IAEA SECTION OF DOSIMETRY AND MEDICAL RADIATION PHYSICS (DMRP)

Report on Activities, 2007–2008

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Introduction

The Dosimetry and Medical Radiation Physics (DMRP) section works on the Quality Assurance (QA) aspects of the use of radiation in medicine to ensure safety and effectiveness. Furthermore, it contributes to the increase in scientific and technical capacity in medical physics worldwide by fostering research and development in dosimetry techniques and playing a role in the education and training of medical physicists. The primary beneficiaries of these activities are hospital patients undergoing therapy and diagnosis with radiation, radiation workers who benefit from the standardization of radiation protection measurements and the general public due to improved dosimetry practice. DMRP also provides two types of service directly to Member States: dosimetry calibration and dosimetry auditing.

1. Projects in Dosimetry and Medical Radiation Physics

During the period 2007–2008, DMRP's programme included four projects, with the titles as indicated, followed by the objectives in each case:

- **Recurrent Project 2.2.4.1**: Quality audits in dosimetry for radiation medicine

  The objective of this project is to ensure the quality of the entire dosimetric chain in Member States at the hospital level, through an independent means of verification of the dose to be delivered to the patients during radiotherapy (using mailed TLDs).

- **Recurrent Project 2.2.4.2**: Radiation metrology supporting the network of Secondary Standards Dosimetry Laboratories

  The objective of this project is to enhance the capability of Member States to achieve and maintain a high level of quality and consistency in radiation measurements and dosimetry standards, used in radiotherapy, diagnostic radiology, and radiation protection, that are linked to the international measurement system in accordance with the Mutual Recognition Arrangement (MRA).

- **Project 2.2.4.3**: Quality assurance and guidelines for medical physics in the optimization of clinical radiation imaging

  The objective of this project is to establish and maintain high quality medical imaging capabilities for diagnosis and related treatment in Member States that follow appropriate standards in quality assurance and safety at the hospital.

- **Project 2.2.4.4**: Quality assurance and medical physics developments in radiotherapy and therapeutic nuclear medicine

  The objective of this project is to enhance the capability of Member States to develop new techniques, methodologies and training materials for dose auditing and quality assurance for radiation treatment.

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 of the IAEA on the strategies of the Dosimetry programme of the IAEA that will meet the needs of the Member States. The 13th meeting of the Committee took place in Vienna from 10–14 March 2008; the report was published in the SSDL Newsletter No. 56 (December 2008).

2. Services provided by the IAEA

The experimental work of DMRP is carried out at the IAEA's Dosimetry Laboratory, which is physically located at the Agency's Laboratories, in Seibersdorf. 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, mammography, and radiation protection). Radiation quality: X rays (10 - 300 kV) and gamma rays from ^{137}Cs and ^{60}Co.[1]

ii) Calibration of well-type ionization chambers for Low Dose Rate (LDR) brachytherapy. Radiation quality: gamma rays from ^{137}Cs.

iii) TLD dose quality audits for external radiotherapy beams (for SSDLs and hospitals). Radiation quality: gamma rays from ^{60}Co and high-energy X-ray beams.

iv) TLD dose quality audits for radiation protection (for SSDLs). Radiation quality: gamma rays from ^{137}Cs and ^{60}Co.

v) Reference irradiations for dosimeters for radiation protection. Radiation quality: X rays (40 - 300 kV) and gamma rays from ^{137}Cs and ^{60}Co.

The calibration services provided to the SSDLs of the Member States are listed in the IAEA Calibration and Measurement Capabilities (CMCs), which can be found in the BIPM Key Comparison Database.

3. Quality system at the IAEA's Dosimetry Laboratory

A Quality Management System (QMS) has been established for the IAEA's Dosimetry Laboratory (DOL) following ISO Guide 17025: *General Requirements for the Competence of Calibration and Testing Laboratories* [ISO 1999 with the update in 2005]. The purpose of the QMS is to help ensure quality through documented policies and procedures. The document consists of a Quality Manual followed by several Dosimetry Operating Laboratory Procedures (DOLPs) describing the dosimetry systems that are maintained in the Dosimetry Laboratory as secondary/reference standards and the services that are offered to the Member States (see Section 2 above). A separate DOLP describes the operation and safety aspects of the various irradiation units and sealed sources that are used for calibration of dosimeters.

The process of reviewing the Quality Management System of the IAEA's Dosimetry Laboratory was completed in 2006 "Resolution 17/1: the JCRB accepted the QMS of the IAEA." As a consequence, the DOL's calibration and measurement capabilities remain formally included in the "BIPM Key comparison data base" available on the internet at http://kcdb.bipm.org/.

[1] The calibration services in X-ray beams have been interrupted since September 2008, because of equipment replacement and laboratory renovation. The services will resume as of October 2009.

Revisions of DOLPs are being made to follow the changes in the laboratory equipment and new developments in DOL activities. At the same time the DOL QMS undergoes regular reviews and audits, both internal and external. A feedback system is incorporated in the audit schemes in order to monitor the changes and document improvements.

4. Radiation metrology supporting the network of Secondary Standards Dosimetry Laboratories (SSDLs) (IAEA Recurrent Project 2.4.4.2)

Membership in the IAEA/WHO SSDL Network is open to laboratories designated by their national competent authority. The network presently consists of 80 laboratories in 67 Member States, of which more than half are developing countries. The network includes 20 affiliated members, all of which are international organizations or Primary Standards Dosimetry Laboratories (PSDLs). Most SSDLs provide traceable instrument calibrations for radiation protection, radiation therapy, and in some cases, mammography. Some SSDLs also provide quality audits of radiotherapy beams by postal TLD or on-site measurements, and some perform measurements for nuclear medicine. 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 comparisons.

As of 2008, a new on-line annual reporting system was put in place. 80% of SSDLs submitted their 2008 annual report by the end of March 2008.

Traceability in the IAEA/WHO SSDL network

The review of the SSDL annual report for 2008 shows that about 20% of SSDLs are traceable to the IAEA, whereas 15% are traceable to the BIPM (see Figure 1)

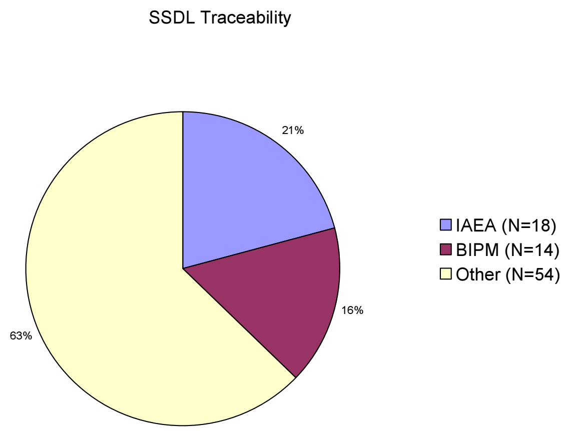

FIG. 1. Traceability in the IAEA/WHO Networtk of SSDLs

4.1 IAEA participation in comparisons organized by Regional Metrology Organizations (RMOs)

The Agency has participated in the following comparisons organized by Regional Metrology Organizations (RMOs): EURAMET, APMP and SIM.

- EUROMET project No. 813 comparison: report in preparation
- APMP/TCRI Key Comparison Report of Measurement of Air Kerma for ^{60}Co Gamma-Rays (APMP.RI(I)-K1): report in preparation

- APMP/TCRI key comparison report of measurement of air kerma for medium-energy x-rays (APMP.RI(I)-K3): report published
- EUROMET Hp(10) comparison (EUROMET project No. 738): report in preparation
- EUROMET project no. 526: paper published.
- SIM ^{60}Co air kerma comparison SIM.RI(I)-K1 and SIM ^{60}Co absorbed-dose-to-water comparison SIM.RI(I)-K4 : both reports published.

4.2 IAEA support to SSDLs

4.2.1 Preparation of guidance documents SSDLs

– **Training material:** A stand-alone document that includes training material for SSDL staff is in preparation. When completed, the document will be published as IAEA training material and used for training SSDL staff in calibration and related quality control procedures.

– **Uncertainty of measurements:** the document was published as IAEA-TECDOC-1585 "Measurement Uncertainty A Practical Guide for Secondary Standards Dosimetry Laboratories"

– **Revisions of IAEA TRS-374 "Calibration of dosimeters used in radiotherapy":** The document is in printing**.**

– **Audit of Secondary Standards Dosimetry Laboratories:** a report was published in the SSDL Newsletter No. 56 (December 2008)**.**

4.2.2 Setting-up and upgrading of SSDLs

– Under its technical cooperation programme, the IAEA is assisting in the estbalishment of 5 new SSDLs in Azerbaijan, Cote d'Ivoire, Kenya, United Arab Emirates and Uruguay.

– The IAEA has been also assisting in upgrading SSDLs in Croatia, Cuba, Cyprus, Israel, Algeria, Kuwait, Libya, Macedonia, Saudi Arabia, Serbia and Syria by introducing new calibration services and strengthening their quality system.

4.2.3 Calibration of national measurement standards of the Member States

During 2007–2008, the IAEA calibrated 86 ionization chambers (see Figure 2), of which about 63% were for radiotherapy, 29% for radiation protection level dosimetry and 8% for mammography. Most of the calibrations were done for SSDLs (79%). The calibrations provided to hospitals have decreased due to the use of calibration laboratories in the region.

The number of ion chambers calibrated during this period was lower than the previous periods due to ongoing upgrading of the laboratory, that included the installation of new irradiators (medium and low energy X ray tubes, calibration benches, shielding cabinet, etc.). These activities required an interruption of the calibration service. Calibrations of SSDL's radiotherapy and radiation protection standards in X ray beams was in urgent cases provided by BEV.

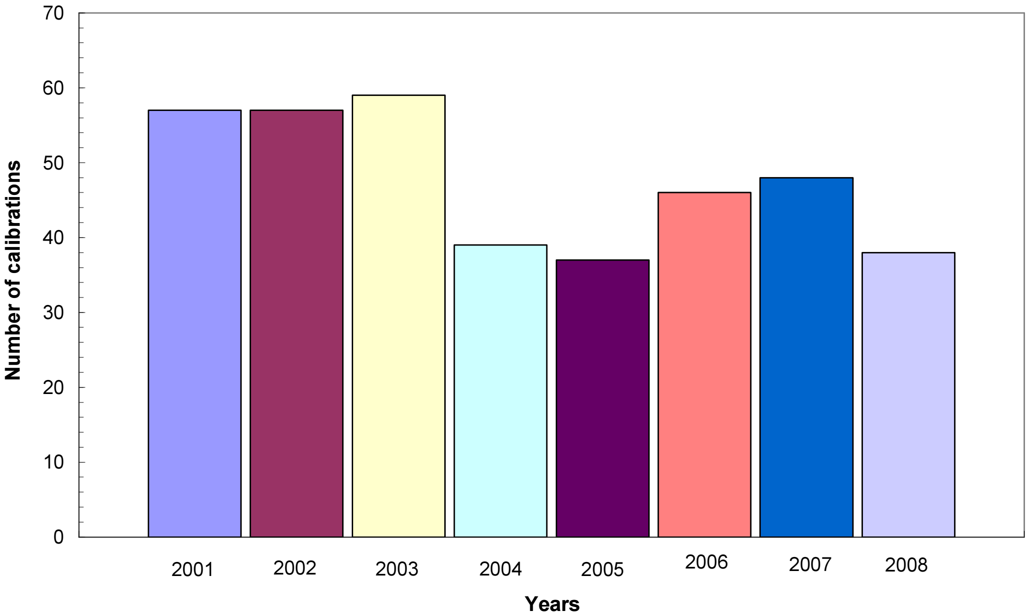

FIG. 2: Number of ionization chambers calibrated each year.

4.2.4 Calibration for diagnostic radiology

New Code of Practice

The Technical Reports Series No. 457, "Dosimetry in Diagnostic Radiology: An International Code of Practice", was published in September 2007. The report was drafted in close cooperation with the ICRU and complements ICRU No. 74. TRS-457 reflects the diverse nature of diagnostic radiology dosimetry, broadly covering the dosimetry framework, quantities and units, instrumentation and calibration procedures. The dosimetric quantities include both fundamental quantities describing radiation fields and the deposition of radiation in matter, and quantities used for applied dosimetry measurements for five main elements of clinical practice, namely general radiography, fluoroscopy, mammography, computed tomography (CT) and dental radiography. All application specific quantities used in the document are based on measurements of air kerma. They range from incident and entrance surface air kerma describing measurements in a single point, to quantities that integrate the air kerma over a specified length or area. Quantities related to effects of ionizing radiation, like absorbed dose with the example of quantity mean glandular dose as is the case for mammography, are calculated from the application specific quantities using appropriate conversion factors. These are based on models and include certain clinical assumptions. The instrumentation described in the document also varies notably with the inclusion of kerma area product (KAP) meters for fluoroscopic and radiography applications and pencil CT chambers for kerma length measurement in CT and some dental applications. For all the modalities mentioned above, the report systematically describes phantom and patient measurement quantities, gives details of the measurement procedures, calculations and estimation of measurement uncertainties. To assist users with a practical implementation, the report also includes worked examples for clinical and calibration procedures and includes appropriate sections on estimation of measurement uncertainty.

The calibration of mammography detectors was suspended in 2008 due to the installation of a new X ray generator and 3 tubes to allow calibration of detectors used in diagnostic radiology dosimetry using TRS457. Commissioning of the new facility is scheduled for 2009 when services will recommence.

A survey of SSDL laboratories was carried out in 2008 to determine the current level of calibration of dosimeters used for diagnostic radiology as well as the implantation of TRS 457. There were responses from 38 SSDLs, representing 37 different countries. The analysis of the responses from these centres gave the following results:

- Currently 15 SSDL sites have the facility to make diagnostic X ray, with a further 13 indicating they plan to have a facility in 3 years time.
- Of the 15 sites above, 11 follow TRS457 and 13 use IEC beam qualities.
- There is a large range in the activity of diagnostic radiology calibrations with a range of 5 to 60 detectors calibrated in a year, with a total of 335 detectors for 2007. The one commercial facility registered as an SSDL on the other hand calibrated 4,881 detectors in the same period.
- At some facilities there is some confusion about what is meant by diagnostic radiology dosimetry calibration. This term should not include activities of calibration for protection purposes using ISO 4037 beam qualities. Instead the publication TRS457 and appropriate IEC beam qualities should be used.

4.2.5 Comparison of ionization chamber calibration coefficients for absorbed dose to water and air kerma

A proficiency testing programme, initiated in 1995, verifies the ability of SSDLs to transfer a calibration from their standard to the user. The SSDL calibrates a transfer ionization chamber, sends it to the IAEA for calibration and repeats the calibration once the chamber has been returned to the SSDL.

The ratio of calibration coefficients determined by the SSDL and the IAEA is used as a criterion to judge the metrological quality of the calibration performed by the SSDL. Assuming a typical relative standard uncertainty for air kerma and absorbed dose to water calibration of an ion chamber at SSDLs of about 0.75% (at k=2) as recommended in IAEA TRS-374, the Agency has set the action level at ±1.5%.

Eight SSDLs participated in the comparison programme (two of them with 2 chambers) during 2007-2008, but only six of them completed the comparison process. Calibrations both in terms of air kerma and absorbed dose to water were included. The ration of calibration coefficients was corrected for any difference between the standard at the PSDL used by the SSDL and the corresponding standard of the IAEA. The particular IAEA standards are traceable to BIPM so the values of $k_{PSDL/BIPM}$ published in the BIPM key comparison database were used for this purpose. No discrepancies outside the action level were identified. The results are shown in Figure 3.

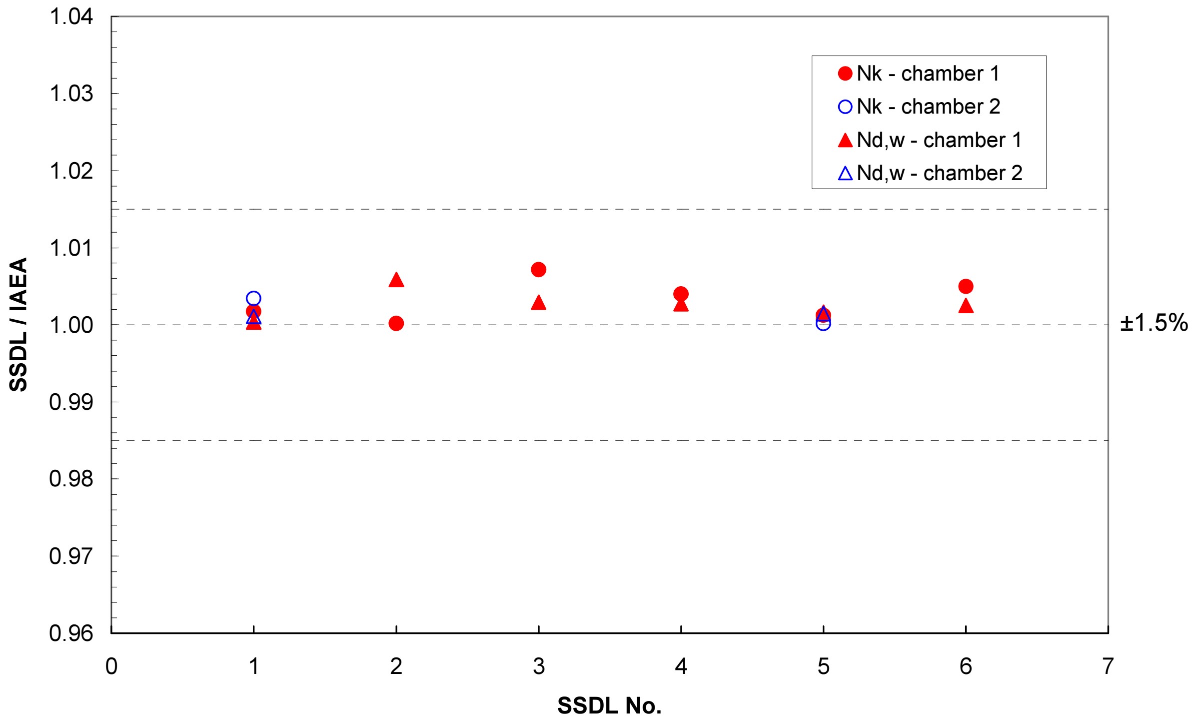

FIG.3. Results of comparison of radiotherapy chamber calibrations in 2007-2008. Ratios of ionization chamber calibration coefficients supplied by the SSDLs to those measured by the IAEA are corrected for differences in the standards of the BIPM and the PSDL to which the SSDLs were traceable. Circles correspond to air kerma calibration coefficients and triangles to absorbed dose to water factors. Open symbols are used for the second ionization chamber in case the SSDL participated with two ionization chambers. Results are considered acceptable if the deviation of the ratio from unity is less than 1.5%.

4.3 TLD-based monitoring of SSDL measurements

4.3.1 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 approximately 99% of the SSDLs that participated in the TLD audits in this biennium have results within the 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 Figure 5, where deviations from the IAEA's results are plotted for ^{60}Co and high energy X rays. During the review period, two SSDL TLD runs (2007 and 2008) were completed for 52 laboratories, in which 102 beams were checked (79 ^{60}Co and 23 high energy X ray beams from medical accelerators).

For laboratories with deviations outside the acceptance limit, a follow-up programme was 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 and deviations outside the 3.5% limit are explained and corrected.

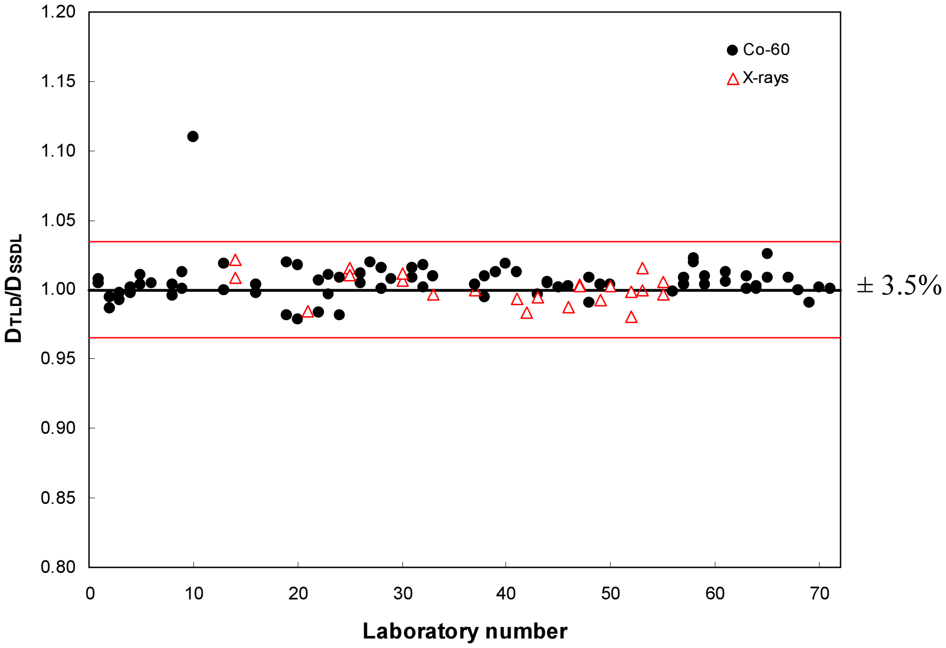

FIG. 4: Results of the IAEA/WHO TLD postal dose audits for SSDLs for the delivery of dose to water under reference conditions for the 2007 and 2008 TLD runs. Data in the graph correspond to the ratio of the IAEA's determined dose from the TL-response (D_{TLD}) to that stated by the SSDL (D_{SSDL}). Each data point corresponds to the average of three dosimeters. A total of 102 beam calibrations was checked in 52 laboratories, which included 79 ^{60}Co (circles) and 23 high energy X ray beams (triangles). The number of therapy beams checked in different TLD runs was: 51 beams in 2007 and 51 beams in 2008. One deviation was found outside the acceptance limit of 3.5% in 2007 TLD run that has been followed-up.

4.3.2 Protection level

The IAEA has developed a thermoluminescence dosimetry (TLD) system with the aim of checking ^{137}Cs and ^{60}Co radiation protection calibrations provided by the Secondary Standards Dosimetry Laboratories. The laboratories are supplied with TLDs and asked to irradiate them at 5 mGy air kerma. The dosimeters are evaluated by the IAEA. The SSDLs with results outside the acceptance limit of 7%[2] are contacted and support is provided to resolve the discrepancies. As a routine, they are invited to participate again in the next run.

One run was organized during 2007 and two runs during 2008. Fifty two SSDLs participated in these runs. One deviation in 2008 was not resolved and the laboratory was invited to participate again in 2009. The cumulative results obtained since the initiation of the service in 1999 are shown in Figure 5. The results show that most SSDLs are capable of measuring air kerma for radiation protection calibration purposes within the newly established acceptance limit of 7%. One can see that about 7% of laboratories exceed the 7% acceptance limit in the first run and most of discrepancies are corrected during the first and second follow-ups.

[2] A previous acceptance limit was 5%. Following the advice of the SSC-13, the acceptance limit of 7% was set in 2007.

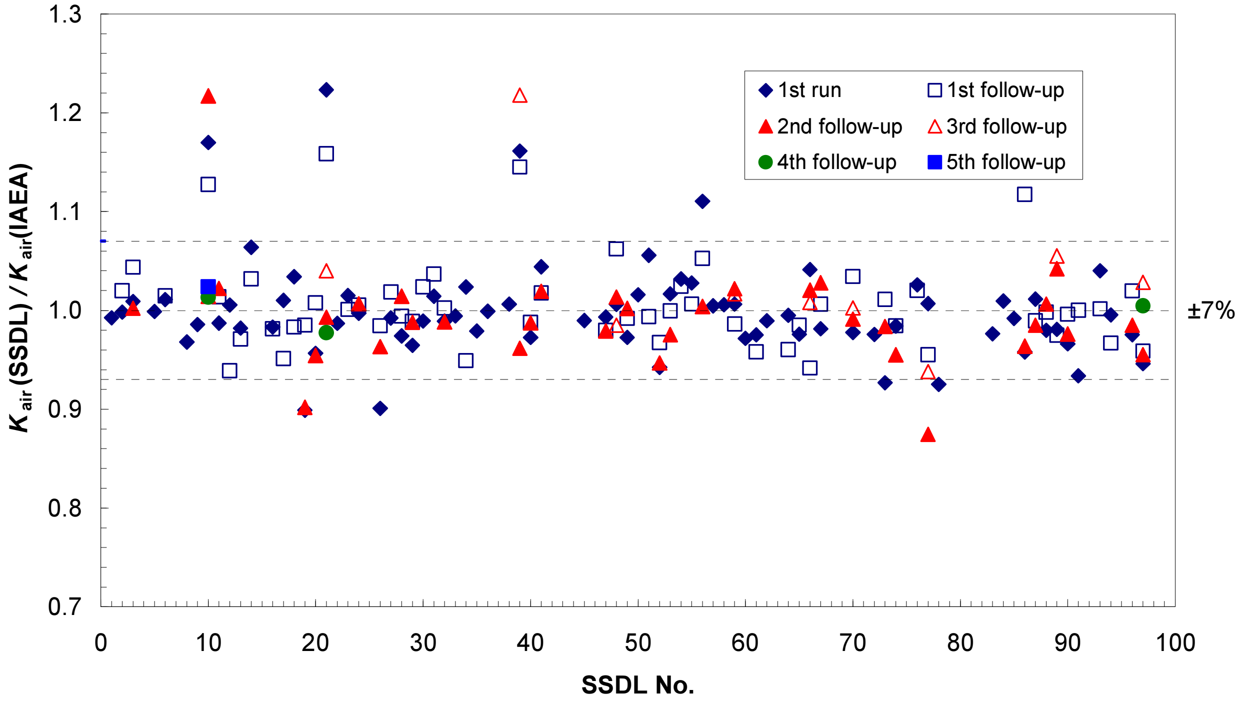

FIG.5: Ratios of the air kerma stated by SSDLs to the TLD measured value at the Agency's Dosimetry Laboratory for runs at protection level in 1999-2008 (acceptance limit 7%[2]).

Selected PSDLs are also asked to irradiate dosimeters for quality control purposes. These dosimeters are used as an independent check of the IAEA measurement system. Two PSDLs (BEV and OMH) provided reference irradiations for the 2007 and 2008 runs. The IAEA/PSDL ratio was 1.021 ± 0.004 (k=2). The results by BEV and OMH have not been corrected for the difference in standards between the PSDLs and the BIPM to which the IAEA is traceable.

5 Quality audits in radiotherapy dosimetry (Recurrent Project 2.2.4.1)

5.1 The IAEA/WHO TLD postal service

In 2007–2008, the IAEA/WHO TLD postal dose audit service for hospitals continued its previous development by improving the organization and efficiency of the service. At present the number of hospital beams monitored is approximately 500 per year. Due to the efforts of the IAEA, the return rate of the irradiated dosimeters has been maintained at approximately 95% level; however area for improvement exists, in particular in Latin America.

During this review period, the TLD programme audited 1035 beams in 468 radiotherapy centres in 78 countries. The global results are shown in Figure 5. Approximately 93% of the results were found within the acceptance limit of 5%. All results outside the acceptance limit were followed-up in order to resolve discrepancies and correct errors in dosimetry.

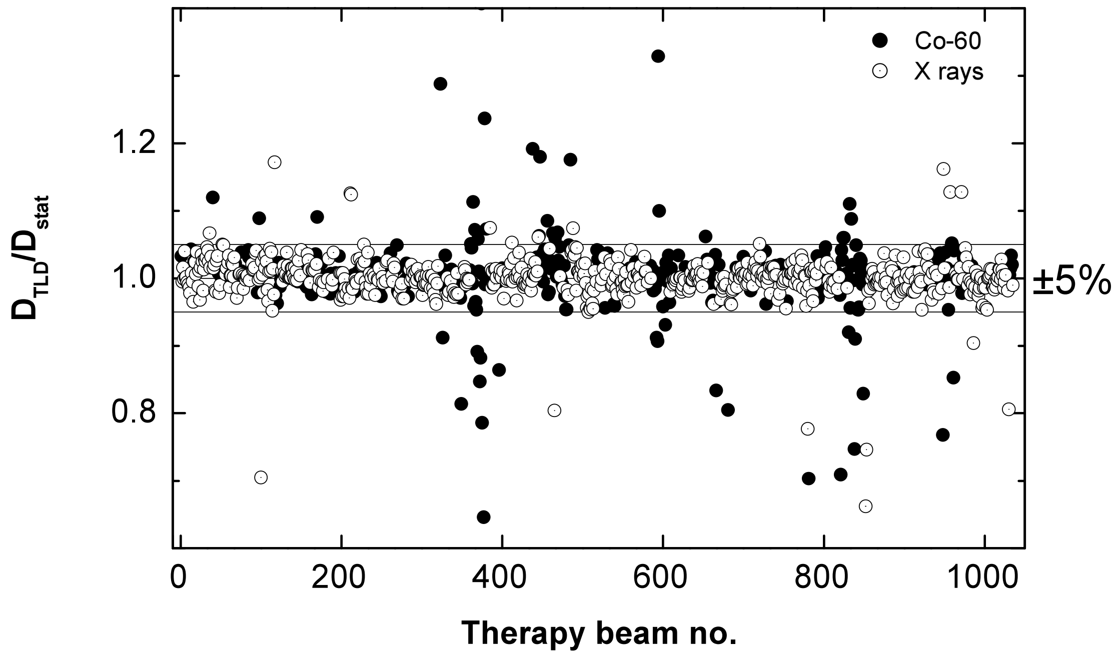

FIG. 6: Results of the IAEA/WHO TLD postal dose audits of radiotherapy hospitals for the delivery of absorbed dose to water under reference conditions for TLD batches B180 to B200 (from December 2006 to December 2008). Data in the graph correspond to ratios of the IAEA's determined dose (D_{TLD}) relative to the dose stated by the hospital (D_{stat}). Each data point corresponds to the average of two dosimeters. A total of 1035 beam calibrations were checked in 468 hospitals, which included 389 ^{60}Co (black dots) and 646 high energy X ray beams (open circles). Approximately 7% of the results were found outside the 5% acceptance limit. Of these, 3% were corrected by April 2009 due to subsequent follow-up action or by expert visits.

Thanks to the follow-up action, the percentage of acceptable results increased from 93% to 96% in 2007–2008, leaving approximately 4% of the results that have not been corrected. Of these 4%, 3% of the cases pertain to on-going follow-up action (not completed by April 2009) with the follow-up TLDs that are still expected to be returned from hospitals. The remaining 1% of the deviations persists due to local problems that could not be resolved without the allocation of additional resources.

The percentage of acceptable results for ^{60}Co beams is relatively low (87%) compared to 97% acceptable results for high energy X ray beams (see Figure 4). Many ^{60}Co units are obsolete machines awaiting replacement. They are often operated without properly qualified medical physicists. Occasionally, the physics support exists, but dosimetry systems are not available.

At present, the main focus in the TLD programme is given to expanding the service to new hospitals since the number of radiotherapy facilities in the world continues to increase. In 2007–2008, 131 additional radiotherapy centres joined the TLD network. Approximately 90% of the beam checks in hospitals that received TLDs for the first time showed results within the 5% acceptance limit, while 94% of the beam checks in institutions that benefited from a previous TLD audit had results within the 5% limit. The percentage of institutions that get results beyond the 10% limit is very high for the new hospitals (7%) compared to those having participated in previous audits (4%).

To provide appropriate QA for the TLD system, in addition to contacts with BIPM and PSDLs, systematic collaborations with other TLD-based QA networks in Europe and USA are maintained.

In order to foster independence, the IAEA assists Member States to establish national TLD programmes and whenever possible, establishes links between these national programmes and the IAEA's Dosimetry Laboratory. A Coordinated Research Project (CRP E2.40.12) run in 2001-2006 for national TLD audits in non-reference conditions is followed with a new CRP "Development of a TLD based quality audits for complex treatment techniques", which deals with TLD audits of irregular MLC shaped and small fields.

5.2. Quality Assurance team for Radiaiton Oncology (QUATRO)

In order to optimize clinical outcomes, it is equally important that the clinical aspects as well as the physical and technical aspects of patient treatment are audited, because, though essential for the radiotherapy process, accurate beam dosimetry and treatment planning alone cannot guarantee the required outcome of patient's treatment. The comprehensive audit methodology is described by the IAEA publication "Comprehensive Audits of Radiotherapy Practices: A Tool for Quality Improvement". The IAEA audit methodology, also known as Quality Assurance Team for Radiation Oncology (QUATRO) methodology, puts emphasis on radiotherapy structure and process rather than treatment outcome. It includes assessment of infrastructure as well as of patient-related and equipment-related procedures involving radiation safety and patient protection aspects, where appropriate. Staffing levels and professional training programmes for radiation oncologists, medical radiation physicists and radiation therapists are also reviewed.

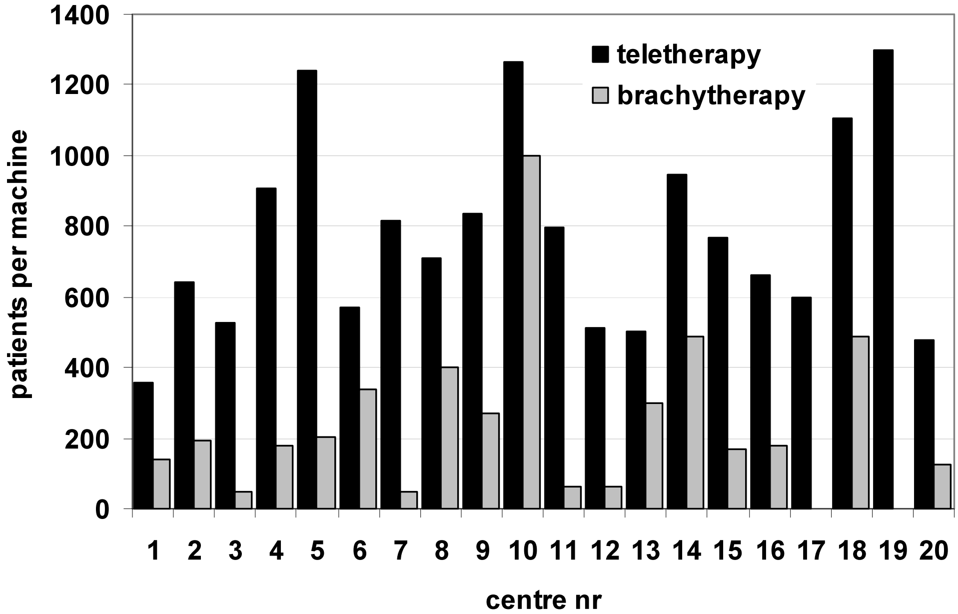

FIG. 7: Patient throughput on radiotherapy machines in 20 radiotherapy centres of Central and Eastern Europe participating in the IAEA QUATRO audits. Equipment shortages in some centres have been addressed by the national governments following the QUATRO audits.

6. Quality Assurance & Guidelines for Medical Physics in the Optimization of Clinical Radiation Imaging (Project 2.2.4.3)

This new project continues to establish within the IAEA the contribution of imaging sciences in radiation medicine. One component of this activity includes the development adoption of quality assurance guidelines for optimised and safe use of medical radiation including QA manuals for complex equiment including: PET and PET/CT systems (in preparation), SPECT systems (in preparation), screen-film mammography (in publication), digital mammography and computed tomography (in preparation). Work in collaboration with international organisations such as WHO is developing and would include a focus on countries at a basic level of health care. The role of digital technologies is also to be investigated in this context.

One major step forward in the promotion and review of quality assurance and optimisation has been the development of a clinical audit guide for diagnostic radiology (in publication) to allow the assessment of health care in radiology in basic and advanced environments. This guideline has been piloted in two countries to date and is ready for implementation.

The provision of education for medical physicists in radiation imaging is continuing with development of the Handbooks in diagnostic radiology and in nuclear medicine. Development of clinical training guides for these disciplines is also in progress.

7. Quality Assurance and Medical Phyics Developments in Radiotherapy and Therapeutic Nuclear Medicine (Project 2.2.4.4)

The objectives of this project focus on enhancing the capability of Member States to develop new techniques, methodologies and training materials for quality assurance and medical physics activities for radiation treatment in Member States. This is achieved through Coordinated Research Projects (CRPs), convening conferences and meetings, publishing research results, maintaining computer databases, developing and implementing training courses in QA, and disseminating information through electronic media. The implementation of the project supports increasing the scientific and technical capacity in medical radiation physics worldwide by fostering research and development and playing a role in the education of medical physicists.

A new guidance document, *Setting up a Radiotherapy Programme: Clinical, Medical Physics, Radiation Protection and Safety Aspects,* was published in 2008 to support the development of radiotherapy centres in Member States. This work was complemented with the publication of two technical documents providing guidance for the effective implementation of advanced treatment modalities, such as 3-dimensional conformal radiotherapy and intensity modulated radiotherapy (IMRT). Educational programmes on the use of the above mentioned technologies have been made possible through workshops and courses organized by the Agency's Technical Cooperation Programme and through collaboration with the International Centre for Theoretical Physics, the American Association of Physicists in Medicine and the European Federation of Organizations for Medical Physics. Such programmes have included training opportunities for about 100 medical physicists, coming from diverse regions of the world.

A new activity was initiated in 2007-2008, related to developing guidelines for dosimetry measurements for small and irregular fields used in radiotherapy. A series of consultants' meetings are being conducted to develop a new dosimetry code of practice which will serve as a complement to TRS-398 and will be addressed to those users of modern technology (radiosurgery, tomotherapy, microMLCs, IMRT) who are not able to calibrate the beams in the reference conditions as these are not available on their machines. This activity is being conducted in consultation with NGOs, which develop similar dosimetry protocols.

The recent advancements in radiotherapy - related technology have been significant, including complex treatment and imaging modalities. However, independent of the level of technological sophistication, accuracy in radiation therapy and the means by which it is achieved and maintained remain crucial to the process. Recognising that there are issues related to radiation treatment uncertainties, a new activity was initiated in 2008 focusing on analysis of accuracy requirements and uncertainties in radiation therapy. It involves convening a series of consultants' meetings and will lead to developing a publication on the factors contributing to uncertainties in dose delivery in radiotherapy with the purpose of reducing these uncertainties for safer and more effective patient treatments.

In the area of nuclear medicine physics, proper image acquisition and internal dosimetry methods were developed to support CRP E1.30.33 on the clinical use of Lu-177-EDTMP for bone pain palliation. Since Lu-177 is not commonly used in most nuclear medicine practises, novel protocols were established for the participants of this CRP. Special care had to be taken since this radiopharmaceutical was to be delivered in therapeutic amounts.

8. Coordinated Research Projects

Table 1 provides a compilation of the CRPs within the Subprogramme that were operational during the reporting period.

TABLE 1. Coordinated Research Projects (CRPs) in dosimetry, operational in 2007–2008.

Year of commencement	CRP code and title	Year of completion	Participating institutions
2004	**E2 40 13:** Development of procedures for quality assurance for dosimetry calculations in radiotherapy	2008	7
2004	**E2.40.14:** Development of procedures for *in vivo* dosimetry in radiotherapy	2007	8
2004	**E2.10.05:** Harmonization of quality practices for nuclear medicine radioactivity measurements	2008	8
2005	**E2.10.06:** Testing of the implementation of the Code of Practice for dosimetry in X-ray diagnostic radiology	2008	11
2008	**E2.40.15:** Doctoral CRP on Quality Assurance of the Physical Aspects of Advanced Technology in Radiotherapy	2013	9

E2.40.13: CRP on the development of procedures for quality assurance for dosimetry calculations in radiotherapy:

The objective of the CRP is to create a set of simple and practical tests for verification of dosimetry calculations, defined in a dedicated protocol, which can be followed at hospitals with limited resources. With the introduction of more sophisticated radiation treatment techniques, this set of basic tests should be extended to guarantee the safe and consistent implementation of the advanced techniques. The practicability of the developed quality assurance guidelines will be assured through trial use in clinical facilities of varying size. Reduction of extensive published quality assurance recommendations to a QA programme that is feasible in hospitals with limited resources will be achieved without loss of comprehensiveness by appropriate and optimized division of effort between treatment planning system vendors and hospital staff. The expected outputs will be an increase in the safe use of radiation therapy treatment planning systems for external beam therapy and reduction of the number of potential mis-administrations of the dose to patients undergoing radiotherapy treatments.

E2.40.14: CRP on the development of procedures for *in vivo* dosimetry in radiotherapy:

This CRP was completed in 2007. It had an emphasis on patient dose studies, evaluating the clinical value of *in vivo* dosimetry and comparing different techniques for *in vivo* dosimetry in a clinical setting. Phantom studies to characterize new dosimeters and develop the relevant methodology complemented the patient studies. In order to determine efficacy under the local conditions in Member States, established dosimetry methods based on TLD and semiconductor diodes were compared to new devices based on MOSFET and OSL technologies.

The outputs of this CRP contributed to increased expertise in radiation dosimetry in the clinical environment leading to increased precision of treatment delivery, better detection of systematic errors and the prevention of radiation accidents in radiotherapy.

E2.10.05: CRP on the harmonization of quality practices for nuclear medicine radioactivity measurements:

This CRP was completed in 2008. It aimed at harmonizing nuclear medicine radioactivity measurement practices in Member States and extended radioactivity calibration and auditing services to end users in their country. Protocols for the comparison and auditing of measurement results between secondary laboratories, the Agency, and end users were produced. International comparisons of measurements of I-131 activity (CCRI(II)-S6.I-131) was facilitated and the results published in Zimmerman et al, 2008. Similar comparisons were made for measurements of Co-57 radioactivity. The results of this, as well as national comparisons of Tc-99m measurements, were compiled and are expected to be published in scientific journals. Additionally, a greater knowledge of factors that influence the quality of radioactivity measurements by end users was identified so that improvements can be made. The result of following the established protocols will be an overall increase in the safety and efficacy of nuclear medicine practice in participating Member States.

E2.10.06: CRP on the testing of the implementation of the Code of Practice for dosimetry in X ray diagnostic radiology at SSDLs and hospitals:

The objective of the continuation CRP was to test the implementation of the Code of Practice for dosimetry in X ray diagnostic radiology (TRS 457) that was developed under CRP E2.10.03. The CRP focussed on: 1) Testing the establishment of calibration facilities for diagnostic X rays and the calibration of selected instruments. and 2) Testing measurement procedures with phantoms and on patients in hospitals. The results, which will be published as a TECDOC, showed that the instruction given by TRS457 for implementation at SSDLs was generally suitable. Similarly the work on clinical dosimetry was able to be implemented by the participating countries. The significant areas of interested focused around the use of relevent (new) beam qualities for calibration. Firstly the area of mammography was identified, where digital mammography has introduced new filter and target materials also operating at higher tube potentials to those currently specified. Secondly the use of KAP meters was highlighted, particularly in view of its energy dependance, and its consequently more serious concerns about relevant beam qualities for calibration. At least 4 papers so far have been published by participants relating to the work of the CRP. A future CRP in this area is recommended and is scheduled to begin in 2010 with recommended areas of interest to include dosimetry measurements for CT, calibration of KAP meters, conversion factors for organ and tissue dose and the effect of size on dosimetric outcome.

E2.40.15: Doctoral CRP on Quality Assurance of the Physical Aspects of Advanced Technology in Radiotherapy

The objective of this project is to enhance the capability of Member States to implement advanced radiotherapy treatments with curative intent, such as IMRT, stereotactic radiosurgery (SRS), image-guided radiotherapy (IGRT) et cetera, by training a number of medical physicists at the Ph.D. level with research and clinical capability.

9. Training courses

The Dosimetry and Medical Radiation Physics Section placed considerable emphasis on organizing training courses and coordinating fellowships for medical radiation physicists and staff from SSDLs within the framework of IAEA Technical Cooperation projects.

The courses and workshops held during 2007–2008 were as follows:

2007

ESTRO/IAEA Teaching Course on Radiotherapy Treatment Planning: Principles and Practice, Dublin, Ireland

IAEA/ESTRO Teaching Course on Dose Calculation and Verification for External Beam Therapy, Bruxelles, Hungary

IAEA/RCA Regional Training Course on 3D Conformal Radiotherapy and QA (Imaging and Treatment Planning) - for Radiation Oncologists, Suita, Japan

IAEA/ESTRO Teaching Course on 3D Planning and Imaging, St. Petersburg, Russian Federation

National Training Course on Basic Diagnostic Radiology Medical Physics and National Symposium on QA in Radiology, Sarajevo, Bosnia and Herzegovina

Regional Training Course for the IAEA/TRS-430 Implementation: Quality Assurance in TPS, Bogotá, Colombia

Regional (AFRA) Training Course on Dosimetry, QA/QC, Patient and Personnel Safety in Brachytherapy, Johannesburg, South Africa

Regional (AFRA) Training Workshop on Medical Internal Dosimetry Relevant to Nuclear Medicine, Tunis, Tunisia

ESMP Training Course on Medical Imaging with Ionising Radiation, Archamps, France

Regional Training Course on Implementation of IAEA TRS 430 in Quality Assurance for Radiotherapy Treatment Planning Systems, Gliwice, Poland

Regional (AFRA) Training Workshop on Commissioning of Linear Accelerators, Alger, Algeria

IAEA/RCA Regional Training Course on the Implementation of the International Code of Practice for Radiotherapy Dosimetry, IAEA TRS-398, Singapore, Singapore

Regional (AFRA) Training Course on Performing an Acceptance Test of a Dual-Head Gamma-Camera, Seibersdorf, Austria

2008

Regional (AFRA) Training Course on Therapeutic Nuclear Medicine Dosimetry for the Medical Physicist, Durban, South Africa

Regional Training Course on implementation of IAEA TRS 430 in quality assurance for Radiotherapy Treatment Planning Systems., Riyadh, Saudi Arabia

IAEA/ESTRO Teaching Course on Dose Calculation and Verification for External Beam Therapy, Dublin, Ireland

Regional (AFRA) Training Course on In-vivo Dosimetry Techniques in Radiotherapy, Tripoli, Libyan Arab Jamahiriya

IAEA/RCA Regional Training Course on 3D Conformal Radiotherapy and QA - Part I (for Radiation Oncologists), Bangkok, Thailand

ESTRO Teaching Course on Radiotherapy Treatment Planning: Principles and Practice, Dublin, Ireland

Regional (AFRA) Training Course on Nuclear Cardiology for the Medical Physicist, Abuja, Nigeria

National Training Course for Quality Assurance in Diagnostic Radiology and Radiology Symposium, Banja Luka, Bosnia and Herzegovina

IAEA/ESTRO Teaching Course on Basic Clinical Radiobiology with Russian translation , St. Petersburg, Russian Federation

Regional (AFRA) Training Course on Networking Technologies and Related QA in Radiation Oncology Departments, Rabat, Morocco

Workshop on Quality Assurance in Radiotherapy, Jakarta, Indonesia

IAEA/RCA Regional Training Course on 3D Conformal Radiotherapy and QA - for Medical Physicists, Singapore, Singapore

Training Course on Performing an Acceptance Test of a Dual-Head Gamma-Camera, Seibersdorf, Austria

IAEA/RCA Regional Training course on 3D Conformal Radiotherapy -QA for Imaging and Treatment Planning (with focus on gastrointestinal, genitor-urinary and cervix cancer), Mumbai, India

Diagnostic radiology: Quality assurance and radiation protection for patients, Sao Paulo

IAEA/RCA Regional Training Course on Medical Physics in Diagnostic Radiology, Manila, Philippines

10 IAEA publications in dosimetry and medical radiation physics

Below is the list of publications that appeared in 2007–2008. In addition to the titles below, 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. A list of Non-IAEA publications authored or co-authored by staff members of the DMRP Section during 2007–2008 is given in the Appendix.

2007

- Dosimetry in Diagnostic Radiology: An International Code of Practice (Technical Reports Series No. 457) (STI/DOC/010/457).
- Comprehensive Audits of Radiotherapy Practices: A Tool for Quality Improvement. Quality Assurance Team for Radiation Oncology (QUATRO) (STI/PUB/1297).
- On-site Visits to Radiotherapy Centres: Medical Physics Procedures (TECDOC-1543).
- Specification and Acceptance Testing of Radiotherapy Treatment Planning Systems (TECDOC-1540).

- SSDL Newsletter No. 53. January 2007
- SSDL Newsletter No. 54. October 2000

2008

- Transition from 2-D Radiotherapy to 3-D Conformal and Intensity Modulated Radiotherapy (TECDOC-1588).
- Setting up a Radiotherapy Programme: Clinical, Medical Physics, Radiation Protection and Safety Aspects (STI/PUB/1296).
- Commissioning of Radiotherapy Treatment Planning Systems: Testing for Typical External Beam Treatment Techniques. Report of the Coordinated Research Project (CRP) on Development of Procedures for Quality Assurance of Dosimetry Calculations in Radiotherapy (TECDOC-1583).
- Measurement Uncertainty: a practical guide for Secondary Standards Dosimetry Laboratories (TECDOC-1585)

11 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, last published in 1968. The present electronic version of the Directory of Radiotherapy Centres (DIRAC) includes data on teletherapy machines, sources and devices used in brachytherapy, and on equipment for dosimetry, treatment planning systems and quality assurance. Staff strength at the installations (radiation oncologists, medical physicists, technicians, etc.) is included as well.

The present electronic version of DIRAC is equipped with an on-line web interface (http://www-naweb.iaea.org/nahu/dirac/). The remote users are given active access to DIRAC that enables any necessary modifications and updates of the information regarding their radiotherapy centres. Thus the DIRAC database is being continuously updated, based on on-line completion of the electronic questionnaires by radiotherapy centres. At the same time other sources of information are used and data obtained from the existing registries are compiled.

At present DIRAC is the only centralized database that describes the capacity for delivery of radiation therapy worldwide. It encompasses approximately 90% of the existing radiotherapy facilities and constitutes an important source of information for the analysis of provision of radiation therapy in the world and for estimating the needs for radiotherapy facilities in the various regions or countries.

Appendix: Non-IAEA publications authored or co-authored by staff members of the IAEA Dosimetry and Medical Radiation Physics (DMRP) Section, 2007–2008

2007

McLEAN, I.D., HEGGIE, J.C.P., HERLEY, J., THOMSON, F.J., GREWEL, R.K., Interim recommendations for a digital mammography quality assurance program. Australasian Physical & Engineering Sciences in Medicine **30**(2) 65-100 (2007).

IZEWSKA, J., GEORG, D., **BERA, P.**, THWAITES, D., ARIB, M., SARAVI, M., SERGIEVA, K., LI, K., GARCIA YIP, F., MAHANT, A.K., BULSKI, W., A methodology for TLD postal dosimetry audit of high-energy radiotherapy photon beams in non-reference conditions, Radiotherapy and Oncology, **84**, 67-74 (2007).

THIERRY-CHEF, I., MARSHALL, M., FIX, J.J., BERMANN, F., GILBERT, E.S., HACKER, C., HEINMILLER, B., MURRAY, W., PEARCE, M.S., UTTERBACK, D., BERNAR, K., DEBOODT, P., EKLOF, M., GRICIENE, B., HOLAN, K., HYVONEN, H., KEREKES, A., LEE, M-C., MOSER, M., **PERNICKA, F.**, CARDIS, E., The 15-country collaborative study of cancer risk among radiation workers in the nuclear industry: study of errors in dosimetry, Radiation Research, **167**, 380-395 (2007

2008

IZEWSKA, J., HULTQVIST, M., **BERA, P**., Analysis of uncertainties in the IAEA/WHO TLD postal dose audit system, Radiat. Meas., **43**, 959-963 (2008).

ZIMMERMAN, B.E., **MEGHZIFENE, A**., SHORTT, K.R., Establishing measurement traceability for national laboratories: Results of an IAEA comparison of ^{131}I, Appl. Radiat. Isot., **66**, 954-959 (2008).

SHORTT, K., DAVIDSSON, L., HENDRY, J., DONDI, M., ANDREO, P., International perspectives on quality assurance and new techniques in radiation medicine: outcomes of an IAEA conference, Int. J. Radiation Oncology Biol. Phys., **71**, No. 1, Supplement, S80-S84 (doi:10.1016/j.ijrobp.2007.07.2390) (2008).

ROSS C.K., SHORTT K.R., SARAVI M., **MEGHZIFENE A**., TOVAR V.M., BARBOSA R.A., DA SILVA C.N., CARRIZALES L., SELTZER S.M, SIM 60Co air-kerma comparison SIM.RI(I)-K1, *Metrologia*, 2008, **45**, *Tech. Suppl.*, 06010

ROSS C.K., SHORTT K.R., SARAVI M., **MEGHZIFENE A**., TOVAR V.M., BARBOSA R.A., DA SILVA C.N., CARRIZALES L., SELTZER S.M., SIM 60Co absorbed-dose-to-water comparison SIM.RI(I)-K4, Metrologia, 2008, **45**, Tech. Suppl., 06011

LEE, J.H., HWANG, W.S., KOTLER, L.H., WEBB, D.V., BÜERMANN, L., BURNS, D.T., TAKEYEDDIN, M., SHAHA, V.V., SRIMANOROTH, S., **MEGHZIFENE, A**., HAH, S.H., CHUN, K.J., KADNI, T.B., TAKATA, N., MSIMANG, Z., APMP/TCRI key comparison report of measurement of air kerma for medium-energy x-rays (APMP.RI(I)-K3), Metrologia, 2008, **45**, Tech. Suppl., 06012.

ALFONSO, R., **ANDREO, P.**, CAPOTE, R., SIFUL HUQ, M., KILBY, W., KJÄLL, P., MACKIE, T.R., PALMANS, H., ROSSER, K., SEUNTJENS, J., ULLRICH, W., **VATNITSKY, S.,** A new formalism for reference Dosimetry of small and nonstandard fields, American Association of Physicists in Medicine, Nov. 2008, 35 (11) 5179

GERSHKEVITCH, E., SCHMIDT, R., VELEZ, G., MILLER, D., KORF, E., YIP, F., WANWILAIRAT, S., **VATNITSKY, S.,** Dosimetric verification of radiotherapy treatment planning systems: Results of IAEA pilot study, Radiotherapy & Oncology, Elsevier Irland Ltd, 2008.07.007. Vol. 89, Issue 3.