ACTIVITIES OF THE DOSIMETRY AND MEDICAL RADIATION PHYSICS SECTION, IAEA

Report on Activities, 2009-2010

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1. 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 developments 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 to Member States: dosimetry calibration and dosimetry auditing. A Standing Advisory Group denominated "Scientific Committee of the IAEA/WHO Network of Secondary Standards Dosimetry Laboratories (SSDLs)", was established to review and evaluate the work of the DMRP. The 14th meeting of the Committee took place in Vienna from 16–19 March 2010; the report was published in the SSDL Newsletter No. 59 (April 2011). This report includes 4 appendices:

- Appendix 1: Coordinated Research Projects (CRPs) . This apendix lists all CRPs which are active during the reporting period.
- Appendix 2: Training courses. This appendix lists all courses organized or suported bt the IAEA in medical phsyics during the reporting period.
- Appendix 3: IAEA Publications in Dosimetry and Medical Radiation Physics. This appendix lists documents and reports published by the IAEA in medical phsyics during the reporting period.
- Non-IAEA publications authored or co-authored by staff members of the IAEA Dosimetry and Medical Radiation Physics (DMRP) Section.

2. Overview of Projects in Dosimetry and Medical Radiation Physics

During the period 2009–2010, DMRP's programme included four projects, with the titles as indicated, followed by the objectives in each case:

- Project 2.2.4.1: Quality audits in dosimetry for radiation medicine.

  Project objective: To ensure the quality of the entire dosimetric chain in Member States through an independent means of verification of the dose to be delivered to the patients during radiotherapy.

- Project 2.2.4.2: Radiation Metrology supporting the network of Secondary Standards Dosimetry Laboratories (SSDLs).

  Project objective: 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 2.2.43: Quality Assurance and guidelines for medical physics in the optimization of clinical radiation imaging

  Project objective: To establish and maintain high quality medical imaging capability for diagnosis and related treatment in Member States that follow 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.

  Project objective: To enhance the capability of Member States to develop new techniques, methodologies and training materials for dose auditing and quality assurance in medical physics for radiation treatment in Member States.

3. Services provided by the IAEA

The experimental dosimetry work is carried out at the Dosimetry Laboratory, which is attached to DMRP and is physically located 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:

- Calibration of ionization chambers (radiotherapy, diagnostic radiology including mammography, radiation protection).
  Radiation quality: X rays (10 - 300 kV) and gamma rays from ^{137}Cs and ^{60}Co.[1]
- Calibration of well-type ionization chambers for Low Dose Rate (LDR) brachytherapy.
  Radiation quality: gamma rays from ^{137}Cs.
- 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.
- TLD dose quality audits for radiation protection (for SSDLs).
  Radiation quality: gamma rays from ^{137}Cs and ^{60}Co.
- 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[2].

4. Quality Management 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

[1] The calibration serrvices in X-ray beams have been interrupted in 2009-2010, because of equipment replacement and laboratory renovation. The services was resumed as of October 2010.

[2] The CMCs for X raydiagnostci radiology calibrations are under preparation and will be submitted soon for approval. .

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. The JCRB “Resolution 17/1”; confirms acceptance of the DOL QMS. As a consequence, the DOL's calibration and measurement capabilities remain formally included in the BIPM Key comparison data base.

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.

DMRP submits an annual report on its DOL QMS to the JCRB.

5. The IAEA/WHO Network of Secondary Standards Dosimetry Laboratories (Project 2.2.4.2)

Membership in the IAEA/WHO SSDL Network is open to laboratories designated by their national competent authority. The network presently consists of 86 laboratories in 68 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, diagnostic radiology including 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. In 2008 and 2009, 87% and 77% of SSDLs submitted their annual report respectively. Reports for 2011 are in the submission process (55% at end of March 2011).

5.1 Traceability

The review of the SSDL annual report for 2009 shows that about 30% of SSDLs are traceable to the IAEA, whereas 18% are traceable to the BIPM (see Figure 1)

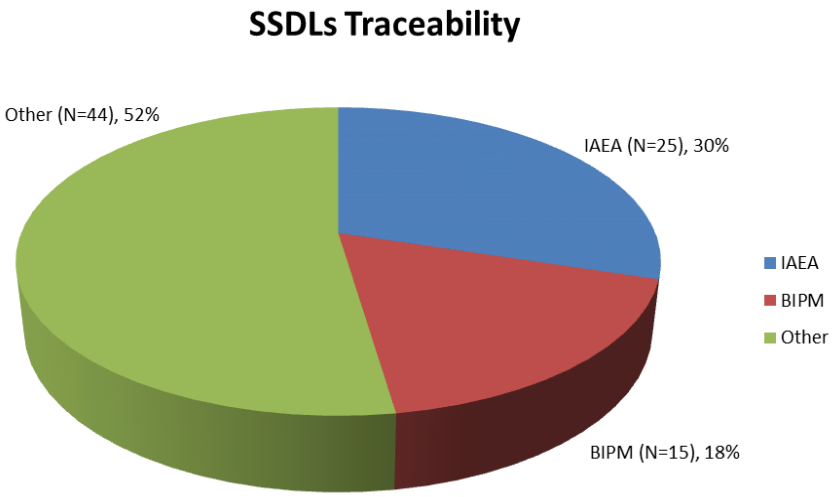

FIG. 1. Traceability in the IAEA/WHO Networtk of SSDLs

5.2 IAEA participation in comparisons

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

- SIM.R(I) – S1: Comparison of air kerma standards from radiation protection level Cs-137 and Co-60 gamma ray beams, report published
- APMP.RI(I)-K2: Comparison of air kerma standards from radiation protection level Cs-137 and Co-60 gamma ray beams, report in progress
- AFRIMETS.RI(I)-S1: IAEA support to AFRIMETS and participation in the comparison (in progress)

5.3 IAEA support to SSDLs

5.3.1 Preparation of guidance documents SSDLs

- *Calibration of reference dosimeters for external beam radiotherapy:* the document was published as Technical Report Series No. 469 in 2009.
- *Implementation of the International Code of Practice on Dosimetry in Diagnostic Radiology (TRS 457):* Review of testing results, Human Health Series, IAEA Vienna (in press).
- *Radiation protection calibrations at Secondary Standards Dosimetry Laboratories:* The update of IAEA Safety reports series No. 16 “Calibration of radiation protection monitoring instruments” (in progress).

5.3.2 Setting-up and upgrading of SSDLs

- Under its technical cooperation programme, the IAEA is assisting in the establishment of new SSDLs in Azerbaijan, Cote d'Ivoire, Kazakhstan, United Arab Emirates, Bahrain and Uruguay.

- The IAEA has been also assisting in upgrading SSDLs in Algeria, Bulgaria, Croatia, Cyprus, Cuba, Guatemala, Israel, Kenya, Macedonia, Nigeria, Phillipines, Saudi Arabia, Syria by introducing new calibration services and/or strengthening their quality system.

5.3.3 Calibration of national measurement standards

During 2009–2010, the IAEA calibrated 86 ionization chambers (see Figure 2), of which about 69% were for radiotherapy, 29% for radiation protection level dosimetry and 2% for brachytherapy. Most of the calibrations were done for SSDLs (92%). 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) and calibration benches. These activities required an interruption of the calibration service. During the refurbishment period, the IAEA provided support for the calibration services in X ray beams from SSDLs in low income countries.

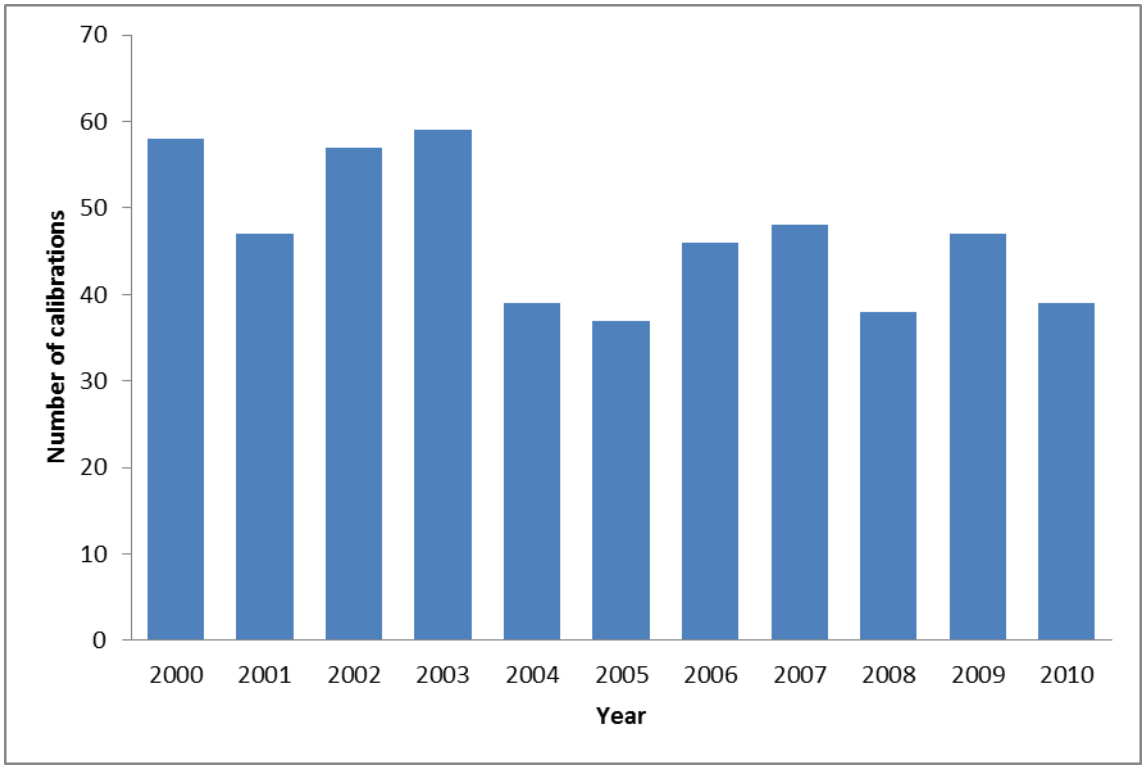

FIG. 2: Number of ionization chambers calibrated each year.

5.3.4 Calibration for diagnostic radiology

The first stage in this establishment has been the procurement of a 160 kV generator with three tubes (targets of tungsten, molybdenum and rhodium) with needed support equipment and the design of the facility including the calibration trolley, shielding cabinet and associated alignment, safety and control systems. This stage was guided by reference to TRS-457. The commissioning stage consisted of alignment of the beam for each tube, examining beam homogeneity and measurement of beam qualities.

Progress has been restrained by a number of technical problems with the equipment. Particularly, problems were experienced with the Mo and Rh tubes that could be traced to the characteristics of the focal spot of these tubes. The impact of penumbra on field homogeneity, once the difficult job of alignment was achieved, was larger than expected, and the importance of focal spot size and the

positioning of collimating apertures was not fully appreciated earlier in the design phase. Final beam characterization was achieved with the use of a scanning small volume ionization chamber.

The quality system for the new calibration services[3] is now under construction including details of service provision to the member states. In this we have been informed by the recent CRP on testing the Code of Practice for dosimetry for X ray diagnostic radiology. This work identified the need to expand the number of possible beam qualities used for mammography and also suggests that additional beam qualities may be needed for the calibration of KAP meters. However this only highlights the current large number of beams already specified in TRS-457 for the calibration of diagnostic radiology measurement equipment. It is clear that for routine calibration some advice should be given to the Member States to limit the number of beams needed for suitable calibration of user instruments. Clarification of this issue will not only benefit the work at the IAEA Dosimetry Laboratory, but also will be of use to SSDLs offering a similar service.

5.3.5 Comparison of ionization chamber calibration coefficients

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 an acceptance limit of 1.5%.

Ten SSDLs participated in the comparison programme (one of them with 2 chambers) during 2009-2010. Calibrations both in terms of air kerma and absorbed dose to water were included. The ratio 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 1.5%acceptance limit were identified (see Figure 3).

[3] Calibration services for X ray diagnostic radiology are not yet included in IAEA CMCs.

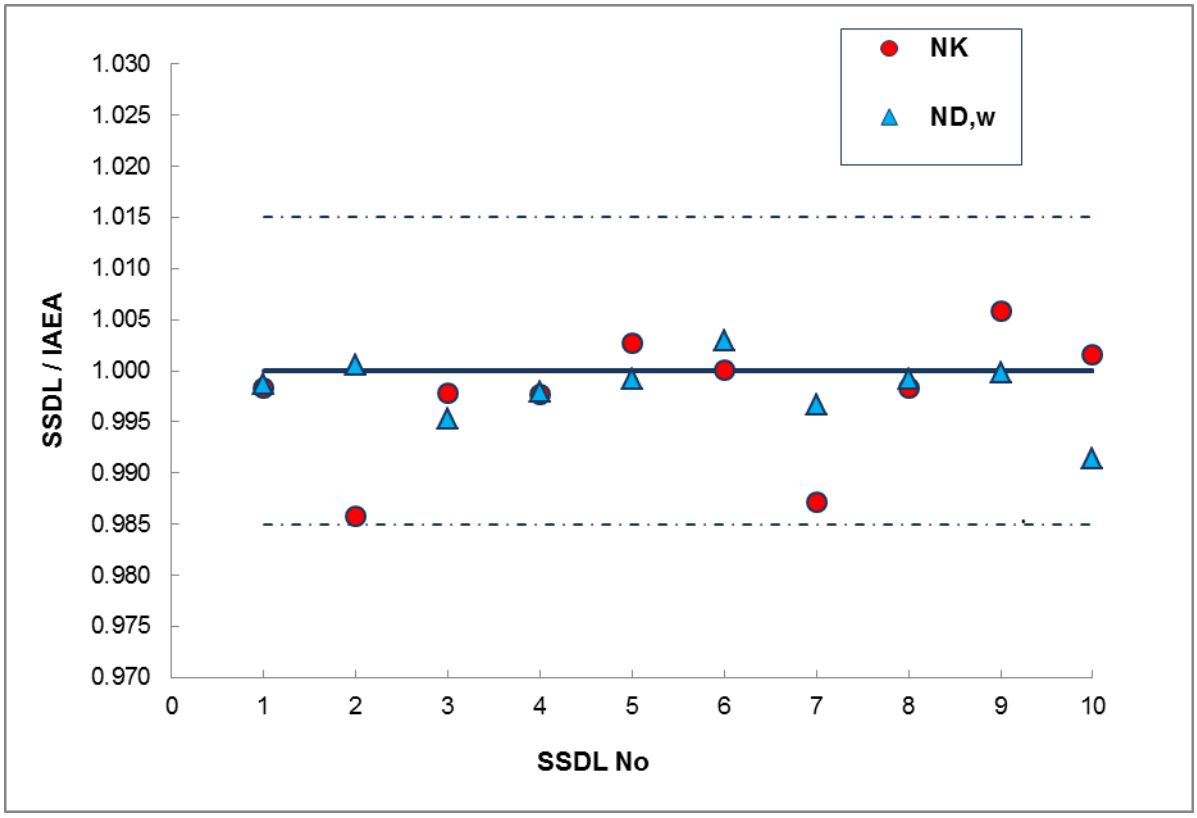

FIG.3. Results of comparison of radiotherapy chamber calibrations in 2009-2010. Ratios of ionization chamber calibration coefficients supplied by the SSDLs to those measured by the IAEA are corrected for differences in the standards of the BIPM and the PSDL to which the SSDLs were traceable. Circles correspond to air kerma calibration coefficients and triangles to absorbed dose to water factors. Results are considered acceptable if the deviation of the ratio from unity is less than 1.5%.

5.3.6 TLD-based monitoring of SSDL measurements

Therapy level

The IAEA/WHO TLD postal dose quality audit service has monitored the performance of 71 SSDLs in the therapy dose range since 1981. Results of this programme indicate that approximately 99% of 55 SSDLs that participated in the TLD audits in 2009-2010 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 4, where deviations from the IAEA's TLD results are plotted for ^{60}Co and high energy X rays. During the review period, two SSDL TLD runs (2009 and 2010) were completed, in which 105 beams were checked (89 ^{60}Co and 16 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.

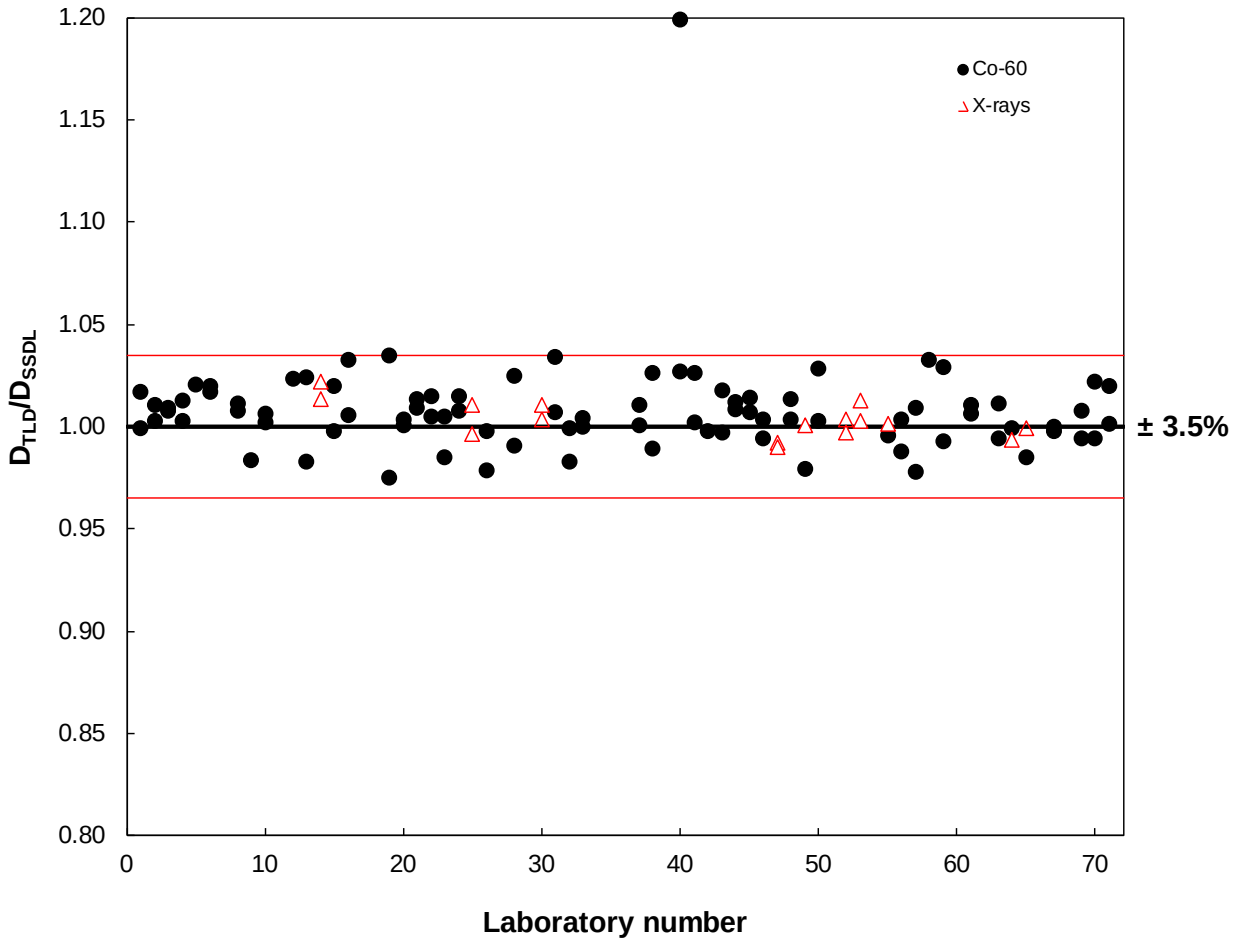

FIG. 4: Results of the IAEA/WHO TLD postal dose audits for SSDLs for the delivery of dose to water under reference conditions for the 2009 and 2010 TLD runs. Data in the graph correspond to the ratio of the IAEA's determined dose from the TLD-response (D_{TLD}) to that stated by the SSDL (D_{SSDL}). Each data point corresponds to the average of three dosimeters. A total of 105 beam calibrations was checked and included 89 ^{60}Co (circles) and 16 high energy X ray beams (triangles). The number of therapy beams checked in different TLD runs was: 54 beams in 2009 and 51 beams in 2010. One deviation was found outside the acceptance limit of 3.5% in 2009 TLD run that has been followed-up.

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 SSDLs. 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% are contacted and support is provided to resolve the discrepancies. As a routine, they are invited to participate again in the next run.

One TLD run was organized in 2009 and another one in 2010. Thirty SSDLs participated in these runs. During the 2009 run, four of the SSDLs irradiated with both ^{137}Cs and ^{60}Co beams with the rest only using ^{60}Co beams. Figure 5 shows that there were no deviations outside the acceptance limit in both runs. These results show that most SSDLs are capable of measuring air kerma for radiation protection calibration purposes within the 7% acceptance limit. During both runs, BEV irradiated dosimeters for quality control purposes. These dosimeters are used as an independent check of the IAEA measurement system. The

IAEA/BEV ratio was 0.992 ± 0.004 (k=2).

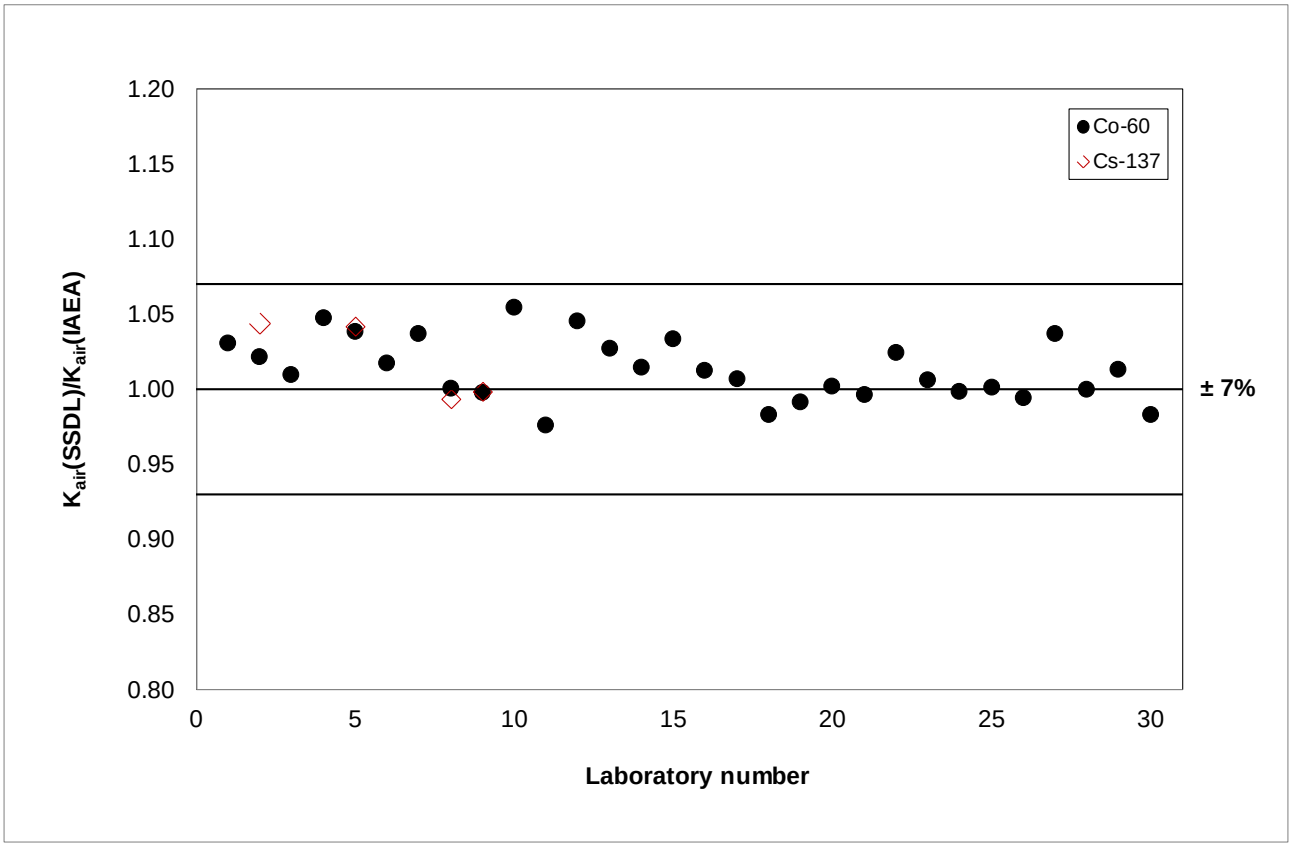

FIG.5: Results of the IAEA/WHO TLD postal dose audits for SSDLs of the air kerma stated by SSDLs to the TLD measured value at the Agency's Dosimetry Laboratory for runs at protection level in for the 2009 and 2010 TLD runs. Data in the graph correspond to the ratio of the air-kerma stated by the SSDL (K_{air}(SSDL) to that determined by the IAEA from the TLD-response (K_{air}(IAEA). Each data point corresponds to the average of three dosimeters.

6. Quality audits in radiotherapy dosimetry (Project 2.2.4.1)

6.1 The IAEA/WHO TLD postal service

In 2009–2010, the IAEA/WHO TLD postal dose audit service for hospitals continued its previous development by improving the organization of the service. At present the number of hospital beams monitored is approximately 500 per year. The return rate of the irradiated dosimeters remains similar to previous period, i.e. approximately 95%. Due to the efforts of the IAEA, there have been improvements in some countries of Latin America in terms of timely return of TLDs to the IAEA but there is still room for improvement in other countries.

During this review period, the TLD programme audited 992 beams in 485 radiotherapy centres in 83 countries. The global results are shown in Figure 6. Approximately 92% 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.

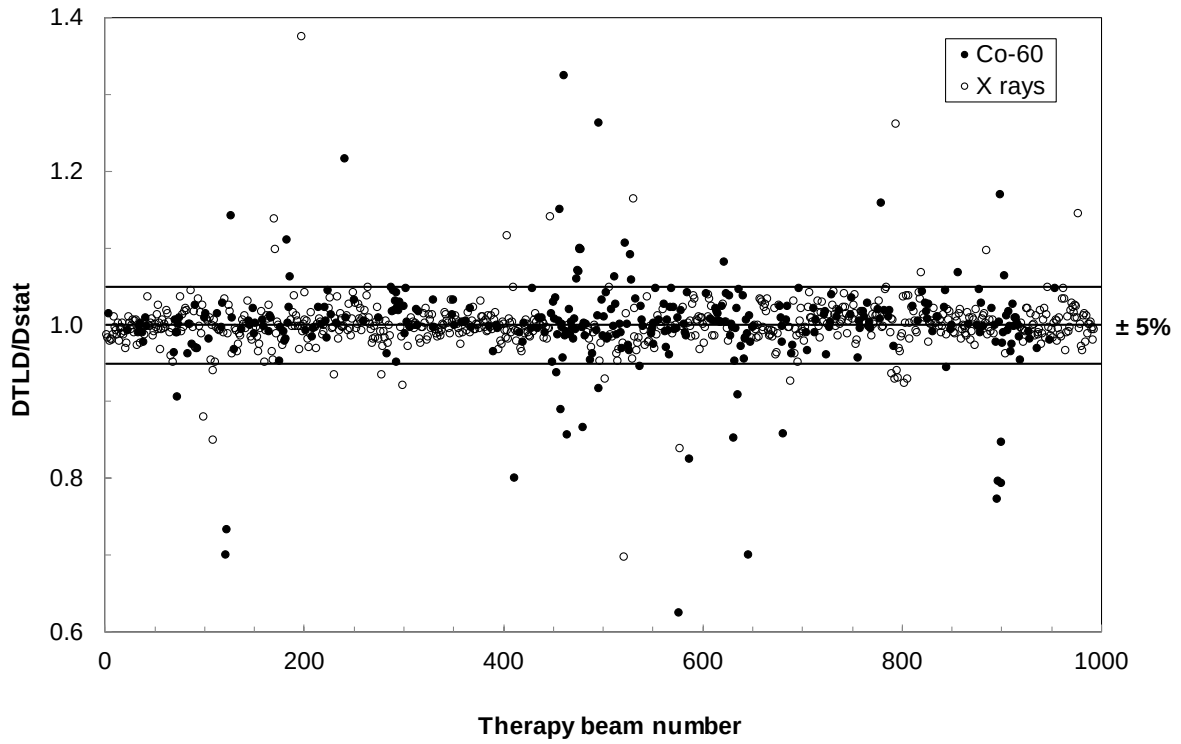

FIG. 6: Results of the IAEA/WHO TLD postal dose audits of radiotherapy hospitals for the delivery of absorbed dose to water under reference conditions for TLD batches B201 to B220 (from January 2009 to December 2010). Data in the graph correspond to ratios of the IAEA's determined dose (D_{TLD}) relative to the dose stated by the hospital (D_{stat}). Each data point corresponds to the average of two dosimeters. A total of 992 beam calibrations were checked in 485 hospitals, which included 332 ^{60}Co (black dots) and 660 high energy X ray beams (open circles). Approximately 8% of the results were found outside the 5% acceptance limit. Of these, 4% were corrected by March 2010 due to subsequent follow-up action or by expert visits.

Thanks to the follow-up action, the percentage of acceptable results increased from 92% to 96% in 2009–2010, 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 March 2011) 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 (86%) compared to 95% acceptable results for high energy X ray beams. Many ^{60}Co units are obsolete machines awaiting replacement. They are often operated without properly qualified medical physicists. Occasionally, the physics support exists, but reliable dosimetry systems are not available.

As the number of radiotherapy facilities in the world continues to increase, in 2009–2010, 130 additional radiotherapy centres joined the TLD network. Approximately 93% of the beam checks in hospitals that received TLDs for the first time showed results which are comparable to results from institutions that benefited from a previous TLD audit had results within the 5% limit. In a few countries, where structural inadequacies exist and medical physics training is deficient, recurrent deviations in TLD results are observed that cannot be resolved in a sustainable manner without the strong local commitment.

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 support sustainability, 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 E2.40.16) "Development of a TLD based quality audits for complex treatment techniques", deals with TLD audits of irregular MLC shaped fields and checks how treatment planning systems deal with the presence of heterogeneities.

6.2 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.

QUATRO has conducted over 50 audits on request, in radiotherapy centres from Central and Eastern Europe, Asia, Africa, and Latin America.

QUATRO audits aim to help radiotherapy centres attain the best level of practice possible for their country. Auditors identify gaps in technology, human resources and procedures, allowing the audited centres to document areas for improvement. Some centres have been acknowledged for operating at a high level of competence, while others have received a comprehensive set of recommendations. Overall, the audits have contributed to significant improvements at centres, and to identifying common issues of concern to address internationally. An example of this is the training of radiation therapists in Central and Eastern Europe, now being implemented through the IAEA's cooperation with the European Society for Therapeutic Radiology and Oncology (ESTRO).

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

The objective of this project is to establish and maintain high quality medical imaging capability for radiation imaging in Member States that follows appropriate standards in quality assurance and safety at the hospital with the use of qualified and clinically trained staff. This work was begun in the last programme cycle and now continues through publications on methodologies for improving medical radiation imaging, the testing of implementation including cooperative research projects, and the auditing procedures for diagnostic radiology and nuclear medicine. There is a focus on education through provision of material for academic teaching, clinical training and access to web based material.

7.1 Development of Guidelines for Quality Assurance/Quality Control Procedures to Maintain Image Quality in Diagnostic Radiology

The new International Basic Safety Standards (BSS) specifically mentions the role of the medical

physicist in dosimetry, calibration and quality assurance, with an increasing role in procedures that are complex and/or pose a greater radiation risk to the patient. Consequently it was seen as important to provide harmonized guidance for imaging modalities and especially for complex equipment that is associated with higher doses.

Human Health Series No. 2*, Quality Assurance for Screen Film Mammography* (2009)

The area of mammography was first addressed and Human Health Series No. 2 was published in 2009 to give this advice. It includes a section for clinicians, published with permission from the American College of Radiologists, as well as a section for technologists, in order to promote the multi-disciplinary approach to quality control that is essential for effective implementation.

Quality Assurance for Digital Mammography* and *Quality Assurance for Computed Tomography: Diagnostic and Therapy Applications

Similar documents on digital mammography and computed tomography (CT) have also been approved for publication and are in press. In the case of the CT document there is a section on quality assurance for therapy imaging, to support the use of the modality that is by far the most prevalent in the adaption of imaging to radiotherapy. It is anticipated that these documents, including interactive worksheet files that can be downloaded, will assist greatly in new clinical training programmes currently being piloted using newly developed documents. Additionally the new professional web site will allow communication of needed supplementary information as new advances in technology emerge.

Human Health Series No. 4, *Comprehensive Clinical Audits of Diagnostic Radiology Practices, A Tool for Quality Improvement: Quality Assurance Audit for Diagnostic Radiology Improvement and Learning (QUAADRIL)* (2010)

Another line of work in the area of quality assurance has been the development of clinical audit guidance for diagnostic radiology. This was developed by a team of physicists and radiologists, with the chair of the committee also involved in the drafting of European standards. The resulting document and attached files, states the standards for diagnostic radiology practice with assistance to the auditor and with a coordinated report format for rapid audit feedback to the audited institution. The material has been piloted at two centres and was published in January 2010. During 2010 a translation into Spanish was initiated. The relationship between clinical audit, the medical physicist and other modality QA programmes is easy to establish. There are a growing number of member states that have dedicated medical physicists in diagnostic radiology.

7.2 Develop Guidelines for Member States to Adopt Modern Technology in Order to Provide Basic Level Radiology Services (in Collaboration with WHO*)*

DMRP was invited to cooperate with WHO in the area of diagnostic radiology digital imaging as a result of the SSC-12 meeting in 2006. At this meeting, it was presented that the best form of help for member states at a basic level of radiology, was to provide an alternative for film based technology, with the introduction of digital technology. From this beginning a number of initial meetings have taken place to determine the form of assistance that might be useful in the member states and to understand the form of possible collaboration with WHO. It was agreed in 2009 that a meeting be held to investigate the need for a document on tele-radiology and digital imaging in conjunction with WHO and PAHO. This meeting strongly recommended that a guidance document be developed to cover the issues of digital imaging and communication, the core technical considerations and the implementation and sustainability of digital and communication technologies. This document is indeed now at a well-developed stage. Examples for three scenarios,

based on site connectivity, are to be included.

7.3 Dosimetry Code of Practice for Radiation Measurements in Diagnostic Radiology

An international Code of Practice (CoP) for dosimetry in diagnostic radiology has previously been established through TRS-457 to address dosimetry issues both at the SSDL and also in the clinical environment. A Coordinated Research Project (CRP E2.10.06) was developed to test the CoP. A technical document describing the work done under the CRP was accepted for publication in 2010. From this CRP it was seen that the advice to calibration laboratories found in TRS457 was sufficient to enable the development of the needed beam qualities for calibration of dosimetry standards and clinical instruments. It was found that the IEC defined beam qualities; however, do not adequately describe the needed set of beam conditions for reasonable clinical usage, with an extension of beam qualities required in mammography, and also for beams commonly used in interventional procedures. This is particularly relevant for the calibration KAP meters. Also of concern is the use of solid state detectors for beam qualities for which they are not calibrated. This can even cause concern in typical clinical beams where RQR type beams have additional filters, typically 0.1 or 0.2 mm Cu.

The advice and harmonization of dosimetric methodology was similarly found satisfactory for clinical application. However a need to extend the guidance material for CT equipment was identified, as the collection of dosimetric data is increasingly becoming specific to CT equipment type.

The CRP also identified areas of work that require further attention. These included calibration of KAP meters and CT chambers and associated inter comparisons. In the clinical area it was felt that the area of paediatrics, which is not specifically addressed in TRS-457, should be addressed, as well as the determination of organ doses, with the determination of skin dose being a prime example. A new CRP has been approved and began in 2010 to address these and other related issues.

7.4 Development of Procedures for Quality Assurance of Nuclear Medicine Radioactivity Measurements, Imaging Techniques and Instrumentation

The IAEA has been very active in promoting the use of nuclear medicine technology around the world, especially in developing countries, as an effective way of treating cancer. These efforts have been so successful that there are only a small number of countries worldwide that do not have at least some degree of nuclear medicine practice. As countries adopt these techniques, it is necessary for them to have a uniform, effective quality assurance (QA) programme that can ensure the quality of all nuclear medicine practices.

During the reporting period, the series of publications replacing the IAEA TECDOC-602 (Quality Control of Nuclear Medicine Instruments) from 1991 was completed. The TRS-454 (Quality Assurance for Radioactivity Measurement in Nuclear Medicine) from 2006 was followed by the Human Health Series No. 1 (Quality Assurance for PET and PET/CT Systems) and No. 6 (Quality Assurance for SPECT Systems) in 2009.

Human Health Series No. 1, *Quality Assurance for PET and PET/CT Systems* (2009)

This publication provides guidelines for the implementation of quality assurance and control programmes concerning the combined medical diagnostic modality of positron emission tomography (PET) and computed tomography (CT). These independent, but complementary, imaging techniques are in frequent and increasing use within the fields of diagnostic imaging, oncology, cardiology and neurology, where they allow physicians to locate and diagnose malignant

diseases accurately. This publication establishes guidelines for acceptance testing and routine quality control as necessary for optimal clinical performance. Specific topics of discussion include frameworks for reference values, tolerances and action levels, minimal required configurations with corresponding performances characteristics, and the management of ancillary equipment.

Human Health Series No. 6*, Quality Assurance for SPECT Systems* (2009)

The objective of this publication is to provide professionals in nuclear medicine centres with detailed quality control test procedures for the scintillation camera and computer system. Three types of quality tests are described in detail: acceptance, reference and routine tests for the scintillation camera, both in single and multiple head configurations, for obtaining images and quantitative data in planar imaging mode; whole body imaging mode; and single-photon emission computed tomography (SPECT). The publication is primarily intended to be of use to medical physicists, technologists, and other healthcare professionals who are responsible for ensuring optimal performance of imaging instruments, particularly SPECT systems. It may also be useful to managers, clinicians, and other decision-makers who are responsible for implementing quality assurance and quality control programmes in nuclear medicine centres.

Quality Control Atlas for PET/CT Systems

A new activity was initiated, aimed at producing a publication and database with artefact images from PET/CT. The format follows the "IAEA Quality Control Atlas for Scintillation Camera Systems" from 2003. The new publication will be an additional resource to the Human Health Series No. 1, and will ideally serve as an updated complement. Two CSs were held on this project under the reporting period.

International comparison on radioactivity measurement in nuclear medicine

CRP E2.10.05: “Harmonization of quality assurance practices for nuclear medicine radioactivity measurements" closed, as scheduled, in 2009. The main purpose of this CRP was to develop uniform codes of practice for radionuclide measurement at the end-user level that enable those measurements to be made in a way that would be traceable to national or international standards. At the same, guidance was to be developed for establishing and maintaining QA programmes in end-user laboratories in order to document the laboratories’ measurement capabilities.

The comparison studies carried in this project were unique in that the Agency had never previously piloted a comparison sanctioned by the Consultative Committee on Ionising Radiation, section II (Measurement of radioactivity) (CCRI(II)) of the Bureau International des Poids et Mesures (BIPM), which is the highest authority in international metrology for radioactivity. Moreover, they were the first CCRI(II) Supplementary Comparisons conducted in which the test sources were prepared and distributed by a commercial supplier directly to the participants and in which the pilot laboratory did not actually take part in the measurements. The Agency, acting as pilot, did receive assistance in all technical aspects by an experienced NMI, which eased CCRI(II) acceptance of the proposed comparisons. The results of the comparisons have been published in two papers and the formalized reports to the CCRI(II) are in preparation.

The most important outcome of these comparisons for the participants was the ability of the laboratories to establish and document measurement equivalence to each other for ^{131}I and ^{57}Co. It also allowed those laboratories not having an established standard for either of these nuclides to establish traceability to the national standard of another country. They also demonstrated that the Agency could effectively work as a liaison between the radionuclide metrology community and laboratories in the Member States.

Guidance document for radioactivity measurement at secondary standard and end user levels

Interacting with clinical measurement laboratories and potential SSRL members as part of the CRP provided valuable information regarding areas in which additional guidance is needed to improve the state of radionuclide measurement. In 2006, the Agency published Technical Report Series 454, "Quality Assurance for Radioactivity Measurement in Nuclear Medicine." This was the first such document that established the requirements for establishing an ISO-17025:2005 compliant radioactivity measurement laboratory in the field of nuclear medicine. This has proven to be a valuable resource for setting up and running QA programmes, but it became clear that more specific guidance regarding how to make the measurements and understand their results was needed.

In response, a new document has been drafted that contains simplified descriptions of the tests described in TRS-454 along with simplified forms that can be used to record the results of acceptance testing and quality control tests that should be performed in the clinic. In order to provide guidance for the clinical end user, a summary of the basic skills and equipment needed for proper radioactivity measurement is also given. Simplified treatments of statistical concepts relevant to clinical measurement, along with more advanced topics such as control charting and uncertainty budgeting are also provided at a level appropriate for both clinical application and use in the SSRLs. Finally, guidance is given on how to deal with the very important problem of making clinical measurements of radionuclides for which no calibration currently exists for the measurement instrumentation (dose calibrator). It is hoped that a final version will be published in mid-2011.

7.5 Quantitative Nuclear Medicine Imaging for Optimized Patient Specific Targeted Radionuclide Therapy

Over the past 15 years there has been a great deal of progress in development of methods for accurately quantifying nuclear medicine images. However, propagation of these methods into clinics has been slow. Nuclear medicine images can be used either for detection tasks, such as identifying perfusion defects, or quantitative tasks, such as estimating ejection fraction, standardized uptake values, or organ absorbed dose. Obtaining images that are suitable for quantitative tasks often requires additional processing compared to those used for visual interpretation. However, this additional processing often results in improved resolution and contrast and reduced artefacts. These improvements in the image can often, but not always, translate directly to improved performance on detection tasks. For example, the development of attenuation correction methods for cardiac SPECT has provided improved detection of myocardial perfusion defects, while at the same time providing quantitatively more accurate images.

As the technology for quantitative molecular imaging has become more mature the techniques have migrated from research institutions into clinical practice. Sites where resources are more limited are now able to be involved in projects requiring these imaging techniques. In order to ensure the best health care for people served by these sites it is timely to investigate the implementation of quantitative imaging at such sites to ensure the adoption of safe and sustainable healthcare at the highest level achievable within the limitations of the available resources.

CRP E2.10.07 (Quantitative nuclear medicine imaging for optimized patient specific targeted radionuclide therapy)

The overall objective of this project is to assist Member States in accurately determining radionuclide distributions for diagnostic and therapeutic nuclear medicine. The specific purposes are i) to develop and test quantitative imaging methods in nuclear medicine practice, and ii) to determine the accuracy with which radionuclide distributions can be quantified at a range of sites with various resources available.

The 6 agreement holders and 8 contract holders met in Vienna for the first in December 2009. A work plan was agreed upon, based on the commitment of NIST to produce standard phantoms containing Ge-68 (mimicking F-18) or Ba-133 (mimicking I-131). Detailed reporting forms were drafted and methodological issues discussed. Timelines and responsibilities for individual tasks were agreed upon.

7.6 Education and Training

7.6.1 Syllabus for Training of Medical Physicists in Diagnostic Radiology

The handbook for diagnostic radiology physics is nearing completion with 23 chapters covering all relevant areas of diagnostic radiology physics. This handbook, which complements the existing one for radiation oncology physics, is designed for MSc level academic programmes and will also be the primary text for the clinical training programme of diagnostic radiology medical physicists, currently under pilot testing (see Appendix 3).

7.6.2 Syllabus for Training of Medical Physicists in Nuclear Medicine

The handbook for nuclear medicine physics progressed with the assignment of four co-editors, each responsible for 5 chapters. Twenty-one chapter authors are committed to each write a chapter. At the end of the reporting period, extended outlines had been agreed upon for all chapters, and full drafts had been submitted by a majority of chapter authors (see Appendix 3).

7.6.3 Joint ICTP-IAEA School

In 2009, a Joint ICTP-IAEA Advanced School on Dosimetry in Diagnostic Radiology and its Clinical Implementation was held from 11 to 15 May at the International Centre for Theoretical Physics (ICTP) in Trieste, Italy, attended by 55 participants from all regions.

In 2010, a Joint ICTP-IAEA Advanced School in Internal Dosimetry for Medical Physicists Specializing in Nuclear Medicine was held from 12-16 April at the International Centre for Theoretical Physics (ICTP) in Trieste, Italy, attended by 40 participants from all regions.

7.6.4 Gamma-camera laboratory

The gamma-camera laboratory in Seibersdorf was equipped with additional instrumentation to prepare it for training in quantification and internal dosimetry calculations. The lab now hosts two gamma-cameras, anthropomorphic phantoms, micro-pipettes, analytical scale, dose calibrator and a NaI gamma-well counter. During the reporting period, two training courses for medical physicists were held on acceptance testing of a gamma camera and one course on internal dosimetry techniques. Such training is rare, since very few clinics would allow the extra time required on the cameras for training purposes.

The dosimetry committee of the European Association of Nuclear Medicine (EANM) visited the gamma-camera lab in 2009 and informal discussions were held on possible joint use for training courses on internal dosimetry.

8. Quality Assurance and Medical Physics Developments in Radiotherapy and Therapeutic Nuclear Medicine (Project 2.2.4.4)

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

The objectives of this project were primarily achieved through conducting CRPs, convening conferences and consultants' meetings, developing guidelines, publishing research results, maintaining computer databases, developing and implementing training courses in QA, and disseminating information through electronic media. Improvements in the physical and technical aspects of quality assurance in radiotherapy in Member States are sought by encouraging the adoption and use of Agency guidelines and recommendations. Through these developments, the project contributes to the creation of a quality assurance culture in all aspects of radiotherapy measurements and patient dosimetry, which, as a parallel effect, will improve radiation safety and effectiveness in hospitals in developing Member States. Collaboration with professional societies such as IOMP (Internatuonal Organization for Medical Physics), ESTRO (European Society for Therapeutic Radiology and Oncology), AAPM (American Association of Physicists in Medicine) and European Federation of Organizations for Medical Physics (EFOMP), is important in order to collaborate in the area of dosimetry and quality assurance and to benefit from early access to on-going projects. Specific achievements in this project are included in the following sections.

8.1 Small Field Dosimetry

An international working group was formed, in collaboration with the AAPM, with the aim of publishing an extension of existing Codes of Practice to provide recommendations on reference conditions and reference dosimetry procedures for small and composite fields. A first step in this direction was the publication of a proposed formalism in a peer-reviewed journal allowing for such an extension. The aim of the publication was to get the ideas of extended reference conditions out and to invite medical physicists and scientists worldwide to contribute to improved knowledge and understanding in this area by discussion and research. The working group met several times through conference calls to discuss the topic. There is a long way to go before the publication of a Code of Practice will be achieved. As a first step, the group is working on a draft IAEA publication that will focus on the dsoiemtry of small static fields.

8.2 Development of Guidelines for QA of Records and Verify Systems

In reviewing the avaialble documentation on this topic, it was recognized that there is very little information published on the quality assurance of record and verify systems. To this end a consultants meeting was held and the draft of a TECDOC on the acceptance, commissioning and QA of record and verify systems has been prepared and wil be published in 2011.

8.3 Development of Guidelines on Uncertainty Requirements in Radiation Oncology

While a number of reports and publications have defined accuracy needs in radiation oncology, most of these reports were developed in an era with different radiation technologies. In the meantime, there have also been improvements in dosimetry standards. Furthermore, the published accuracy requirements were partially based on clinical information and clinical procedures available at that time, prior to the days of image-based 3-D CRT or IMRT. In addition to technological changes and advances in dosimetry, significant data have been published on clinical studies using these new technologies. In view of the new technologies and techniques, improvements in dosimetry methodologies and new clinical dose volume data, a consulting group of experts recommended that the IAEA should develop a new international guidance document on accuracy requirements and uncertainties in radiation therapy in order to reduce these uncertainties to provide safer and more effective patient treatments. The development of the guidance document is done in collaboration with the ICRU.

8.4 International Symposium on Standards, Applications and Quality Assurance in Medical Radiation Dosimetry (IDOS)

The International Symposium on Standards, Applications and Quality Assurance in Medical Radiation Dosimetry (IDOS) was organized by the IAEA and held in Vienna from 9 to 12 November 2010 to foster the exchange of information along the whole dosimetry chain and highlight recent developments in this field. Three hundred and seventy two delegates representing 66 Member States, 45 observers and 12 international and professional organizations attended the meeting. Altogether, 75 oral presentations were delivered, 4 round table discussions were held and 187 posters were presented covering a broad range of topics in medical radiation dosimetry. A refereed selection of papers presented at the symposium forms the core of these Proceedings, which has been submitted for publication.

8.5 Education and Training

8.5.1 Clinical Training in radiation oncology physics

While the shortage of clinically qualified medical physicists is a worldwide problem it is most acute in developing nations. One important reason for this is the migration of promising physics professionals from developing countries to more developed countries where the recognition of the medical physicists is better established. The introduction of a programme of clinical training to supplement academic qualifications has the dual purpose of providing skilled professionals for the developing country as well as providing standards that can be used to raise the recognition on medical physicists. In an increasing number of countries Master level courses in medical physics are offered by universities. The clinical in-service training component however is in many cases missing. This has resulted in incomplete preparation of the medical physicists to practice independently as important aspects of training cannot be completed in the university setting. The Agency has published a structured in-service clinical training programme (IAEA Training Course Series No. 37), which provides a better preparation for medical physicists to ensure that they are capable of independent, safe and effective practice (see Appendix 3).

8.5.2 Training package for the Implementation of a 3-D Conformal Radiotherapy CRT) and Intensity Modulated Radiotherapy(IMRT) in Hospitals

A training material curriculum has been developed for transitioning from 2-D RT to 3-D CRT to IMRT. The testing of the training package wase done in March 2011 trough a workshop held in the Philipines. After its completion, the training package wil be available for free downloads form the IAEA website.

9. 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 1: Coordinated Research Projects

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

Year of commencement	CRP code and title	Year of completion	Participating institutions
2008	**E2.40.15:** Doctoral CRP on Quality Assurance of the Physical Aspects of Advanced Technology in Radiotherapy	2013	9
2009	**E2.40.16:** Development of Quality Audits for Radiotherapy Dosimetry for Complex Treatment Techniques	2011	6
2009	**E2.10.07:** CRP on the Development of Quantitative Nuclear Medicine Imaging for Patient Specific Dosimetry	2013	10
2010	**E2.10.08:** Development of Advanced Dosimetry Techniques for Diagnostic and Interventional Radiology	2013	13

TABLE 1. Coordinated Research Projects (CRPs) in dosimetry, operational in 2009-2010

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), by training a number of medical physicists at the Ph.D. level with research and clinical capability.

With the assistance of local and international supervisors, 6 medical physicists at the PhD level are producing research theses in one or more areas of advanced radiotherapy and will have the knowledge and capability to establish sustainable education and training programmes for the next generation of medical physicists at their centers thus increasing indigenous research activity in the Member States. In addition they will be able to assist their institutions to acquire the appropriate equipment and technology for the implementation of advanced radiotherapy treatments.

E2.40.16: Development of Quality Audits for Radiotherapy Dosimetry for Complex Treatment Techniques:

External audit is a crucial element in QA programmes for clinical dosimetry in radiotherapy. The CRP extends the scope of activities by national TLD-based networks from dosimetry audit for rectangular radiation fields to irregular and small fields relevant to modern radiotherapy.
The CRP's aim is to develop and make available a methodology and procedures for national External Audit Groups for dose measurement of complex radiotherapy parameters used for cancer treatment. This includes TLD based dosimetry for irregular MLC fields for conformal radiotherapy, for heterogeneous situations, and for small MLC shaped fields relevant to stereotactic radiotherapy and applicable to dosimetry for IMRT. In addition it includes a new development of film-based 2D dosimetry for testing dose distributions, specifically beam penumbra in small field geometry. The expected research outcome of this CRP is to assist Member States in developing national quality audit programmes for radiotherapy dosimetry and thus increase radiation dosimetry expertise

internationally in order to potentially reduce the number of mis-administrations of dose to radiotherapy patients.

E2.10.07: CRP on the Development of Quantitative Nuclear Medicine Imaging for Patient Specific Dosimetry

The overall objective of this project is to assist Member States in accurately determining radionuclide distributions for diagnostic and therapeutic nuclear medicine.

Nuclear Medicine instruments have the potential to provide quantitative information and its distribution with time. This information provides the basis for internal dosimetry and is needed to properly optimize the use of any radiopharmaceutical. Patient specific dosimetry is often a legal obligation when administering radiopharmaceuticals for therapy. There are, however, no harmonized protocols or guidelines for acquiring quantitative information from Nuclear Medicine instruments. Nor are there documents that address the possibilities and limitations of these instruments for quantitative information. This CRP is expected to produce guidance documents that i) describe the methods required for quantification, including the definition of a standard set of physical and computer tools for ensuring consistent quantification in nuclear medicine; and ii) define what levels of reliability should be achievable with different levels of technology and for various tasks.

To date, two consultants meetings (2008 and 2010) and the first RCM (2009) have produced a draft guidance document "Quantitative nuclear medicine imaging: concepts, requirements and methods". An initial work plan has also been agreed upon. The first intercomparison involves Ba-133 phantoms, produced to primary standards quality at NIST, USA. The project will later involve Ge-68 (/Ga-68) phantoms for PET quantifications. Eventually these measurements will be collected, compiled, and summarized in an IAEA publication, along with discussions of the experiences of the different clinics.

Areas of knowledge gaps in quantitative nuclear medicine will likely be identified. Centres will be given access to new guidance documents on how they can require the tools to evaluate the possible accuracy and precision for various quantitative tasks for different equipment. Ultimately, the diagnostic precision or therapeutic efficacy of nuclear medicine procedures is expected to improve.

E2.10.08: Development of Advanced Dosimetry Techniques for Diagnostic and Interventional Radiology:

The objective of this CRP is to extend the Code of Practice for dosimetry in x-ray diagnostic radiology (TRS 457) in line with the recommendations from the previous CRP E2.10.06. It will focus on the extension of material in TRS 457 through a supplementary document to include detailed guidance of dosimetry in paediatric radiology, dose determination for the skin during clinical procedures, also the use of DICOM structures as a source of dosimetric data, and dosimetry for new imaging modalities, including advice on dosimetry for wide cone beam scanners. The status of organ dose determination for diagnostic radiology procedures, and the uncertainty involved in clinical and laboratory dose determination will be evaluated.

In the more specific area of calibration there is a focus on establishing the use of kerma length product and kerma area product calibration procedures as used for CT dosimetry instrumentation and for the use of KAP meters in fluoroscopy dosimetry, including the organisation of a comparison of KAP meter calibrations in conjunction with EUROMET.

The overall objective is to assist (i) secondary standard dosimetry laboratories in developing and providing appropriate calibrations of equipment and (ii) hospitals in conducting and interpreting

dosimetry measurements for an extended range of x-ray modalities and patient profiles, in the Member States.

Appendix 2: 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 2009–2010 were as follows:

2009

- National Training Course for Quality Assurance in Diagnostic Radiology including a one-day Symposium for Interventional Radiology and Cardiology, Sarajevo, Bosnia and Herzegovina
- National Training Course on Quality Assurance, Dosimetry and Optimization for Diagnostic Radiology in Jakarta, Indonesia
- National Training Course on Quality Assurance in Treatment Planning Systems, Cebu City, Philippines
- IAEA/RCA Regional Training Course on Quality Assurance in Nuclear Medicine for Medical Physicists, Dhaka, Bangladesh
- Regional Training Course on the Implementation of the International Code of Practice for Radiotherapy Dosimetry (IAEA TRS-398) based on absorbed dose to water standards, Amman, Jordan
- Regional (AFRA) Training Course on Implementation of IAEA TRS 430 on Quality Assurance for Radiotherapy Treatment Planning Systems, Algiers, Algeria
- Regional Training Course on Physical Aspects on Quality Assurance for 3D-CRT - Implementation of TecDoc 1151 Update/ Aspectos Físicos de la Garantía de Calidad en Radioterapia:Act, Sao Paulo, Brazil
- ESTRO/IAEA Teaching Course on 2D-3D Planning and Imaging (Russian Edition), St. Petersburg, Russian Federation
- ESTRO/IAEA Teaching Course on Radiotherapy Treatment Planning Principles and Practice, Dublin, Ireland
- ESTRO/IAEA Teaching Course on Dose Calculation & Verification for External Beam Therapy, Munich, Germany
- Regional (AFRA) Training Course on the Use of Information Communication Technology (ICT) Materials for Medical Physicists Specializing in Nuclear Medicine, Accra, Ghana
- Regional (AFRA) Training Course on Acceptance Testing of a Dual-Head Gamma Camera, Seibersdorf, Austria
- Regional (AFRA) Training Course on Image Processing, Reconstruction, Analysis and Quantification, Bloemfontein, South Africa
- Joint ICTP/IAEA Advanced School on Dosimetry in Diagnostic Radiology and its Clinical Implementation, Trieste, Italy
- ESTRO/IAEA Teaching Course on IMRT and Other Conformal Techniques in Practice, Gliwice, Poland

2010

- Regional (AFRA) Training Course for Implementation of ISO 17025 General Requirements for the Competence of Testing and Calibration Laboratories in SSDL's, Pretoria, South Africa
- Regional (AFRA) Training Course on Diagnostic Radiology Quality Assurance, Dosimetry and Optimization, Nairobi, Kenya
- Regional (AFRA) Training Course on Electron Dosimetry, Cairo, Egypt
- IAEA Regional (AFRA) Training Course on Internal Dosimetry for Medical Physicists, Trieste, Italy
- Regional Training Course on Transition from 2D to 3D in Radiotherapy Technology, Buenos Aires, Argentina
- National Training Course on Transitioning from 2D to 3D Conformal Radiotherapy, Bratislava, Slovakia
- ESTRO/IAEA Teaching Course on Advanced Imaging Course for Physicists, Utrecht, Netherlands
- ESTRO/IAEA Teaching Course on IMRT and Other Conformal Techniques in Practice, Gent, Belgium
- ESTRO/IAEA Teaching Course on Radiotherapy Treatment Planning, Principles and Practice, Dublin, Ireland
- Regional (AFRA) Hands-on Course on Performing an Acceptance Test of a Dual-Head Gamma-Camera, Seibersdorf, Austria
- Regional (AFRA) Training Course on Practical Biokinetics for Medical Physicists Specializing in Nuclear Medicine, Seibersdorf, Austria
- National Training Course on QA on CT and Mammography, Sarajevo, Bosnia and Herzegovina
- National training course on The Role of Medical Physicists in Nuclear Medicine, Depok, Indonesia
- National Training Course on Medical Physics in Diagnostic Radiology, Ciudad de México, Mexico
- IAEA/RCA Regional Training Course on Medical Physics Aspects in Low and High Dose Rate Brachytherapy, Mumbai, India
- Regional Training Course on Diagnostic X-ray Dosimetry Based on TRS 457, Riyadh, Saudi Arabia
- Joint ICTP-IAEA Advanced School in Internal Dosimetry for Medical Physicists Specializing in Nuclear Medicine, Trieste, Italy

Appendix 3: IAEA Publications in Dosimetry and Medical Radiation Physics

Below is the list of publications that appeared in 2009–2010. 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 2009–2010 is given in the Appendix.

2009

- Clinical Training of Medical Physicists Specializing in Radiation Oncology **(IAEA Training Course Series No. 37)**.
  http://www-pub.iaea.org/MTCD/publications/PDF/TCS-37_web.pdf
- Quality Assurance for SPECT Systems **(Human Health Series No. 6)**.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1394_web.pdf
- Quality Assurance Programme for Screen Film Mammography **(Human Health Series No. 2)**.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1381_web.pdf
- Quality Assurance for PET and PET/CT Systems **(Human Health Series No. 1)**.
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1393_web.pdf
- Calibration of Reference Dosimeters for External Beam Radiotherapy **(Technical Reports Series No. 469)**.
  http://www-pub.iaea.org/MTCD/publications/PDF/trs469_web.pdf
- SSDL Newsletter No. 57. July 2009
  http://www-pub.iaea.org/MTCD/publications/PDF/Newsletters/SSDL-NL-57.pdf

2010

- Clinical Training of Medical Physicists Specializing in Diagnostic Radiology (**IAEA Training Course Series No. 47**).
  http://www-pub.iaea.org/MTCD/publications/PDF/TCS-47_web.pdf
- Planning a Clinical PET Centre (**Human Health Series No.11**).
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1457_web.pdf
- El físico médico: Criterios y recomendaciones para su formación académica, entrenamiento clínico y certificación en América Latina **(Human Health Reports No. 1)**.
  http://www-pub.iaea.org/MTCD/publications/PDF/P1424_S_web.pdf
- Comprehensive Clinical Audits of Diagnostic Radiology Practices: A Tool for Quality Improvement — Quality Assurance Audit for Diagnostic Radiology Improvement and Learning (QUAADRIL) **(Human Health Series No. 4).**
  http://www-pub.iaea.org/MTCD/publications/PDF/Pub1425_web.pdf
- SSDL Newsletter No. 58. June 2010 – This was a special issue of the SSDL Newsletter commemorating 40 years of the IAEA/WHO postal dose quality audit service.

  http://www-pub.iaea.org/MTCD/publications/PDF/Newsletters/SSDL-NL-58.pdf

Appendix 4: Non-IAEA publications authored or co-authored by staff members of the IAEA Dosimetry and Medical Radiation Physics (DMRP) Section, 2009–2010

2009

MEGHZIFENE, A.; Education, clinical training and professional recongnition of medical physicists, World Congress on Medical Physics and Biomedical Engineering, Munich, Germany, IFMBE Proceedings, Vol. 25/13, pp10-12, 2009

IZEWSKA, J.; ROSENBLATT, E., Availability of radiotherapy resources worldwide: the IAEA Directory of Radiotherapy Centres (DIRAC), Book of Abstracts of the 3rd International Cancer Control Congress (3rd ICCC), 8-11 November 2009, Cernobbio, Como, Italy.

IZEWSKA, J., VATNITSKY, S., SALMINEN, E., The IAEA Quality Audits in Radiotherapy, Proc. of International Conference, "Modern Radiotherapy: Challenges and Advances in Radiation Protection of Patients", 2-4 December 2009, Paris, France.

MEGHZIFENE, A., McLEAN, I.D., CHHEM, R., "Building capacity in medical physics for radiological imaging: role of IAEA", Chapter in the textbook The Practice of Radiology Education: Challenges and Trends, Springer (2009).

2010

HULTQVIST, M., FERNANDEZ-VAREA, J.M., **IZEWSKA, J.**, Monte Carlo simulation of correction factors for IAEA TLD holders, Phys. Med. Biol., **55**, N161-N166 (2010).

FAULKNER, K., JÄRVINEN, H., BUTLER, P., **MCLEAN**, **I.D.**, PENTECOST, M., RICKARD, M., ABDULLAH, B., A clinical audit programme for diagnostric radiology: the approach adopted by the International Atomic Energy Agency, Radiat. Prot. Dosimetry, 2010 Apr-May, 139 (1-3):418-21. Epu 2010, Feb 16.

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MEGHZIFENE, **A**., DANCE, D.R., **McLEAN, D**., KRAMER, H.M., Dosimetry in diagnostic radiology, Eur. J. Radiol., Oct 2010, 76(1): 11-4

ELGQVIST, J., HULTBORN, R., LINDEGREN, S., **PALM**, **S.**, Ovarian cancer background and clinical perspectives. Book chapter in *Targeted Radionuclide Therapy*. Lippincott Williams & Wilkins, 2010, Chapter 29, pp380-396.

CHHEM, R.K., **MEGHZIFENE, A.**, CZARWINSKI, R., HOLMBERG, O., LAU, L, .**KESNER, A.,** Towards better and safer use of radiation in medicine, The Lancet, Vol, 375, No. 9723, pp 1328-1330, April 2010.

IZEWSKA, J., "The IAEA quality audits in radiotherapy", Proceedings of the 3rd Euro-Asian Congress on Medical Physics and Engineering: Medical Physics -2010, Moscow 21-25 June 2010, Russian Association of Medical Physics, Moscow (2010), Part 2, pp. 380-382

SGOUROS, G., ROESKE, J.C., McDEVITT M.R., **PALM, S.,** ALLEN, B.J., FISHER, D.R., BRILL, A.B., SONG H., HOWELL, R.W., AKABANI, G.; SNM MIRD Committee, BOLCH, W.E., BRILL, A.B., FISHER, D.R,, HOWELL, R.W., MEREDITH, R.F., SGOUROSS, G., WESSELS, B.W., ZANZONICO, P.B. MIRD Pamphlet No. 22 (abridged): Radiobiology and dosimetry of alpha-particle emitters for targeted radionuclide therapy. J. Nucl. Med. **51**, 311-328, (2010).

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