources in the defence shelter. Following discontinuation of its radiation appliance agency operations, the enterprise had applied to STUK for discharge from its safety licence, but the discharge application had mistakenly omitted to mention the radiation sources remaining in the defence shelter.

The enterprise consigned the radiation sources to STUK which advised the enterprise on the dangers of radiation sources.

Incident 4

Some gantries were constructed inside a cellulose boiler at a pulp mill for the purpose of boiler inspections. At the tope of the boiler there was a level switch containing a radiation source (^{60}Co, 2.3 GBq). A permit for tank work had been requested for boiler inspections, which had also included a request to shut off the radiating appliance. Although the appliance was shut off before the inspection work began, the gantries had already been constructed before this was done. Three construction workers were exposed to radiation for a period of about 90 minutes while building the gantries.

It was difficult to assess the effective dose of those exposed, but in no case did the dose sustained by any of the construction workers exceed the annual dose limit of 1 mSv for members of the public.

The responsible party was enjoined to ensure in future that all of the measures referred to in the permit for work have been taken before the work begins.

Incident 5

A party forgot to lock the shutter to the “closed” position of a level switch containing a radiation source (^{137}Cs, 185 MBq) in the course of repairs to a bypass damper in a district heating plant aggregate tank. Two workers worked in the tank for about 30 minutes standing on the crusher blades. Their legs were exposed at knee height to radiation emitted by the level switch. The workers sustained a dose of about 20–30 µSv at this height.

The responsible party was enjoined to prepare instructions for tank work and a list of the measures to be taken before entering the tank.

Incident 6

A small child got into the luggage conveyor system at an airport and was carried through an X-ray appliance used for luggage fluoroscopy. The child was not injured in the conveyor system, but was exposed to X-rays. The radiation dose sustained by the child was 1.5 µSv.

The responsible party will train check-in clerks and review the structures and locking systems of check-in desks.

Incident 7

A steel-capsuled depleted uranium housing for a radiation source used for inspecting welded joints was found in a consignment of scrap metal brought to a scrap processing facility. The housing contained no radiation source. The housing was sent to STUK. The activity of the uranium in the housing was estimated at about 2 GBq.

Incident 8

In the course of an inspection, it was found that a radiation source (^{241}Am, 370 MBq) was missing from an analyser in a research facility. The radiation source was not found even after an extensive search. The responsible party received a written reprimand from STUK regarding the loss of the radiation source. About one year later

the radiation source was found on the premises of the said responsible party. It had been packed in a lead housing, and had therefore caused no exposure or hazard to its handler.

Incident 9

When administering a ^{153}Sm-EDTMP therapeutic dose to a patient, the radiopharmaceutical had spattered over the surroundings and the persons present. This had occurred because the cannula was not properly attached to the blood vessel. 3 ml of the 5 ml volume (total activity of 2.62 GBq) remained in the syringe after the event, and so an estimated 2 ml (activity of 1.05 GBq) was spattered over the surroundings. It is unlikely that any of the radiopharmaceutical entered the patient's blood vessel. The patient immediately washed away the drops remaining on the skin and was instructed to return home and take a shower, change clothes and wash the clothes worn during the incident in a washing machine. The drops in the surroundings were mopped up using cellulose wadding and all surfaces were cleaned. The other persons present at the incident also took showers and changed their clothes.

The case gave no cause for further action.

Incident 10

Two ^{125}I seed implants were lost in the course of prostate brachytherapy. A total of 86 seed implants were placed into the patient. The seeds were 4.5 mm in length, 0.8 mm in diameter and had an activity of 13.5 MBq. Based on the verification images of the patient taken after placing the seeds and a count of the remaining seeds, it was observed that two seeds were missing. A search failed to locate the lost seed implants.

The seeds were probably removed with the solid waste, even though no radiation was detected during an external measurement of the waste bag.

Incident 11

A patient received an overdose in radiotherapy due to an error in dose calculation. Whole brain radiotherapy was administered to the patient on the principle of two opposing fields. The dosing error was due to an operating fault in the calculation program, whereby the thickness of the patient was not entered into the program.

The hospital has modified the output form of the calculation programme to prevent any recurrence of a corresponding error.

Incident 12

Whole body radiotherapy was administered to a patient in preparation for a bone marrow transplant, even though the original intention was only to treat all of the lymph follicle areas in the body. Due to the selected target volume, the patient's head and genital areas received a larger dose than was intended.

Incident 13

The data transmitted to the treatment unit from a radiotherapy dose planning system was modified during transmission, turning one wedge field in three-field therapy into an open field. However, the error was detected after six therapy fractions, enabling the previous overdose to be compensated.

The treatment unit manufacturer has corrected the malfunctioning data transfer software.

Incident 14

In the course of radiotherapy, a technician remained in the treatment room to complete the process of positioning the patient when another technician started the radiotherapy due to human error. The technician in the room noticed that the accelerator was on and immediately left the room. The dose sustained by the technician was about 30 µSv.

Because of the incident, the hospital arranged for special attention to be paid in its staff training to the need for caution by technician staff and to the use of emergency buttons to stop the accelerator.

3 Regulatory Control of Practices Causing Exposure to Natural Radiation

3.1 Background

Under section 45 of the Radiation Act, whoever uses earth, rock or other raw materials existing in nature for industrial purposes is required to investigate the radiation exposure caused by this practice if it is found, or if there is reason to suspect, that the practice constitutes a radiation practice. The same applies to an employer if it is discovered, or if there is reason to suspect that the radiation exposure originating from natural radiation and occurring in the employer's working facilities or other workplace causes or is liable to cause a health hazard.

3.2 Radon

Radon at workplaces

The principal factor causing exposure to natural radiation at workplaces is indoor radon. STUK monitors radon in mines, excavation works and other underground workplaces and in other workplaces where there is a high concentration of radon. The action level for radon concentration in regular work is 400 $Bq \cdot m^{-3}$.

The responsible party is required to notify STUK of the results of radon measurements made at workplaces whenever the concentration exceeds the level of 400 $Bq \cdot m^{-3}$. During 2003, STUK was notified of a total of 220 track detector measurements and 64 measurements made during working hours using a continuously monitoring instrument. 133 of the measurements notified concerned the first occasion on which the radon concentration measured at a work area had exceeded the action level, and the rest concerned further investigations of previously measured excessive levels. 148 workplaces including a total of 276 work areas were monitored by STUK during the year.

A total of 136 inspection reports were sent to enterprises on the basis of radon measurements. These reports required reductions in radon concentrations or an investigation of radon concentration during working hours at 96 work areas, and a measurement at another time of year in order to determine an annual average at 24 work areas. Even though the radon concentration exceeded 400 $Bq \cdot m^{-3}$ at 28 work areas, no requirements were imposed, as annual working hours at these work areas were shorter than normal. Monitoring was discontinued at 21 work areas during the year due to successful radon reductions. Monitoring was discontinued for a total of 50 work areas on the basis of further investigations (measurement during working hours or determination of annual averages). Monitoring was discontinued at 36 work areas for other reasons (e.g. closure of the premises). Orders were issued to 49 workplaces on account of failure to take remedial measures or to perform investigations. One workplace was also ordered to keep records of working hours and perform regular radon measurements in order to monitor worker exposure. A total of 90 workplaces and 141 work areas were under control at the end of the year.

A radon inspection was conducted at two underground mines, at both of which the average radon concentration fell below the action level of 400 $Bq \cdot m^{-3}$. Four underground excavation sites were inspected, and the radon concentration action level was exceeded at one of these. Worker

exposure was monitored through regular radon measurements and recording of working hours until the radon concentrations had been reduced to less than the action level.

Approval of radon measuring instruments

The measuring instruments or methods used for establishing radon concentrations when determining worker exposure to radiation must be approved by STUK. It is a condition of such approval that the measuring instrument is properly calibrated. Table XVI shows a list of organizations (enterprises, corporations, institutions etc.) having instruments that are approved for determining worker exposure to radon and possess a current calibration. The Table includes the dates by which the instrument must be recalibrated in order for the approval to remain in force.

3.3 Other Natural Radiation from the Ground

STUK monitors the radioactivity of water intended for human consumption pursuant to Guide ST 12.3. The Guide applies to water distributed by water utilities for consumption by more than 50 people or 10 households. Inspection reports were prepared during 2003 on activity measurements made for a total of 21 water samples. Instructions were issued in three cases to reduce the concentration of radioactive substances in the water. The main reason for exceeding the concentration limits was radon in the water. A time limit of one year was set for remedial measures.

An inspection was conducted at one production plant to investigate whether workers were exposed to radiation when processing zirconium beads containing naturally occurring radioactive substances for use in milling. The exposure was found to be so slight that no special measures were considered necessary to limit or monitor exposure. A statement was also issued on the radioactivity of crushed red aggregate used for surfacing sports fields and the resulting radiation exposure.

3.4 Cosmic Radiation

Section 28 a of the Radiation Decree (Amendment 1143/1998) requires monitoring of radiation exposure and medical surveillance to be arranged for aircraft crews on the same principles as for those engaged in radiation work where the effective dose of crew members may exceed 1 mSv per year.

The exposure of aircraft crews to cosmic radiation has been monitored in Finland since 1992. The doses are estimated using a special computation program. The calculation is based on the flight routes and flying times of aircrews and on changes in the cosmic radiation dose rate at altitudes of 8–12 kilometres. The individual doses sustained by aircrews from cosmic radiation have been recorded in the Dose Register since 2001.

Individual radiation doses in 2003

The doses sustained by the staff of Finnair Oyj and Oy Air Finland Ltd were recorded in the Dose Register. The largest individual doses of cosmic radiation were 4.2 mSv sustained by a pilot and 4.7 mSv sustained by a cabin crew member. In no case did the individual dose sustained by a worker exceed the action level of 6 mSv. The average doses sustained were 1.5 mSv for pilots and 1.7 mSv for cabin crew. The number of workers subject to individual monitoring and their combined effective doses are shown in Table XVII, which also shows the corresponding figures for 2001 and 2002 to facilitate comparison. The figures for pilots and cabin crew are shown separately.

Table XVI. Organizations having instruments approved for determining worker exposure to radon.

Organization	**Instrument**	**Calibration valid until**	**Notes**
Gammadata Mätteknik i Uppsala AB/ Gammadata Finland Oy, Helsinki	Alpha track detector	1 Jul 2004	Alpha track detector can determine the average radon concentration over an extended period. The method is not suitable for determining variations in radon concentration over time. The method is also approved for radon measurements in homes.
• Etelä Karjala Polytechnic • City of Lahti • Turku Polytechnic • Tampere Polytechnic	• Pylon AB-5 • Pylon AB-5 • Pylon AB-5 • Pylon AB-5 and AlphaGuard	• 28 Oct 2004 • 18 Jul 2004 • 13 Jun 2004 • 23 Oct 2004 23 Oct 2004	Continuously monitoring instruments that can record variations in radon concentration over time. These instruments are suitable for measuring radon concentration during working hours.

Table XVII. Number of air craft crew members subject to individual monitoring and total effective dose of cosmic radiation in 2001–2003.

Year	**Number of workers**		**Total dose (Sv)**	
	Pilots	**Cabin crew**	**Pilots**	**Cabin crew**
2001	677	1751	1.14	3.03
2002	692	1799	1.07	2.93
2003	739	1746	1.09	3.02

4 Regulatory Control of the Use of Non-Ionizing Radiation

4.1 Background

The expression “non-ionizing radiation” refers to ultraviolet radiation, visible light, infrared radiation, radio-frequency radiation, and low-frequency and static electric and magnetic fields. STUK controls practices giving rise to non-ionizing radiation, even though this control is not directly comparable to regulatory control of the use of ionizing radiation. Regulatory control by STUK focuses particularly on areas involving safety risks that are not controlled by other public authorities.

Regulatory control of non-ionizing radiation by STUK is based on the Radiation Act and subordinate statutes.

4.2 Optical Radiation

Regulatory control of sunbeds and phototherapy appliances

A total of 31 sunbed facilities including 41 sunbeds were inspected. The inspections paid particular attention to ensuring that the intensity of UV radiation and user instructions of the appliances (including their recommended annual workload) complied with the Decree of the Ministry of Social Affairs and Health on the Limitation of Public Exposure to Non-Ionizing Radiation (294/2002), and that the responsible parties were familiar with the requirements of the said Decree restricting the use of sunbeds by persons under 18 years of age. The report “Radiation Safety Trends at Sunbed Facilities 1998–2002” prepared during the year is discussed in chapter 6 of this Annual Report.

Co-operation began with the Finnish Psoriasis Association to study ways of improving safety in the use of UVB phototherapy appliances hired out by the Association's member associations for home use by patients. It was also discovered that a few patient injuries had occurred each year at phototherapy units in both hospitals and the private sector due either to appliance defects or therapy accidents. The National Agency for Medicines had not been duly notified of the said appliance defects, however.

In May 2003, CENELEC (European Committee for Electrotechnical Standardization) approved, as an “A-dispensation” from the European Standard EN 60335-2-27, a maximum annual UV radiation dose for Finland concerning the use of sunbed appliances that comply with the foregoing Decree of the Ministry of Social Affairs and Health. In practice, this means one third of the value referred to in the said standard and corresponds to about 20 sunbed sessions per year.

Other regulatory control

One item of high power laser equipment for use in public performances was inspected.

A statement was issued on the radiation safety of a UV appliance used for hardening priming paint.

4.3 Electromagnetic Fields

Market control of mobile phones

A programme of market control for mobile phones on the market was initiated. The SAR values of twelve mobile phone models were measured according to the EN 50361 standard. The highest SAR value measured was 1.12 $W \cdot kg^{-1}$, which did not exceed the maximum value of 2 $W \cdot kg^{-1}$ prescribed by the foregoing Decree of the Ministry of Social Affairs and Health. The difference between the SAR values given by the manufacturer and those measured by STUK remained within the 30 per cent limit specified by the standard for ten of the models examined.

Control of MRI appliances

With respect to imaging of testees required in technical development of MRI appliances, it was found that the AMI centre of the Helsinki University of Technology and Philips Medical Systems must seek approval for imaging from the ethical commission. To ensure safety, the imaging must comply with the requirements stipulated in the standard EN 60601-2-33. Through guidance provided by STUK an adequate standard of imaging safety was secured.

Other regulatory control

Five inspections were conducted of radio and radar installations and mobile phone base stations for the purpose of on-site surveillance.

Statements were issued on the radiation safety of a radio mast project and on radiation exposure arising from a GSM base station.

4.4 Abnormal Incidents

The abnormal incident notification required by section 17 of the Radiation Decree also applies to abnormal incidents arising in the use of non-ionizing radiation (see item 2.1 above). STUK was notified of one abnormal incident involving the operation of a sunbed in 2003.

Incident 1

A customer sustained skin burns in a sunbed at a sports centre. Measurements indicated that the UV radiation dose rate of the sunbed exceeded the permitted limits. The supplier of the lamp had failed to notice that UV lamps procured from abroad were not of the type that had been ordered. The UV radiation output of the lamps was greater than intended.

STUK ordered replacement lamps to be fitted.

5 Regulation Work

5.1 ST Guides

To achieve the standard of safety that complies with the Radiation Act, STUK publishes Radiation Safety Guides (ST Guides) for responsible parties that use radiation or that engage in practices causing exposure to natural radiation.

The following guides were published in 2003:
ST 1.7 Radiation Protection Training in Health Care
ST 2.1 Quality Assurance for Radiotherapy
ST 6.3 Use of Radiation in Nuclear Medicine
ST 9.1 Radiation Safety Requirements and Regulatory Control of Tanning Appliances
ST 9.2 Radiation Safety of Pulsed Radars
ST 9.3 Radiation Safety during Work on Masts at FM and TV Stations
ST 12.2 Radioactivity of Construction Materials, Fuel Peat and Peat Ash.

Before publishing Guide ST 9.1 negotiations were conducted with the European Commission Enterprise Directorate regarding any obstacles to trade that the Guide might cause. As the specific, legally binding regulations were issued in the Decree of the Ministry of Social Affairs and Health (294/2002), it was found that Guide ST 9.1 imposes no obstacle to trade.

5.2 Other Regulation Work

On behalf of the Ministry of Social Affairs and Health, STUK participated in consideration by the Atomic Questions Group of the Council of the European Union of a Directive on the control of high activity sealed radioactive sources and orphan sources. The Directive took effect on 31 December 2003.

The NIR Laboratory assisted the Ministry of Social Affairs and Health in preparing an occupational safety Directive on electromagnetic fields. Amendments were achieved in the Directive enabling the application of an unweighted peak value method developed at STUK for assessing radiation exposure caused by broadband electric and magnetic fields.

6 Research

The aim of research work conducted by STUK is to provide information that will improve expertise, support regulatory activities and enhance preparedness to respond to nuclear and radiological emergencies.

6.1 Ionizing Radiation

The DIMOND project

The DIMOND project is a project on digital radiography, radiological procedures and dosimetry financed by the European Union. It seeks to study and develop clinical, technical and physical quality criteria and parameters for X-ray examinations, determination of patient doses, establishment of examination-specific reference dose levels, and special issues in interventional radiology and mammography.

The final reports of the patient dosimetry work packages and the mathematical X-ray image analysis work package were completed on schedule in 2003. The DIMOND findings will be considered and utilized in other current and future research projects (quality assurance in digital imaging, dose determination in paediatric examinations, calibration of DAP meters). The research findings and their use were reported in publications and lectures.

Calculation of patient doses in X-ray examinations

A program for reckoning patient doses in X-ray examinations (surface dose) was completed and may be purchased via the website of STUK (www.stuk.fi). Two publications were also made on the subject.

Ensuring the accuracy of dose planning systems for brachytherapy

Methods necessary for ensuring the accuracy of dose planning in brachytherapy were designed and tested. Methodological guidelines suitable for ensuring the accuracy of dose planning programs were produced for the internal quality guidelines of STO, and were introduced in brachytherapy inspections.The guidelines are mainly based on the TRS 398 and TECDOC-1079 guidelines of the IAEA.

Improved optimization in the use of CT appliances

The number of computerized tomography (CT) examinations has risen continually and new areas of use have been discovered for this technique as the appliance technology has developed. Even though CT scans constitute only 5 per cent of all X-ray examinations, they give rise to about 40 per cent of the total X-ray dose administered to patients for diagnostic purposes. The quality criteria and reference levels issued by the European Union are partially out of date, and optimization in the use of new multi-slice appliances in respect of image quality and dose has often placed too much emphasis on good image quality. The aims of the research project of STUK are:

- to prepare recommendations for improving optimization
- to update the reference levels for CT scans and to issue such levels also for paediatric examinations
- to develop a suitable routine method for inspections

- to update the CT scan quality assurance guide (a new guide will be published in edition no. 1/2004 of STUK bulletin series).

BNCT dosimetry

A BNCT research project that began in 1998 and was partially funded by the European Union came to an end in 2003. A European recommendation was prepared for BNCT dosimetry during the year, and was submitted to the European Union in September 2003. The recommendation was published as a project co-ordinator's report (ECN, the Netherlands) in January 2004. After a further statement on the report has been requested from the project's external experts, it will be finalized and published as a European recommendation in 2004.

Master's thesis work

Work began in 2003 on three master's theses in STO. The results of these theses may be utilized in the activities of STUK or will help to improve radiation safety in Finland.

Quality assurance in digital imaging

The aims of the work are:

- to prepare a summary of the principles that may be applied to quality control for various types of digital imaging appliances
- to investigate any recommendations that may be issued for quality control of digital X-ray imaging systems.

Reference levels for paediatric X-ray examinations

The aim of the work is to study the basis for establishing patient dose reference levels for paediatric X-ray examinations.

Calibration and measurement methods for DAP meters

The aims of the work are:

- to produce a guide for STUK and radiation users on a calibration procedure for DAP meters (instruments measuring the product of dose and surface area) used in X-ray diagnostics
- to produce a methodology and operating format for arranging calibration of DAP meters as a service function of the Radiation Metrology Laboratory (DOS Laboratory) of STO.

6.2 Non-Ionizing Radiation

Most of the research and development work on non-ionizing radiation was done in the course of the jointly financed research projects set out below.

Development of irradiation systems for research (CEMFEC)

The effects of mobile phone radiation on rats was studied at the University of Kuopio using exposure equipment developed by STUK. Dosimetric quality control of exposures was implemented as planned (calibration of intensity meters and measurements of the stability of the radiotechnical properties of exposure chambers). A draft of the final report was prepared.

Health risk evaluation of wireless communications (LaVita)

The main objective was to verify the dosimetry of the "vertical chamber" used in cell research at STUK and to investigate its thermal properties. It was found that the chamber and bowls could not be modelled with sufficient accuracy to verify an absolute SAR level by calculation based on measurements. Instead, it is possible to calculate a relative SAR distribution. The temperature distribution of the bowls was studied using a home-made two-dimensional thermodynamic MATLAB model based on an energy equilibrium method.

Research into methods of determining exposure arising from mobile phones (AMEST)

A calculation algorithm based on a Finite Integration Technique (FIT) was developed for determining magnetic field exposure arising from mobile phone battery currents. This algorithm was used to calculate the current density induced by magnetic fields in a realistic numerical model simulating the human head. The source data required for the calculation were obtained by measuring the magnetic field distribution in the vicinity of the mobile phone using a small

measurement probe developed for this purpose. Work began to prepare a scientific article for publication. As far as we know, this is the first time that the FIT method has been applied in magnetic field exposure dosimetry calculations at frequencies of less than 100 kHz.

Development of practical methods of quality assurance for UV phototherapy appliances (UV therapy)

An effective solution was achieved for spectral measurements of UV phototherapy and tanning appliances in the field, whereby the accuracy of a commercial CCD spectroradiometer is improved by filtering, accurate calibration and radiometric adjustments. The first draft of a scientific article documenting the method was completed.

Radiation measurements were performed on UV phototherapy and sunbed lamps (31 models) and the results were analysed. A quality control guide for phototherapy appliances was completed.

Other research activities

Besides jointly financed research projects of non-ionizing radiation, research and technical development work also continued as part of the basic activities of the NIR Laboratory.

A meter for broadband magnetic fields

A new type of broadband magnetic field meter was developed for measuring low frequency magnetic fields. This enables measurement of peak magnetic field values weighted according to exposure limits in the manner stipulated in the Decree of the Ministry of Social Affairs and Health (294/2002). In the course of the year, a circuit board was designed for the meter and the second working prototype was constructed in the Laboratory. Design work began on a third working prototype for field work. Negotiations began to commercialize the meter and to construct a small prototype series of 5–10 appliances.

Radiation Safety Trends at Sunbed Facilities 1998–2002

Research information tracking the development of radiation safety at sunbed facilities was gathered on the basis of STUK inspections and reports submitted by municipal health authorities. A report of this research was prepared, but its publication was deferred until 2004.

Deficiencies affecting safety in the use of sunbeds were found at almost all facilities. However, the situation has improved over the last 3–4 years with increased control by STUK and municipal health authorities. It is estimated that the intensity of UV radiation exceeds the limits prescribed in the Decree of the Ministry of Social Affairs and Health in just under 10 per cent of tanning appliances. Spot checks conducted during 2003 (at 31 facilities) revealed that one reason for the use of excessively powerful lamps was incorrect information supplied by one appliance manufacturer regarding the UV intensities of certain appliances. In 2002, only one appliance in ten lacked written operator instructions and the timer required by the regulations, but it was noted in the 2003 spot checks that three appliances in ten had no operator instructions at all and no timer for selecting recommended irradiation times. Two out of three appliances in 2002 and 2003 had an exposure schedule for the guidance of sunbed clientele, while a couple of years ago such schedules had been available for only one appliance in three.

7 International Co-operation

International conferences arranged by STUK

STUK arranged the following international conferences on the regulatory control of the use of radiation and metrological activities for ionizing radiation:

Symposium on clinical auditing

To promote international exchanges of experience in clinical auditing and receipt of feedback, the Ministry of Social Affairs and Health, STUK and Qualisan Oy (a company that performs audits in Finland), together with some professional organizations operating in the sector and with the support of the European Commission, arranged an international symposium on the implementation of clinical auditing on 24–27 May 2003 in Tampere.

The symposium provided a good picture of the current situation in respect of the implementation of clinical auditing and problem areas. It also revealed that there is no established or uniform concept, significance or content to clinical auditing, nor any practical implementation format in the Member States of the European Union. Plans have been drawn up in several Member States, but their practical implementation is obstructed by a lack of clear instructions, operating formats and financing arrangements.

The symposium also indicated that the ten-point list of evaluation criteria adopted in Finland and incorporated into the Decree of the Ministry of Social Affairs and Health on the Medical Use of Radiation (423/2000) conforms to the correct trend in optimal development of clinical auditing. The timetables and practical implementation formats imposed in Finland are influential in internal comparisons within the European Union, representing a very thoroughgoing policy and attracting both interest and respect.

Meeting of the ESTRO EQUAL working group

A meeting of an ESTRO (European Society for Therapeutic Radiology and Oncology) working group (EQUAL group), promoting and maintaining radiotherapy dosimetry auditing activities, was arranged in Tampere to coincide with the international symposium on clinical auditing.

The meeting took the view that dosimetry auditing should be part of clinical radiotherapy auditing. EQUAL has audited photon and electron beam dose measurements from a large number of European radiotherapy centres using thermoluminescent dosemeters sent by post, and has also developed this procedure for conformal radiotherapy and brachytherapy. ESTRO audits have been used in Finland as reference material for verification measurements in the activities of public authorities.

Meeting of EUROMET ionizing radiation liaison officers

As part of its metrological activities for ionizing radiation, STUK arranged and hosted a meeting of ionizing radiation liaison officers of the EUROMET (European Collaboration on Measurement Standards) on 6–7 November 2003.

Meeting of the IEC TC 61/MT 16 standardization working group

On 3–5 June 2003, STUK arranged and hosted a meeting of the IEC (International Electrotechnical Commission) standardization working group TC 61/MT 16 on radiation safety standardization of sunbeds.

Participation in meetings of international working groups

During 2003, representatives of STUK took part in meetings of the following international organizations and working groups:

- The expert working group referred to in Article 31 of the EURATOM treaty. This group focused on the radioactivity of consumer goods. The group held two meetings at which reports under preparation were discussed.
- Radiation Safety Standards Committee (RASSC) of the IAEA. The Committee held two meetings at which several radiation protection regulations and instructions under preparation were discussed.
- Nordic working group on sealed sources. This working group held its first meeting in Copenhagen on 2 October 2003.
- Nordic dosimetry working group. This working group held a meeting in Stockholm on 29–30 September 2003. The working group discussed current areas of concern for dosimetry in radiotherapy and X-ray diagnostics.
- Nordic X-ray diagnostics working group. This working group held its annual meeting in Copenhagen on 22–23 May 2003.
- ESTRO physics committee. This committee held its annual meeting in Geneva on 15 September 2003.

Participation in other international conferences

Representatives of STO and the NIR Laboratory took part in several international conferences and congresses in the field of radiation safety and gave presentations and lectures at these events (organizers included e.g. IAEA, ESTRO, EUROMET and CIPM).

Foreign visitors to STUK

STUK hosted a visit from a representative of the Swedish Radiation Protection Authority (SSI). This visit was part of calibration methods development work at the DOS Laboratory on dose-area-product meters for X-ray diagnostics.

Other international co-operation

STUK took part in two PHARE projects involving assistance to public authorities in Romania and Slovenia in developing statutes on the regulatory control of the use of radiation in accordance with the European Union Basic Safety Standards. STUK also took part in the European Union Twinning project with a view to achieving the European Union standard of radiation protection in Lithuania and reinforcing the capacities of the Radiation Protection Centre of Lithuania (RSC).

A specialist from STUK took part in inspections of a radiotherapy clinic in Minsk, Belarus, as an expert appointed by the IAEA.

Representatives of STO and the NIR Laboratory are involved in several international organizations, commissions and expert groups dealing with regulatory control and research in the use of ionizing and non-ionizing radiation and with standardizing activities in the field of radiation (IAEA, NACP, EURADOS, EUROMET, ESTRO, ICRU, NEA, AAPM, NOG, IEC, ISO, CEN, CENELEC, ICNIRP).

8 Co-operation in Finland

Finnish conferences arranged by STUK

Two annual or biennial jointly funded events arranged in 2003 were the conference of nuclear medicine specialists in Tampere on 30–31 October 2003, and the conference of radiotherapy physicists at Siilinjärvi on 5–6 June 2003.

The annual Radiation Safety Conference was arranged jointly with the Radiological Society of Finland on 16–17 October 2003 in Tampere. Several lectures were given in a radiation protection course arranged for the Conference.

On 22–24 October 2003, STUK arranged an Industrial Radiation Safety Conference for about 100 radiation safety officers working in industry, research and education.

Participation in meetings of Finnish working groups

Representatives of STUK took part in the following meetings of Finnish organizations:

- The National Board for Metrology and its measurement services and calibration subcommittees. Each subcommittee held two meetings.
- The SK 106 and SK 61 standardization committees for radiation safety of electromagnetic fields and domestic electrical appliances. Each committee held two meetings at which the corresponding standards proposals of the IEC and CENELEC were discussed. Comments were made on six standards proposals and opinions were issued on seven proposals in the final vote.

Participation in other Finnish conferences

Representatives of STO and the NIR Laboratory took part in several Finnish conferences in the field of radiation safety and gave presentations and lectures at these events.

Other co-operation in Finland

A quality system description of metrological activities of the DOS Laboratory was prepared for external assessment in association with the Centre for Metrology and Accreditation (MIKES) (see chapter 10).

A working group appointed by the National Research and Development Centre for Welfare and Health (Stakes), which also includes representatives of the Finnish Cancer Registry and STUK, prepared a Stakes guide on recording the data gathered from mammography screenings and notifying the said data to public registers. This guide replaces the instruction of the National Board of Health (7/1990) on registration of mass examinations with respect to mammography screenings. The working group completed its proposal for a guide, but this has yet to be approved for use.

The establishment of a national clinical auditing monitoring group independent of auditing organizations was prepared in association with the Ministry of Social Affairs and Health. The group will seek to co-ordinate and develop auditing operations and to evaluate auditing programmes. The group was established in March 2004.

Guidance for three master's theses began in 2003. The subjects of these theses are quality assurance in digital imaging, reference levels in paediatric X-ray examination, and DAP meter calibration and measurement methods (for further details see item 6.1).

Representatives of STO and the NIR Laboratory are involved in several Finnish commissions and expert groups dealing with regulatory control and research in the use of ionizing and non-ionizing radiation and with standardizing activities in the field of radiation (including the National Board for Metrology, the Radiation Safety Conference committee, Eurolab-Finland, SESKO).

9 Information Activities

Books, bulletins and reviews

STUK publishes the Radiation and Nuclear Safety book series including a total of seven books. The situation with respect to books edited at STO and the NIR Laboratory in 2003 was as follows:

- The text of the "Use of Radiation" book (no. 3 in the book series) was completed. Work on the finished illustrations and layout is due to begin in spring 2004.
- Approximately 90 per cent of the manuscript was completed for the "Non-ionizing Radiation – Electromagnetic Fields" book (no. 6 in the book series). The book is expected to be ready for editing in March–April 2004.
- Writing work began on the "Non-ionizing Radiation – Ultraviolet and Laser Radiation" book (no. 7 in the book series).

A review dealing with mobile phones and base stations was published in the radiation and nuclear safety leaflet series of STUK (March 2003). Due to high demand, a second printing of this leaflet was prepared and some minor errors detected in the first printing were rectified.

The following bulletins were published or prepared in the bulletin series of STUK:

- Magnetic field measurements in buildings (1/2003)
- Transportation of radioactive substances (2/2003)
- Determination of patient radiation exposure in X-ray examinations. Publication of this bulletin was deferred until 2004.

Public information on current affairs

The radiation arising from mobile phones and base stations continued to be a topic of considerable public interest. A press conference was arranged on this subject coinciding with the introduction of mobile phone market control in spring 2003, and the first test results were released at the end of the year. The mobile phone information provided on the website of STUK was also brought up to date.

STUK continued publishing the UV radiation index on its website, and has done so since the year 2000. The required measurement data are continuously gathered between April and September by a UV radiation meter installed on the roof of STUK building at Roihupelto in Helsinki.

Press releases were prepared on the following subjects:

- Trade in radioactive substances
- The requirements of regulatory control for high activity sealed sources being prepared in the European Union
- Publication of an ST Guide on the radioactivity of construction materials and ash.

Other information activities:

- Information on radiation protection, on new regulations, and on the background thereto was actively disseminated to responsible parties and radiation users at conferences, seminars and training events.
- Media interviews were given on questions of exposure to ionizing and non-ionizing radiation.
- Guidance on radiation protection problems was provided in the form of both telephone and Internet-based services to private individuals, enterprises and the public sector.
- Press articles and other written contributions were prepared.
- Articles were written for the ALARA magazine published by STUK.

Educational lectures

The Director of the NIR Laboratory gave a course of lectures at the Helsinki University of Technology on the subject "Biological effects and measurements of electromagnetic fields and optical radiation" (course equivalent to 2 study credits). The booklet "Principles of Radiometry" forming part of the written material of the course was updated.

10 Metrology

The aim of metrological activities is to ensure adequate accuracy and international comparability in radiation measurements.

STUK has a duty under section 23 of the Radiation Act (Amendment 1334/1994) to maintain the metrological standards necessary to ensure reliable radiation measurements.

International approval of the DOS Laboratory quality system

When joining the international Mutual Recognition Agreement (MRA) in 2003 the Radiation Metrology Laboratory (DOS Laboratory) of STO formulated its quality system for national metrological activities according to the standard ISO 17025 and submitted it to quality assessors at the EUROMET (European Collaboration on Measurement Standards). The quality system covered the metrological activities for dose quantities of ionizing radiation. The quality assessors accepted that the quality system complied with the requirements of the MRA agreement. As is customary for Finland's national metrological standards laboratories, the reliability and operational validity of the DOS Laboratory quality system are based on the "self declaration" principle and not on accreditation.

Development work on DOS Laboratory measurement and irradiation equipment and methods

A calibration and dose measurement method for radiotherapy meters based on the absorbed dose to water was introduced for measuring high-energy gamma radiation in Finland. The DOS Laboratory calibrated the reference instruments of all hospitals in accordance with the new method. In accordance with the IAEA guidelines, the calibration certificates also included the derived calibration factors for the radiation qualities produced by hospital accelerators.

A project was launched in the DOS Laboratory to develop calibration and measurement methods for dose-area-product meters (DAP meters) in X-ray diagnostics. A dose-area-product meter suitable for use as a metrological standard was procured for the Laboratory, the calibration of which could be traced directly to a primary laboratory (PTB, Physikalisch-Technische Bundesanstalt, Germany) as a DAP quantity. The laboratory also recruited a student for the DAP project to serve as an assistant researcher initiating the Laboratory calibrations and associated methodological testing (see item 6.1). The development and implementation of the DAP method was also agreed at the Nordic dosimetry working group.

Work continued to improve the mechanical operation and radiation safety of the irradiation appliance used for producing ^{137}Cs and ^{60}Co gamma ray beams in radiation protection calibrations. To renew both the mechanical and electrical components of the source moving mechanism of the appliance, a description of a new mechanism was made and the necessary components were procured. The radiation shielding of the highly active ^{60}Co gamma irradiation appliance was improved to ensure safe working practices.

Specification of radiation quality parameters of the X-ray beams used in calibration continued. The radiation quality parameters used in radiation protection calibrations were specified in accordance with radiation quality standards.

The X-ray appliance used in the DOS Laboratory for diagnostic research broke down several times and had to be serviced frequently. Steps were taken to begin procurement of a new appliance.

Meter and measurement comparisons at the DOS Laboratory

The results of the EA (European Co-operation for Accreditation) IR3 survey meter calibration comparison performed in 2001 were received in September 2003. STUK result for ^{137}Cs gamma radiation differed from the reference value by less than 1.3 per cent and the corresponding deviation for ^{60}Co gamma radiation was less than 0.8 per cent. Both results were within the notified uncertainties. The deviations divided by the measurement uncertainty were between -0.32 and 0.22 (the approval limit of the EA is below 1.0).

STUK participated in the annual IAEA TLD comparison for ^{60}Co gamma radiation. The difference between the IAEA and STUK measurements was 0.2 per cent, which is within the action level (3.5 per cent) for comparisons.

Development work on NIR Laboratory measurement and irradiation equipment and methods

A transfer standard in the 900 MHz and 1800 MHz frequency bands based on a miniature RIPA waveguide filled with tissue-equivalent liquid was developed for calibrations of SAR measurement probes to be performed in SAR testing laboratories outside STUK. Work was began to prepare a scientific article for publication.

To calibrate the antennae used in measurements of base stations for mobile phones, new waveguide calibration standards were developed for 900 MHz and 1800 MHz frequencies. The calibration will be transferred to an open radio-frequency field in an anechoic chamber by using small electric field probes.

Negotiations were began with the Dutch company Kipp & Zone to commercialize a detector-monitored lamp standard developed for field calibrations of solar UV radiometers.

11 Services

Calibration, testing and irradiation

The DOS Laboratory performed radiation meter calibrations on request. 100 radiation meter calibration certificates and 30 irradiation certificates were issued. About one third of these calibrations and irradiations were performed for measuring instruments and samples of STUK itself.

The NIR Laboratory performed a total of 23 radiation meter calibrations and tests and 11 safety assessments and radiation measurements.

During the year, STUK conducted a customer satisfaction survey for users of its standard services. The general customer approval rating for the calibration, testing and irradiation services of the DOS Laboratory was 8.9 on a scale of 4 to 10. The customers were satisfied with the reliability of services and least satisfied, in the main, with the price of services.

Training services

STO arranged its annual training conference on radiation safety and quality in X-ray examinations on 3–4 April 2004.

In association with Kuopio University Hospital, STO organized a course on dosimetry in CT scanning in Kuopio on 6 November 2003.

The DOS Laboratory took part in radiation protection training for Baltic customs officials hosted by STUK on 28–30 October 2003 by organizing and directing the practical radiation measurement exercises and demonstrations that formed part of the training.

APPENDIX 1 Publications in 2003

The following publications completed in 2003 were authored by one or more employees of STO or the NIR Laboratory:

International publications

Hakanen A, Järvinen H, Soimakallio S. Trends in radiology in Finland between 1995 and 2000. European Radiology 2003; 13 (12): 2705–2709.

Neofotistou V, Vano E, Padovani R, Kotre J, Dowling A, Toivonen M, Kottou S, Tsapaki V, Willis S, Bernardi G, Faulkner K. Preliminary reference levels in interventional cardiology. European Radiology 2003; 13 (10): 2259–2263.

Koivunoro H, Auterinen I, Kosunen A, Kotiluoto P, Seppälä T, Savolainen S. Computational study of the required dimensions for standard sized phantoms in boron neutron capture therapy dosimetry. Phys. Med. Biol. 2003; 48: N291–N300.

Pöllänen R, Ikäheimonen TK, Klemola S, Vartti VP, Vesterbacka K, Ristonmaa S, Honkamaa T, Sipilä P, Jokelainen I, Kosunen A, Zilliacus R, Kettunen M, Hokkanen M. Characterisation of projectiles composed of depleted uranium. Journal of Environmental Radioactivity 2003; 64: 133–142.

Kärhä P, Ylianttila L, Koskela T, Jokela K, Ikonen E. A portable field calibrator for solar ultraviolet measurements. Metrologia 2003; 40: S17–S20.

Ylianttila L, Jokela K, Kärhä P. Ageing of DXW-lamps. Metrologia 2003; 40: S120–S123.

Heikkinen P, Kosma V-M, Alhonen L, Huuskonen H, Komulainen H, Kumlin T, Laitinen JT, Lang S, Puranen L, and Juutilainen J. Effects of mobile phone radiation on UV-induced skin tumourigenesis in ornithine decarboxylase transgenic and non-transgenic mice. Int. J. Radiat. Biol. 2003; 79(4): 221–233.

Conference papers and lectures at conferences

International

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Järvinen H. Clinical audit versus regulatory control. Proceedings of the International Symposium on Practical Implementation of Clinical Audit for Exposure to Radiation in Medical Practices, Tampere, Finland, 24–27 May 2003: 26–30.

Mäkeläinen I, Venelampi E, Vesterbacka P. Monitoring of radioactivity in Finnish drinking water. In: Korhonen LK, Miettinen IT, Slobodnik J, van der Hoven T (eds.). WEKNOW. Web-based European Knowledge Network on Water. Publications of the National Public Health Institute B22/2003. Proceedings of the 1st WEKNOW Annual Drinking Water Conference in Europe, Kuo-pio, Finland. Helsinki: National Public Health Institute; 2003.

Waltenburg HN, Gron P, Leitz W, Servomaa A, Einarsson G, Olerud H. Nordic working group on x-ray diagnostics – practical implementation of the directive on medical exposures in the Nordic EU countries. In: Paile W (ed.). Radiation Protection in the 2000s – Theory and Practice. Nordic Society for Radiation Protection. Proceedings of the XIII ordinary meeting. 25–29 August 2002, Turku/Åbo, Finland. STUK-A195. Helsinki: Radiation and Nuclear Safety Authority; 2003. p. 250–255.

Leitz W, Gron P, Servomaa A, Einarsson G, Olerud H. Nordic working group on x-ray diagnostics: Diagnostic reference levels within x-ray diagnostics – experiences in the Nordic countries. In: Paile W (ed.). Radiation Protection in the 2000s – Theory and Practice. Nordic Society for Radiation Protection. Proceedings of the XIII ordinary meeting. 25–29 August 2002, Turku/Åbo, Finland. STUK-A195. Helsinki: Radiation and Nuclear Safety Authority; 2003. p. 256–261.

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Kepler K, Lintrop M, Servomaa A, Filippova I, Parviainen T, Eek V. Radiation dose measurement of paediatric patients in Estonia. In: Paile W (ed.). Radiation Protection in the 2000s – Theory and Practice. Nordic Society for Radiation Protection. Proceedings of the XIII ordinary meeting. 25–29 August 2002, Turku/Åbo, Finland. STUK-A195. Helsinki: Radiation and Nuclear Safety Authority; 2003. p. 287–292.

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Servomaa A, Komppa T, Parviainen T, Heikkilä M. Dose-area product and entrance surface dose in paediatric radiography. In: Paile W (ed.). Radiation Protection in the 2000s – Theory and Practice. Nordic Society for Radiation Protection. Proceedings of the XIII ordinary meeting. 25–29 August 2002, Turku/Åbo, Finland. STUK-A195. Helsinki: Radiation and Nuclear Safety Authority; 2003. p. 309–315.

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APPENDIX 2 ST Guides published by STUK. Situation as of 31 December 2003.

General Guides

ST 1.1 Radiation Practices and Regulatory Control, 20 June 1996
ST 1.3 Warning Signs for Radiation Sources, 10 November 1999
ST 1.4 Organization for the Use of Radiation, 24 October 1991
ST 1.5 Exemption of the Use of Radiation from the Safety Licence and Reporting Obligation, 1 July 1999
ST 1.6 Operational Radiation Protection, 29 December 1999
ST 1.7 Radiation Protection Training in Health Care, 17 February 2003

Radiation Therapy

ST 2.1 Quality Assurance for Radiotherapy, 22 May 2003 (in Finnish)
ST 2.2 Radiation Safety of Radiotherapy Equipment and Treatment Rooms, 2 February 2001.

Diagnostic Radiology

ST 3.1 Use and Regulatory Control of Dental X-ray Installations, 27 May 1999
ST 3.2 Mammography Equipment and their Use, 13 August 2001
ST 3.3 Diagnostic X-ray Equipment and Its Use, 27 August 1992
ST 3.4 Quality Control of Image Intensifier - Television Chains, 24 October 1991
ST 3.5 Quality Control of Diagnostic X-ray Equipment and Film Processing, 3 December 1991
ST 3.6 Radiation safety in X-ray facilities, 24 September 2001.
ST 3.7 Breast Cancer Screening Based on Mammography, 28 March 2001

Industry, Research, Education and Commerce

ST 5.1 Radiation Safety of Sealed Sources and Equipment Containing Them, 17 February 1999
ST 5.3 Use of Ionizing Radiation in the Teaching of Physics and Chemistry, 17 February 1999
ST 5.4 Trade in Radiation Sources, 2 October 2000
ST 5.6 Radiation Safety in Industrial Radiography, 17 February 1999
ST 5.8 Installation, Repair and Servicing of Radiation Appliances, 17 February 1999

Unsealed Sources and Radioactive Wastes

ST 6.1 Radiation Safety Requirements for Radionuclide Laboratories, 1 July 1999
ST 6.2 Radioactive Wastes and Discharges, 1 July 1999
ST 6.3 Use of Radiation in Nuclear Medicine, 18 March 2003 (in Finnish)

Radiation Doses and Health Surveillance

ST 7.1 Monitoring of Radiation Exposure, 25 February 2000
ST 7.2 Application of Maximum Values for Radiation Exposure and Principles for the Calculation of Radiation Dose, 1 July 1999
ST 7.3 Calculation of the Dose Caused by Internal Radiation, 1 July 1999
ST 7.4 Registration of Radiation Doses, 25 February 2000
ST 7.5 Medical Surveillance of Occupationally Exposed Workers, 29 December 1999 (in Finnish)

Non-Ionizing Radiation

ST 9.1 Radiation Safety Requirements and Regulatory Control of Tanning Appliances 1.12.2003 (in Finnish)
ST 9.2 Radiation Safety of Pulsed Radars, 2 September 2003 (in Finnish)
ST 9.3 Radiation Safety during Work on Masts at FM and TV Stations, 2 September 2003 (in Finnish)
ST 9.4 Radiation Safety of High Power Display Lasers, 8 October 1993 (in Finnish)

Natural Radiation

ST 12.1 Radiation Safety in Practices Causing Exposure to Natural Radiation, 6 April 2000 (in Finnish)
ST 12.2 Radioactivity of Construction Materials and Ash, 8 October 2003 (in Finnish)
ST 12.3 Radioactivity of Household Water, 9 August 1993

APPENDIX 3 Training organizations approved for organizing radiation safety officer competence exams. Situation as of 31 December 2003.

Date of approval	Organization	Field of competence
Use of radiation in health care		
5 May 1997	University of Helsinki Faculty of Veterinary Medicine	Veterinary X-ray activities
29 Feb 1996	University of Helsinki, Physics Department	General use of radiation
15 Apr 1993	University of Helsinki, Department of Diagnostic Radiology	X-ray examinations and use of radioactive substances (exam of specialist in radiology)
10 May 1993	University of Kuopio, Department of Clinical Radiology	X-ray examinations and use of radioactive substances (exam of specialist in radiology)
6 Oct 1992	University of Kuopio, Training and Development Centre	Use of radiation (not general use)
20 Dec 1991	University of Oulu, Faculty of Medicine	X-ray examinations and use of radioactive substances
27 May 1993	University of Oulu, Faculty of Medicine	X-ray examinations and use of radioactive substances (exam of specialist in radiology)
20 Dec 1991	Educational and Training Board in Medical Physics	General use of radiation.
3 Mar 1992	Board of Qualification for Hospital Chemists	Use of radioactive substances
29 Feb 1996	Tampere Technical University, Ragnar Granit Institute	General use of radiation.
17 Aug 1993	University of Tampere, Faculty of Medicine	X-ray examinations and use of radioactive substances (exam of specialist in radiology)
26 Jan 1994	University of Turku, Faculty of Medicine	X-ray examinations and use of radioactive substances
8 Jun 1993	University of Turku, Faculty of Medicine	X-ray examinations and use of radioactive substances (exam of specialist in radiology)

Date of approval	Organization	Field of competence
Use of radiation in industry, research and education, and trade in and servicing of radiation sources		
20 Dec 1991	AEL, Center for Technical Training, NDT Technics	Industrial radiography (including operator in charge)
6 Apr 1993	Stadia, Helsinki Polytechnic, Technology and Transport	Trade in and servicing of radiation sources
29 May 2002	Stadia, Helsinki Polytechnic, Technology and Transport	Use of X-rays and sealed sources in industry and research (not industrial radiography)
3 Apr 1992	University of Helsinki, Department of Physics	General use of radiation, use of unsealed sources, use of X-radiation, (not industrial radiography), use of radiation in educational demonstrations and trade in radiation sources
26 Jan 1994	University of Helsinki Lahti Research and Continuing Education Centre, Palmenia	General use of radiation and trade in radiation sources
8 Apr 1992	University of Helsinki, Faculty of Forestry and Agriculture, Instrument Centre	Use of sealed and unsealed sources
3 Apr 1992	University of Helsinki, Department of Radiochemistry	Use of sealed and unsealed sources
26 Aug 1992	Jyväskylä Polytechnic Technology and Transport	Industrial radiography, use of sealed and unsealed sources, and trade in and servicing of radiation sources
31 Jan 1995	University of Jyväskylä, Department of Physics	Trade in radiation sources, use of radiation sources in industry, research and education
6 Oct 1992	University of Kuopio, Training and Development Centre	Use of radiation (not general use) and trade in and servicing of radiation sources
12 Mar 1992	Lappeenranta University of Technology	General use of radiation, use of X-rays, use of sealed and unsealed sources
4 Aug 1994	University of Oulu, Department of Physics	Trade in radiation sources, use of radiation sources in industry, research and education
4 May 1992	University of Oulu, Department of Biochemistry	Use of sealed and unsealed sources
15 May 1992	Northern Savo Nursing Care District	Trade in and servicing of radiation sources
21 Jan 1992	POHTO, Institute of Management and Technological Training	Use of X-rays and sealed sources (not industrial radiography)
18 May 1992	Satakunta Polytechnic	Use of X-rays, industrial radiography, use of sealed sources and trade in radiation sources
21 Jan 1992	SPEK, Finnish National Rescue Association	Installation and servicing of fire detection appliances
14 Feb 1992	Tampere Polytechnic, Technology and Transport Sector	Use of X-rays and sealed sources (not industrial radiography)
3 Aug 1992	Turku Polytechnic, Technology and Transport	General use of radiation, industrial radiography, use of X-rays, use of sealed sources, and trade in and servicing of radiation sources
3 Aug 1992	University of Turku, Department of Physics	General use of radiation, industrial radiography, use of X-rays, use of sealed sources, and trade in radiation sources.