



IAEA DOSIMETRY AND MEDICAL RADIATION PHYSICS SUBPROGRAMME REPORT ON ACTIVITIES, 1999–2000

A Meghzifene, J Izewska, F Pernicka, H Tölli, S Vatnitsky, P Bera, L Czap, R Girzikowsky and P Andreo*

Dosimetry and Medical Radiation Physics Section, Division of Human Health, Department of Nuclear Sciences and Applications

International Atomic Energy Agency (IAEA), Vienna.

Introduction

The IAEA Subprogramme on Dosimetry and Medical Radiation Physics (DMRP) contributes to improvement of the quality of radiation measurements by providing traceability through dissemination of standards for radiation measurements, conducting dose quality audits and intercomparisons, developing and disseminating dosimetry techniques, assisting Member States in designing and implementing national Quality Assurance (QA) programmes, and organizing education programmes and training courses for staff and hospital physicists at Secondary Standard Dosimetry Laboratories (SSDLs). In addition, technical support is provided to IAEA Technical Co-operation projects.

Projects in the Subprogramme

During the period 1999-2000 the Subprogramme was divided into four projects:

- **Secondary Standard Dosimetry Laboratory (SSDL) Network** (IAEA Project E3.01).

To operate the network of SSDLs in order to achieve international consistency of radiation measurements in Member States according to the performance levels of the International Measurement System. To develop and transfer dosimetry standards for radiation measurements to the SSDLs. To extend the activities of SSDLs to quality assurance programmes in medical radiation physics. To provide intercomparison services to help the SSDLs to check their dosimetry system.

- **Dose Intercomparison and Assurance** (IAEA Project E3.02).

To provide mailed dosimetry services to medical centres in Member States in order to verify the dosimetry of radiation sources used in therapy and diagnostic procedures. To provide an International Dose Assurance Service for radiation processing facilities.

- **Transfer of Dosimetry Techniques** (IAEA Project E3.03).

To develop standard dosimetry procedures and techniques for Medical Radiation Physics and Radiation Processing in Member States. To maintain consistency in dosimetry techniques and disseminate new methods for radiation measurement through Co-ordinated Research Projects (CRPs), publications, databases, and meetings.

- **Technical Co-operation (TC) Projects** (IAEA Project E3.04).

To provide Member States with scientific and technical support for the IAEA's TC projects and training courses on dosimetry and medical radiation physics.

* P. Andreo, former Head of the Dosimetry and Medical Radiation Physics Section, left the IAEA in November 2000. The activities reported on this document were carried out under his supervision. This is duly acknowledged by including his name as a co-author.

A standing Scientific Committee established by the Directors General of the IAEA and WHO reviews and evaluates the work of the Dosimetry and Medical Radiation Physics Section and advises the Director General on the strategies of the Dosimetry Subprogramme of the IAEA that will meet the needs of the Member States. The 9th meeting of the Committee took place in Vienna from 13-17 November 2000; their report was published in the SSDL Newsletter No. 44 (January 2001).

Services provided by the IAEA

The experimental work of the Dosimetry and Medical Radiation Physics Subprogramme is carried out in the IAEA's Dosimetry Laboratory, a unit integrated in the IAEA's Seibersdorf Laboratories. The Dosimetry Laboratory is the central laboratory of the IAEA/WHO network of SSDLs.

The range of laboratory services provided to Member States covers:

- i) Calibration of ionization chambers (radiotherapy, diagnostic radiology including mammography, and radiation protection).
Radiation quality: X-rays (10 - 250 kV) and gamma rays from ¹³⁷Cs and ⁶⁰Co.
- ii) Calibration of well-type ionization chambers for Low Dose Rate (LDR) brachytherapy.
Radiation quality: gamma rays from ¹³⁷Cs.
- iii) TLD dose quality audits for external radiotherapy beams (for SSDLs and hospitals).
Radiation quality: gamma rays from ⁶⁰Co and high energy X-ray beams.
- iv) ESR-alanine dose quality audits for radiation processing (for SSDLs and facilities).
Radiation quality: gamma rays from ⁶⁰Co. Dose range: 0.1 - 100 kGy.
- v) TLD dose quality audits for radiation protection (for SSDLs).
Radiation quality: gamma rays from ¹³⁷Cs.
- vi) Reference irradiations for dosimeters for radiation protection, mainly for IAEA internal use.
Radiation quality: X-rays (40 - 300 kV) and gamma rays from ¹³⁷Cs and ⁶⁰Co.

Secondary Standard Dosimetry Laboratory (SSDL) network

Membership in the IAEA/WHO SSDL network is open to laboratories designated by their national competent authority. The network presently consists of 73 laboratories and 6 national SSDL organizations in 61 Member States (more than half are developing countries) and 20 affiliated members [international organizations and Primary Standard Dosimetry Laboratories (PSDLs)].

Active SSDLs provide traceable instrument calibrations for radiation therapy, diagnostic radiology including mammography, brachytherapy (¹³⁷Cs), occasionally provide quality audits of radiotherapy beams by postal TLD and on-site measurements, and some perform measurements at radiation processing levels. The implementation of such a programme requires that the traceability of the SSDLs to a PSDL or to the IAEA be verified periodically through quality audits and intercomparisons organized by DMRP. It was noted that almost all SSDLs (97%) provide radiation protection level calibrations, many without traceability to a PSDL.

Since 1991, the DMRP has focused efforts on the follow up of results of all of the audit services when an SSDL (or hospital) fails the audit with a disagreement with the IAEA exceeding appropriate action levels. This follow-up programme has been very successful.

Calibration of national measurement standards

During 1999-2000, the IAEA calibrated 95 ionization chambers, of which 18% were for radiation protection level dosimetry and the remaining 78% for radiotherapy. Considering that almost all SSDLs of the network (97%) provide radiation protection level calibrations, the protection level component appears to be rather small. Contacts with some SSDLs have revealed that it is not uncommon for them to rely on manufacturer calibration factors.

Intercomparison of therapy-level ionization chamber calibration factors

The intercomparison programme was initiated in 1995. Under this programme the participating SSDL calibrates an ionization chamber, sends it to the IAEA for calibration and repeats the calibration when the chamber is returned.

The procedures prepared by the IAEA for these intercomparisons were reviewed by a group of consultants. An action level of 1.5% was established, assuming a typical relative standard uncertainty at an SSDL of about 0.75% with a coverage factor $k=2$. Until now, about 70% of the SSDL members have participated in the intercomparison programme.

Twenty SSDLs participated in the intercomparison programme during 1999-2000. A plot of the ratios of calibration factors, SSDL/IAEA, is shown in Figure 1. All deviations were followed up.

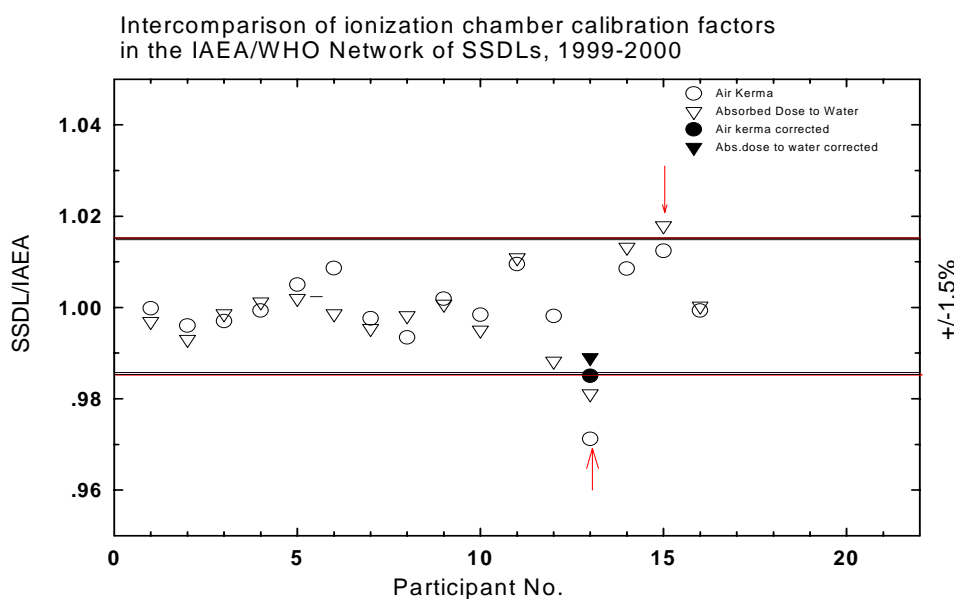


Figure 1. Ratios of ion chamber calibration factors supplied by the SSDLs to those measured by the IAEA. Circles correspond to air kerma calibration factors and triangles to absorbed dose to water calibration factors.

Calibration of diagnostic radiology ionization chambers

A major part of the activities on the development of measurement standards for diagnostic radiology X-rays has been focused on technical adjustments of the mammography calibration system, measurements of beam characteristics and calibration of the secondary standard ionization chambers. The updated experimental set-up required evaluation of field homogeneity and determination of the first and second half value layer for all beam qualities. Stability, leakage and saturation measurements have been conducted for various chambers at the laboratory.

In 1999, a Radcal 10X5-6M ionization chamber was selected as the IAEA's secondary standard for mammography. It was calibrated at PTB for unattenuated and attenuated mammography beam

qualities generated from a molybdenum anode. The uncertainty of the measurements pertaining to the calibration of mammography ionization chambers, for SSDLs, have been estimated at the IAEA to be 0.8%

Three mammography chambers have been calibrated (27 calibration points) at the laboratory since the beginning of 2000 when this new service was made available to Member States.

X-ray spectrometry

A spectrometry system consisting of a planar HPGe detector and a digital spectrum multi-channel analyzer has been acquired by the IAEA. The unfolding software for the system was developed under a contract with PTB. The package contains data files with response matrices, inverse matrices and programs for spectra unfolding and manipulation. It can evaluate X-ray spectra with nominal energy ranges up to 60 keV, 150 keV and 300 keV.

The system will be used to analyze the X-ray spectra at the laboratory.

EUROMET project on calibration of dosimeters used in mammography

The IAEA will participate in the EUROMET project No. 526 in co-operation with 14 European metrological institutes. As a part of this project, a set of selected dosimeters (ionization chambers and semiconductor detectors) will be calibrated at the participant's calibration beams.

TLD-based monitoring of SSDL measurements

Therapy level

The IAEA/WHO TLD postal dose quality audit service has monitored the performance of the SSDLs in the therapy dose range since 1981. Results of this programme indicate that more than 90% of the SSDLs that participate in the TLD audits have results within $\pm 3.5\%$ (acceptance limit).

The results for dose delivery under reference conditions in a water phantom for the laboratories providing therapy level calibrations are presented in Fig. 2, where deviations from the IAEA's results are plotted for ^{60}Co and high energy X-rays. During the review period, four SSDL TLD runs (1998/2, 1999/1 and 1999/2, and 2000/1) were completed for 56 laboratories, in which 161 beams were checked (103 ^{60}Co and 58 high energy X-rays from medical accelerators).

For laboratories with deviations outside the acceptance limit, a follow up programme has been established to resolve the discrepancies. Those laboratories are informed by the IAEA about the discrepancy and assisted to understand and resolve the problem. A second (follow-up) TLD set is sent to each of these SSDLs. All but one deviation outside the $\pm 3.5\%$ limit have been explained and corrected.

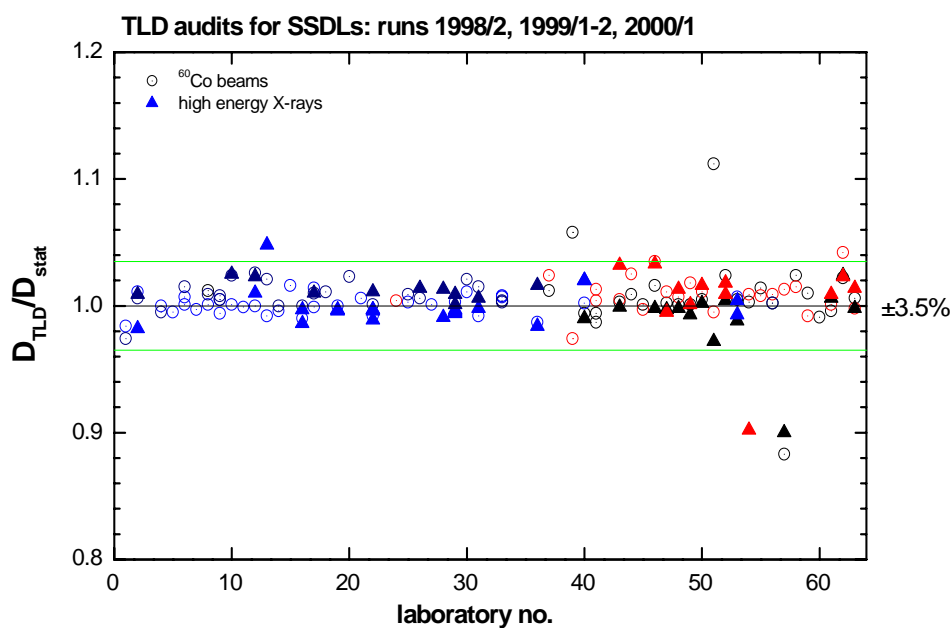


Figure 2. Results of the IAEA/WHO TLD postal dose audits for SSDLs for the delivery of dose to water under reference conditions for the TLD runs 1998/2, 1999/1, 1999/2 and 2000/1. Data in the graph correspond to the ratio of the IAEA's determined dose from the TL-response (D_{TLD}) to that stated by the SSDL (D_{stat}). Each data point corresponds to the average of three dosimeters. A total of 161 beam calibrations were checked in 56 laboratories, which include 103 ^{60}Co (circles) and 58 high energy X-ray beams (triangles). The number of therapy beams checked in different TLD runs was: 39 beams in 1998/2, 53 beams in 1999/1, 35 beams 1999/2 and 34 beams in 2000/1. A total of 7 deviations were found outside the acceptance limit of $\pm 3.5\%$ (five deviations in 1998/2 run, one in 1999/1, two in 1999/2 and none in 2000/1 run).

Protection level

This service started in 1999 and it is organized in 2 runs per year. Each run involves 15 laboratories. In addition, selected PSDLs are supplied with a set of dosimeters and asked to irradiate them at prescribed air kerma. These dosimeters are used as an independent check of the system. The results of the runs in 1999 and in 2000 are given in Figure 3 and show that about 30% of the SSDLs are outside the acceptance limit of $\pm 3.5\%$. These SSDLs are contacted and support is provided to resolve the discrepancies. As a routine, they are invited for the next run. The SSDLs' performance during the follow-up exercise is also shown in the figure.

A survey shows that some SSDLs use ^{137}Cs and ^{60}Co for radiation protection calibrations and that very few SSDLs (only 3) use exclusively ^{60}Co . The response of the present TLD system to ^{60}Co radiation was investigated. The results show a 1% decrease in the TLD response when the dosimeters are irradiated by ^{60}Co instead of ^{137}Cs . The system can thus be used also for the audit of ^{60}Co sources calibrations.

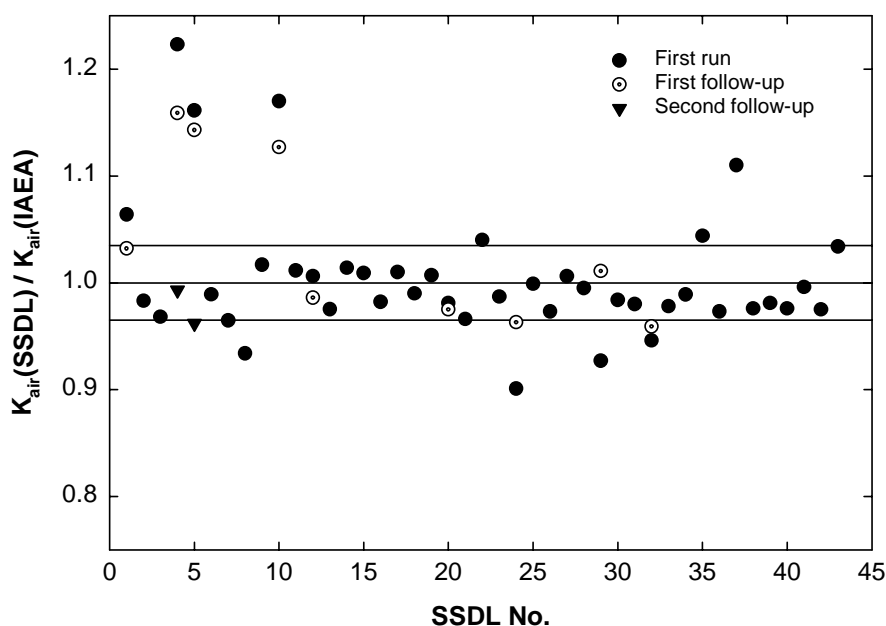


Figure 3. Ratios of the air kerma stated by SSDLs to the TLD measured value at the IAEA Dosimetry Laboratory.

Measurements on personal dosimeters for IARC

An International Collaborative Study of Cancer Risk among radiation workers is being carried out by the International Agency for Research on Cancer (IARC), Lyon, France. The objective of the study is to provide a direct assessment of carcinogenic effects of long term low-level radiation exposure in humans and to test the adequacy of current radiation protection recommendations.

A review of the available documentation and expert estimates has shown that most workers are predominantly exposed to photons of energies 0-100, 100-300 and 300-3000 keV under anterior-posterior, rotational and isotropic geometry. Measurements have been carried out at the IAEA Dosimetry Laboratory in order to assess the response of dosimeters to energies and geometries similar to those existing in working conditions.

The study involved the irradiation of about 650 dosimeters using ISO X-ray beam qualities N-150, N-250, and ^{137}Cs and ^{60}Co gamma rays on the ISO water phantom and an anthropomorphic Rando phantom. The results of these measurements are being analyzed and will be published together with IARC.

Brachytherapy calibrations

A calibration service for brachytherapy well type ionization chambers for ^{137}Cs sources has been available since 1996. According to a survey conducted in 1999, about 50% of the SSDLs in the network carry out calibrations of well type chambers, or have plans to implement such a service. SSDLs have engaged in this activity only very recently and their measurements standard was purchased with a calibration from a standard laboratory. During the report period, four well type chambers have been calibrated, mainly at the end of the period.

Dose Intercomparison and Assurance

Dose quality audits are conducted for radiotherapy centres and industrial facilities. In both services, users are requested to irradiate the dosimeters with a given dose under known irradiation conditions; the dosimeters are then returned to the IAEA for evaluation.

The IAEA/WHO TLD postal service

During 1999-2000, the IAEA/WHO TLD postal dose audit service for hospitals has maintained the developments of 1997-1998 related to organization and efficiency of the service.

The automation of the TLD system has allowed shortening the time of TLD evaluation and increasing the number of hospitals monitored to 300-400 per year. The total response time to the participants is typically 1-2 months.

Due to the joint efforts of IAEA and WHO, the return rate of the irradiated dosimeters exceeds now 90%.

In 1999-2000 the TLD programme audited 660 beams in 382 radiotherapy centres. In this period 183 additional radiotherapy centres have joined the TLD network. The global results are shown in Fig. 4. Approximately 84% of the results are within the acceptance limit of $\pm 5\%$.

Only 79% of the hospitals that have received TLDs for the first time have results within the acceptance limit ($\pm 5\%$), while 88% of institutions that have benefited from a previous TLD audit have results within the $\pm 5\%$ limit. The percentage of the results beyond the $\pm 10\%$ limit is twice as high for the new hospitals (8%) as for those having participated in the audits (4%).

The follow-up procedure was strengthened through closer contacts with local experts where available (mainly from SSDs), or by recruitment of external experts in medical physics. A contract between the IAEA and the RPC, Houston, has been developed to provide experts for on-site measurements to resolve discrepancies in Latin America.

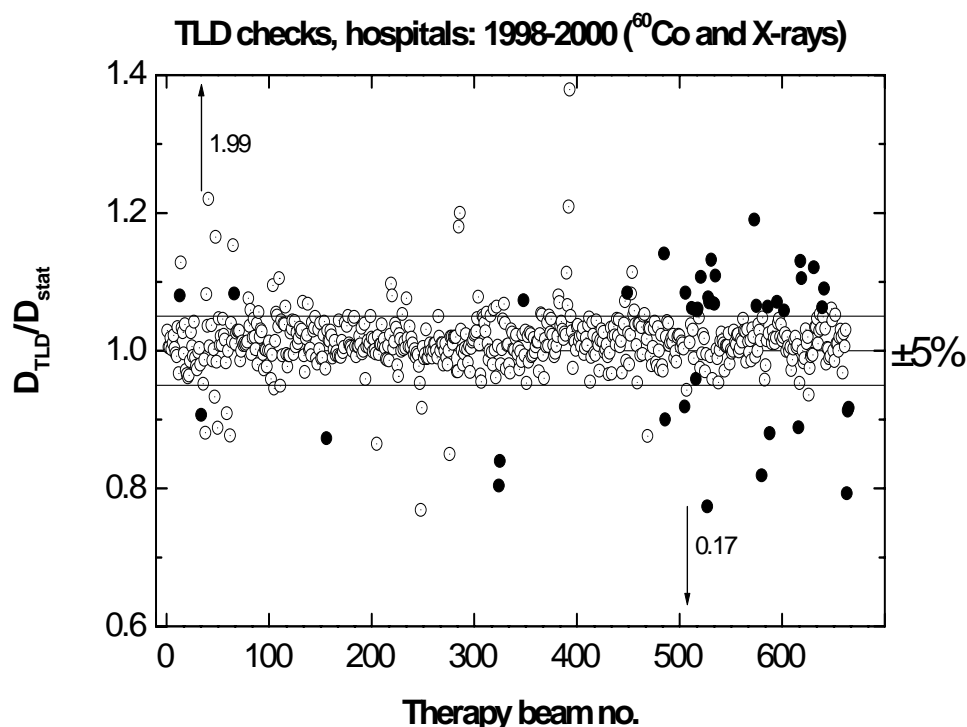


Figure 4. Results of the IAEA/WHO TLD postal dose audits of radiotherapy hospitals for the delivery of absorbed dose to water under reference conditions during 1999-2000 for the TLD batches B96 to B115. Data in the graph correspond to ratios of the IAEA's determined dose (D_{TLD}) relative to the dose stated by the hospital (D_{stat}). Each data point corresponds to the average of two dosimeters. A total of 660 beam calibrations were checked in 381 hospitals. Approximately 16% of the results were found outside the $\pm 5\%$ acceptance limit. Two extreme deviations, $D_{TLD}/D_{stat}=1.99$ and $D_{TLD}/D_{stat}=0.17$, have been explained and corrected. Black dots indicate the results that had not been corrected by September 2000.

To provide appropriate QA of the TLD system, in addition to contacts with BIPM and PSDLs, systematic collaborations with other TLD-based QA networks in Europe and USA have been

maintained. The “Memorandum of Understanding” between the IAEA and the EQUAL/ESTRO TLD network enables mutual exchange of TLDs for a reciprocal quality control of both TLD systems and facilitates co-ordination of the activities of both TLD audit services in Europe.

To reduce costs of the TLD service, the cheaper natural LiF TLD powder was introduced, as more than 95% of the recently audited beams are ^{60}Co and low energy X-rays (less than 10 MV). Tests of TLD-100 (natural LiF) have been conducted at the IAEA’s Dosimetry Laboratory.

Intercomparison of TLD systems for measurements in mammography

An intercomparison of the TLD dosimetry systems was organized during 2000, in the framework of an IAEA Co-ordinated Research Programme on “Image quality and patient dose optimization in mammography in Eastern European Countries”. The purpose was to assess the performance of the TLD systems used by participants for measurements of entrance surface air kerma, and to investigate special problems associated with such measurements. Participants were requested to send their TLD dosimeters to the IAEA for irradiation. The dosimeters were irradiated at reference values of air kerma in unattenuated mammography beams generated by a molybdenum anode at 25, 28 and 35 kV tube potentials and they were returned to the participants for evaluation.

The results of the intercomparison are given in Table I. They clearly indicate a need for improving clinical dosimetry if the requirements of the European Protocol are to be met (accuracy better than 10%). As a follow-up action the participants were contacted with the aim of resolving discrepancies. The subsequent analysis shows that their main problems rest with the calibration of the TLDs. This includes lack of national standards, practically non-existence of traceability to PSDLs and application of inadequate methods for calibration. The intercomparison will be repeated.

Table I. Results of the IAEA intercomparison of TLD systems for the Co-ordinated Research Project “Image quality and patient dose optimisation in mammography in Eastern European Countries”

Participant No.	Participant/IAEA ¹⁾		
	MoMo-25 ²⁾	MoMo-28 ²⁾	MoMo-35 ²⁾
1	0.68	0.76	0.73
2	0.83	0.87	0.87
3	0.36	0.44	0.40
4	1.06	1.10	1.10
5	0.98	1.00	0.89

¹⁾Ratio of the air kerma measured by the participant and the value stated by the IAEA

²⁾The beam codes are a combination of the chemical symbol of the anode and the filter, respectively, followed by the potential of the tube in kV

The International Dose Assurance Service (IDAS) for industrial applications

The International Dose Assurance Service (IDAS) performs dose quality audits for the SSDLs, the industrial and pilot-scale facilities, and research laboratories used for radiation processing applications. The service is limited to ^{60}Co gamma rays. The overall uncertainty of the alanine-ESR dosimetry system used for this service is 1.7% (k=1). This dosimetry system is compared against a PSDL about once a year, which provides an external quality control. Alanine-ESR dosimeters,

supplied by the IAEA, are irradiated at the facilities or laboratories at radiation doses relevant to industrial applications (0.1 to 100 kGy) and then returned for evaluation to the IAEA. The reference irradiation conditions are monitored and this information is forwarded to the IAEA along with the dose values. The dosimeters are then analyzed at the IAEA and the results compared with the stated values. IDAS thus provides an independent check on the entire dosimetry system of the participant. In case of a discrepancy greater than 5%, advice is provided as to its possible causes and then followed by another dose check. Figure 5 shows the results for the last two years. A total of 141 dose checks were performed and approximately 37% of the results were found outside the $\pm 5\%$ acceptance limit.

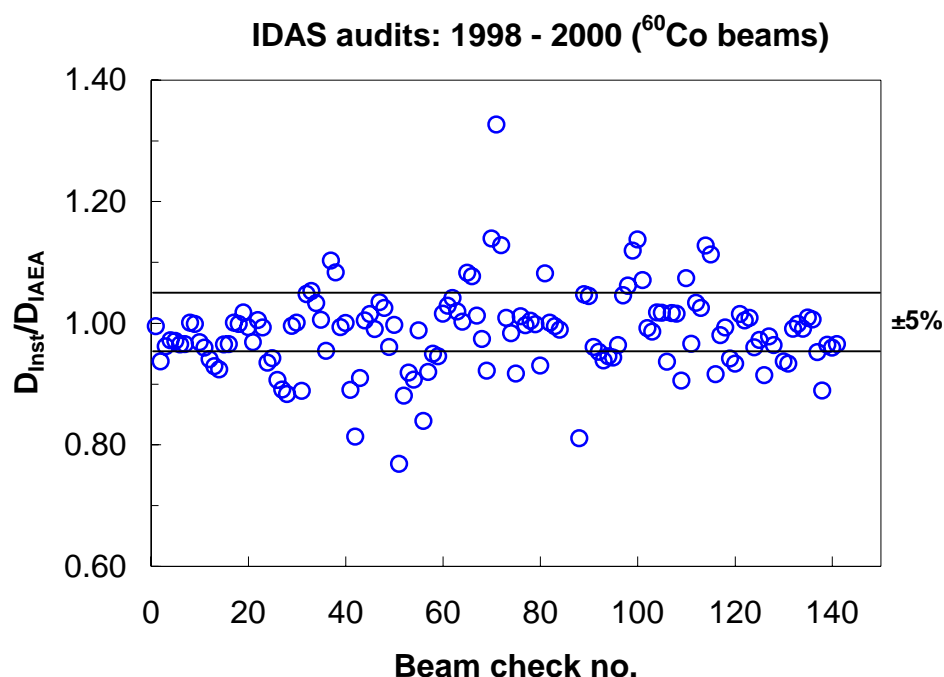


Figure 5. Results of the IDAS dose audits for the years 1999 to 2000. Data in the graph correspond to ratios of the dose stated by the institution (D_{inst}) relative to the IAEA's determined dose (D_{IAEA}). Each data point represents the average of three dosimeters.

Transfer of dosimetry techniques

The transfer of dosimetry techniques to Member States is provided through co-ordinated research projects (CRPs), meetings, training courses, fellowships, seminars, symposia and publications; computer databases also belong to this area.

Co-ordinated Research Projects

Table II provides a compilation of the various CRPs within the Subprogramme.

Table II. Compilation of Co-ordinated Research Projects (CRPs) in Dosimetry

Year of Start	Subject	Year of Completion	Participating Institutions
1995	Development of a TLD based Quality Assurance programme for radiation therapy dosimetry in developing countries	2000	8
1995	Characterization and evaluation of high dose dosimetry techniques for Quality Assurance in radiation processing	1999	10
1996	Development of a Quality Assurance programme for Secondary Standard Dosimetry Laboratories	1999	5
1996	Testing the Code of Practice for radiation measurement with plane parallel ionization chambers	2000	7
1997	Development of a Code of Practice for dose determination in photon, electron and proton beams on measurement standards of absorbed dose to water. Extension of the CRP for 2001-2002 was approved, to test the CoP at hospitals (with five participants)	2000	7
1998	EPR Biodosimetry	2001	8
2000	Dosimetry in X-ray diagnostic radiology: An international Code of Practice	2003	5
2000	A new CRP was submitted and approved for 2001-2003: it will support the development of techniques at the SSDLs for the dissemination of the new standards based on absorbed dose to water for radiotherapy dosimetry	2003	6

Training courses and seminars

Considerable emphasis is placed by the Dosimetry and Medical Radiation Physics Section on organizing training courses and co-ordinating fellowships for medical radiation physicists and staff from SSDLs within the framework of IAEA Technical Co-operation projects. Support for the development of university degrees in medical radiation physics has become an important task and a successful regional programme has been developed for Latin America and will soon be implemented also in Africa.

Courses held during 1999 and 2000 are as follows:

1999

- i) Training Course on clinical treatment planning for teletherapy and brachytherapy (RER/6/008), Palanga, Lithuania, 7-18 June 1999.

- ii) AFRA Workshop on harmonized methods of beam calibration in external radiotherapy (C7-RAF/6/014-015), Rabat, Morocco, 21-25 June 1999.
- iii) Regional Training Course on the basis of clinical quality assurance in radiation oncology (RAS/6/027-003), Manila, Philippines, 5-9 July 1999 (in collaboration with the Applied Radiation Biology and Radiotherapy Section).
- iv) Workshop on IAEA and ESTRO networks for external quality audits in radiotherapy (RER/6/008), Patras, Greece, 31 August 1999 (in co-operation with ESTRO).
- v) Regional Training Course on Modern Techniques and Dosimetry in Brachytherapy (RAF/6/020), Cairo, Egypt, 18-29 September 1999.
- vi) Interregional Training Course on Calibration Procedures and Quality Assurance in SSDLs (C7-INT-1.053), Havana, Cuba, 27 September-8 October 1999.

2000

- i) Group Training on calibration procedures (LAT/1/002), Vilnius, Lithuania, 16-17 March 2000.
- ii) AFRA Workshop on maintenance of Co-60 units (RAF/4/014), Nairobi, Kenya, 20-26 May 2000.
- iii) Regional Training Course on physical aspects of quality assurance in radiotherapy (RAW/6/009-001), Damascus, Syria, 18-29 June 2000.
- iv) Workshop on calibration procedures in radiation protection and radiotherapy level dosimetry (RAF/9/024), Algiers, Algeria, 24-28 June 2000.
- v) Regional Training Course on physical aspects of quality assurance in radiotherapy (RAS/6/027), Sydney, Australia, 13-24 November 2000.
- vi) Regional Master in Medical Physics (ARCAL L), Caracas, Venezuela, whole year.

IAEA publications in Dosimetry and Medical Radiation Physics

A new Code of Practice, based on standards of absorbed dose to water, for the dosimetry of radiotherapy beams was developed within the framework of a CRP. The new CoP will replace the N_K based TRS-277. The CoP is endorsed by the World Health Organization (WHO), the Pan American Health Organization (PAHO) and the European Society of Therapeutic Radiology and Oncology (ESTRO). Its publication by the IAEA is expected soon.

An IAEA SSDL Newsletter is published biannually and distributed among the members of the SSDL network and the scientific community. The Newsletter is also available on the Internet.

Table III. IAEA Publications in Dosimetry, 1999-2000

Series and No.	Title
Technical Reports Series No. 398, in press	Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry based on Standards of Absorbed Dose to Water (2000)
IAEA-TECDOC-1173	Validation of Data and Methods recommended in the International Code of Practice in Technical Reports Series No. 381 (2000)
IAEA-TECDOC-1151	Aspectos Físicos de la Garantía de Calidad en Radioterapia: Protocolo de Control de Calidad (2000)
IAEA-TECDOC-1156	Dosimetry for Radiation Processing: Final Report of the Co-ordinated Research Project on Characterization and Evaluation of High Dose Dosimetry Techniques for Quality Assurance in Radiation Processing (2000)
IAEA Safety Reports Series No. 17	Lessons Learned from Accidental Exposures in Radiotherapy (2000)
IAEA-TECDOC-1079	Calibration of Brachytherapy Sources: Guidelines on Standardized Procedures for the Calibration of Brachytherapy Sources at Secondary Standard Dosimetry Laboratories and Hospitals (1999)
IAEA-TECDOC-1070	Techniques for High-Dose Dosimetry in Industry, Agriculture and Medicine, Proceedings of an International Symposium, Vienna, 2–5 November 1998 (1999)
General type publication	SSDL Network Charter: IAEA/WHO Network of Secondary Standard Dosimetry (1999)
SSDL Newsletter	SSDL Newsletter Nos. 40 and 41 (1999), 42 and 43 (2000)

Directory of Radiotherapy Centres (DIRAC)

Since 1959, the IAEA has maintained a register of radiotherapy hospitals and clinical institutions having radionuclide and high-energy teletherapy machines. This was initially available in printed form only and its last edition was published in 1968. The present electronic version of the Directory of Radiotherapy Centres (DIRAC) is a joint effort with WHO. It is a continuous update, based on replies to questionnaires circulated to users. It includes data not only on teletherapy machines, but also on sources and devices used in brachytherapy, and on equipment for dosimetry, patient dose calculation and quality assurance. Staff strength at the installations (radiation oncologists, medical physicist, technicians, etc.) is included as well.

The database was released provisionally in the form of a CD-ROM, which includes copies of the database in Access 97 and Access 2000. The data are being verified and updated before the Internet version of DIRAC is released.

Appendix I. Publications by staff members of the IAEA Dosimetry and Medical Radiation Physics Section

1999

I GUDOWSKA, W GUDOWSKI, P ANDREO, A BRAHME, J KIERKEGAARD, Calculations of absorbed dose and biological effectiveness from photonuclear reactions in a bremsstrahlung beam of 50 MeV, *Physics in Medicine and Biology* **44** (1999) 2099-2125.

T TABATA, P ANDREO, K SHINODA, Fractional energies of backscattered electrons and photon yields by electrons, *Radiation Physics and Chemistry* **54** (1999) 11-18.

P ANDREO, C HOPPNER, G S IBBOTT, A IMMERS, P ORTIZ-LOPEZ, Safety measures to address the year 2000 issue at medical facilities which use radiation generators and radioactive materials, IAEA Tec-Doc 1074. INTERNATIONAL ATOMIC ENERGY AGENCY, Vienna 1999.

H TÖLLI, et al, Calibration of brachytherapy sources: Guidelines on standardized procedures for the calibration of brachytherapy sources at Secondary Standard Dosimetry Laboratories (SSDLs) and Hospitals, IAEA Tec-Doc 1079. INTERNATIONAL ATOMIC ENERGY AGENCY, Vienna 1999.

P ANDREO, J IZEWSKA, A MEGHZIFENE, K MEHTA, F PERNICKA, H TÖLLI, P BERA, L CZAP, R GIRZIKOWSKY, IAEA Dosimetry Programme Report on Activities in 1997-98, Report CCRI(I)99-5, Working documents of the 14th Meeting of the Comité Consultatif des Rayonnements Ionisants (Section I), CCRI(I), Bureau International des Poids et Mesures, Sevrès, 1999.

P ANDREO, High-energy photon beam quality specification in the $N_{D,w}$ -based International Code of Practice for external beam radiotherapy dosimetry, Report CCRI(I)99-31, Working documents of the 14th Meeting of the Comité Consultatif des Rayonnements Ionisants (Section I), CCRI(I), Bureau International des Poids et Mesures, Sevrès, 1999.

L CZAP, F PERNICKA, G MATSCHEKO, P ANDREO, Standards in Radiation Protection at the IAEA Dosimetry Laboratory, In "Intercomparison for individual monitoring of external exposure from photon radiation", IAEA Tec-Doc 1126, pp. 27-34. INTERNATIONAL ATOMIC ENERGY AGENCY, Vienna 1999.

G S IBBOTT, P ORTIZ-LOPEZ, P ANDREO, Y2K & medical facilities using radiation sources: protecting patients, IAEA Bulletin 41/2/1999 40-43. INTERNATIONAL ATOMIC ENERGY AGENCY, Vienna 1999.

P ANDREO, Dose determination with plane-parallel ionization chambers in therapeutic electron and photon beams, IAEA SSDL Newsletter **40** 4-16 (1999).

F PERNICKA, P ANDREO, A MEGHZIFENE, L CZAP, R GIRZIKOWSKY, Standards for Radiation Protection and Diagnostic Radiology at the IAEA Dosimetry Laboratory, IAEA SSDL Newsletter **41** 12-23 (1999).

P ANDREO, D T BURNS, K HOHLFELD, MS HUQ, T KANAI, F LAITANO, V SMYTH, S VYNCKIER, An International Code of Practice for radiotherapy dosimetry based on absorbed dose to water standards, *Radiotherapy and Oncology* **51** Suppl. 1 (1999), p S19 (73). Abstracts 5th Biennial Meeting on Physics in Clinical Radiotherapy (ESTRO). Göttingen, Germany, 1999.

J IZEWSKA, P BERA, P ANDREO, The IAEA/WHO TLD postal dose quality audits: international experience in QA networking, *Radiotherapy and Oncology* **51** Suppl. 1 (1999), p S30 (117). Abstracts 5th Biennial Meeting on Physics in Clinical Radiotherapy (ESTRO). Göttingen, Germany, 1999.

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