IAEA/WHO NETWORK OF SECONDARY STANDARD DOSIMETRY LABORATORIES

SSDL NEWSLETTER

Prepared by the
Joint IAEA/WHO Secretariat
of the SSDL Network

Published semi-annually by the
International Atomic Energy Agency
Vienna

CONTENTS

No. 46 January 2002

ISSN 1011-2669

EDITORIAL NOTE

The first two articles of this issue of the SSDL Newsletter deal with guidelines for setting up the TLD based Quality Assurance (QA) network at the national level and propose a set of standardized procedures for on-site dosimetry review visits to hospitals for resolving discrepancies occurred in the TLD audits. The third article presents an analysis of the deviations identified through the IAEA/WHO TLD audit service.

The fourth article is a short technical note on the results of a comparison conducted between the IAEA and the SSDL-STUK (Finland) of calibration coefficients of a well type chamber. This note is followed by an announcement on the publication of an update of the IAEA TECDOC-1079. The new document is published as IAEA TECDOC-1274.

The fifth article is also a technical note on a pilot study to verify electrometer calibration coefficients. The note describes the procedures to be used and invites interested SSDLs of the IAEA/WHO network to participate in the pilot study. The IAEA Dosimetry Laboratory will participate in this pilot study. The verification of calibration coefficients of electrometers is of particular interest to SSDLs who have their reference ionization chamber calibrated alone (without the electrometer) in terms of air kerma or absorbed dose per unit charge or current collected. Before the chamber can be used with an electrometer, it is necessary to verify the calibration coefficient of the electrometer (in terms of charge or current).

The sixth article was prepared by the Head of a new SSDL member, the Ionizing Radiation Metrology Laboratory (IRML) of South Africa, who has recently joined the network. It gives an overview of the facilities, activities and QA programme of the IRML.

The last article is a short note prepared by the IAEA Secretariat on the use of calibration coefficients instead of calibration factors.

Finally, the editor would like to draw the attention of the readers on the upcoming IAEA Symposium on Standards and Codes of Practices in Medical Radiation Dosimetry to be held at the IAEA Headquarters during 25-28 November 2002. A short announcement on the Symposium is included in this issue of the Newsletter. Detailed information is available on the IAEA Internet address. It is hoped that may scientists from SSDLs and PSDLs, hospitals, universities and research institutes will contribute to make this Symposium a success.

THE PRESENT STAFF OF THE DOSIMETRY AND MEDICAL RADIATION PHYSICS (DMRP) SECTION

Name	Position/tasks	E-mail address
Ken Shortt	Section Head	k.shortt@iaea.org
Bera, Pranabes	Laboratory Technician (TLD)	p.bera@iaea.org
Czap, Ladislav	Laboratory Technician Ionization chamber calibration	l.czap@iaea.org
Girzikowsky, Reinhard	Laboratory Technician High dose and Mammography	r.girzikowsky@iaea.org
Izewska, Joanna	TLD Officer, Head, Dosimetry Laboratory Unit	j.izewska@iaea.org
Meghzifene, Ahmed	SSDL Officer Editor, SSDL Newsletter	a.meghzifene@iaea.org
Pernicka, Frantisek	Diagnostic Radiology Dosimetry Officer	f.pernicka@iaea.org
Toelli, Heikki	Brachytherapy Dosimetry Officer	h.toelli@iaea.org
Vatnitsky, Stanislav	Medical Radiation Physicist Treatment Planning Systems	s.vatnitsky@iaea.org
Flory, Rosemary	Secretary	r.flory@iaea.org
DMRP Section		dosimetry@iaea.org[a]

[a] This is the general e-mail address of the DMRP Section where all correspondence not related to specific tasks of the staff above should be addressed. Please note also that there is a considerable circulation of the staff of the Agency, so that messages addressed to someone who has left might be lost. All incoming messages to this mailbox are internally distributed to the appropriate staff members.

SERVICES PROVIDED BY THE IAEA PROGRAMME IN DOSIMETRY AND MEDICAL RADIATION PHYSICS

The IAEA's Dosimetry and Medical Radiation Physics programme is focused on services provided to Member States through the IAEA/WHO SSDL Network and a system of dose quality audits. The measurement standards of Member States are calibrated, free of charge, at the IAEA's dosimetry laboratory. The audits are performed through the IAEA/WHO TLD postal dose assurance service for SSDLs and radiotherapy centres, and the International Dose Assurance Service (IDAS) for SSDLs and radiation processing facilities, mainly for food-irradiation and sterilisation of medical products.

The range of services is listed below.

Services	**Radiation quality**
1. Calibration of ionization chambers (radiotherapy, diagnostic radiology including mammography, and radiation protection, including environmental dose level).	x-rays (10-300kV) and gamma rays from ^{137}Cs and ^{60}Co
2. Calibration of well-type ionization chambers for brachytherapy Low Dose Rate (LDR).	γ rays from ^{137}Cs
3. Comparison of therapy level ionization chamber calibrations (for SSDLs).	γ rays from ^{60}Co
4. TLD dose quality audits for external radiotherapy beams for SSDLs and hospitals.	γ rays from ^{60}Co and high energy X-ray beams.
5. TLD dose quality audits for radiation protection for SSDLs.	γ rays from ^{137}Cs
6. ESR-alanine dose quality audits for radiation processing (for SSDLs and industrial facilities), through International Dose Assurance Service (IDAS).	γ rays from ^{60}Co, dose range: 0.1-100 kGy
7. Reference irradiations to dosimeters for radiation protection (for IAEA internal use).	x-rays (40-300 kV) and γ rays from ^{137}Cs and ^{60}Co

Member States who are interested in these services should contact the IAEA/WHO Network Secretariat for further details, at the address provided below. Additional information is also available through the Internet at the web site: http://www.iaea.org/programmes/nahunet/e3/

IAEA/WHO SSDL Network Secretariat
Dosimetry and Medical Radiation Physics Section
Division of Human Health
International Atomic Energy Agency
P.O. Box 100
A-1400 Vienna
Austria

Telephone: +43 1 2600 21662
Fax: +43 1 26007 21662
E-mail: dosimetry@iaea.org

INTRODUCTORY REMARKS

J. Izewska, TLD officer
Dosimetry and Medical Radiation Physics
Division of Human Health
IAEA

Beginning in 1969, the IAEA, in collaboration with WHO, was the first organization to initiate dosimetry audits of radiotherapy beam calibration on an international scale, using mailed TLD. Over 32 years, the IAEA/WHO TLD audit service has verified the calibration of more than 4200 radiotherapy beams in about 1200 hospitals world-wide. At present the main focus is given to inviting new participants into the auditing process and to resolving persisting deviations. Analysis of the results reveals that in general, hospitals that have never participated in an external audit perform worse than those that participate regularly in the process. The probability of observing a very large deviation for a first time user is significantly greater than for a regular participant, thereby indicating the value of the service.

To extend the fundamental step of dose audit in reference conditions to as many hospitals as possible throughout the world, a Co-ordinated Research Project (CRP), "Development of a Quality Assurance Programme for Radiation Therapy Dosimetry in Developing Countries", was conducted during 1995-2001. National External Audit Groups (EAGs) for TLD audits of radiotherapy beams were set up in Algeria, Argentina, Colombia, Cuba, China, Czech Republic, India, Israel, Malaysia, Philippines, Poland and Viet Nam. Guidelines and recommendations were developed for national TLD programmes in radiotherapy dosimetry, including on-site dosimetry review visits to radiotherapy hospitals. The Agency's methodology has been adapted to the specific conditions in each participating country, which involved scientific investigations leading to new developments at national levels. This CRP not only developed the common methodology to cover technical aspects of the TLD measurements but also provided guidelines for operation of the national QA networks in participating countries.

The first two reports presented in this issue of the SSDL Newsletter deal with guidelines for setting up the TLD based QA network at the national level and propose a set of standardized procedures for on site dosimetry review visits to hospitals for resolving discrepancies detected during in the TLD audits. The second document was primarily written for IAEA experts traveling to hospitals to assist in resolving discrepancies and tracing, understanding and correcting errors. However, the procedures may be valuable to any regional or national organization, such as an SSDL, involved in QA programmes for dosimetry in radiotherapy.

Due to limited space in the Newsletter, the appendices for the two documents have not been attached. They are available on request from the Dosimetry and Medical Radiation Physics Section of the IAEA (e-mail: dosimetry@iaea.org) or can be downloaded from the IAEA web page http://www-naweb.iaea.org/qamanual.html

GUIDELINES FOR THE PREPARATION OF A QUALITY MANUAL FOR EXTERNAL AUDIT GROUPS ON DOSIMETRY IN RADIOTHERAPY

Scientific Secretary: Joanna Izewska
Dosimetry and Medical Radiation Physics Section, Division of Human Health, IAEA

Participants of the Co-ordinated Research Programme on Development of Quality Assurance Programme for Radiation Therapy Dosimetry in Developing Countries: M. Arib (Algeria), M. Saravi (Argentina), E. Castellanos (Colombia), L. Kaibao (China), J. Novotny (Czech Rep.), A. Dutreix (France), G. Ramanathan (India), M. Tatcher (Israel), S. Salikin (Malaysia), N. Lingatong (Philippines), B. Gwiazdowska (Poland), D. T. Luong (Vietnam).

Foreword

This document has been prepared within the framework of a Co-ordinated Research Programme (CRP) on Development of Quality Assurance Programme for Radiation Therapy Dosimetry in Developing Countries, during two Meetings at the IAEA Headquarters in Vienna (11-14 November 1996 and 6-10 October 1997). It is based on the recommendations of ISO 9000 series and ISO/IEC guide No. 25 [5, 6]. The document can be used as a guide on how to prepare a quality manual for national External Audit Groups (EAG), i.e., a nationally recognised group in charge of operating external quality audits for radiotherapy dosimetry. The EAG of a given country includes the SSDL, a Measuring Group and a Medical Physics Group, who work in close co-operation at all steps of the audit. The content herein should be considered as a suggestion and additions or deletions can be made in accordance with the specific conditions in each country.

It is preferable that the manual itself be as concise as possible, limiting it to the core scope. Detailed working sheets describing the procedures should be included in Appendices together with data sheets, questionnaires and reporting forms.

The quality manual of each country should be carefully reviewed by all members of the EAG and, as far as possible, should be approved by relevant professional bodies and supported by health authorities.

1. INTRODUCTION

It has long been recognised that accurate knowledge of the dose in radiotherapy is vital to ensure safe and effective radiation treatments. To achieve this goal, comprehensive quality assurance programmes should be established to cover all steps from dose prescription to dose delivery. These programmes should include internal checks performed by the radiotherapy centres and external audits made by independent external bodies.

It is estimated that not more than 50% of radiotherapy facilities world-wide have participated in some level of dose quality audit by an independent expert. Genuine concern exists that some, or even many, facilities not involved in external quality programmes may deliver inferior radiotherapy treatment due to inadequate dosimetry practices.

To help achieve uniformity among different EAGs, facilitate exchange of experiences and follow ISO and IEC [5, 6] recommendations, the activities of EAGs should be based on quality manuals established according to international recommendations.

2. AIM OF THE EAG

The national EAGs are in charge of performing quality audits for radiotherapy dosimetry with the aim of ensuring adequate precision in the dosimetry of clinical beams. The first parameter to be checked is the beam output of a therapy unit under reference conditions in which beams are calibrated. Subsequent steps should cover dosimetry checks of radiation beam characteristics in conditions other than those used for reference, since additional errors can originate from the estimation of actual dose distribution in the therapy planning system.

The activities of each EAG should be based on international standards to help achieve uniformity (harmonisation) among different EAGs. To gain wide acceptance and full collaboration from radiotherapy centres, it is essential to obtain the approval of the medical community. To ensure that activities are sustained and proper resources are allocated to support this audit programme, agreement of national bodies should be sought.

The EAG prepares its TLD audit programme depending on the local situation. Usually a few to several TLD runs are organised per year according to the number of beams to be

checked, the degree of automation of the reading procedures, the available resources, etc. From the experience of the existing TLD networks, it follows that all beam modalities in clinical use should be audited in each radiotherapy department. Deviations have been observed between the calibrations of different beams from the same treatment unit or between different units in the same hospital, either because of errors in procedures or because of poor maintenance of a particular machine. It is advisable to repeat TLD checks of all beams every year in radiotherapy departments where deviations occurred until an appropriate level of confidence is achieved.

In addition, it is strongly recommended that all new installations be audited before the first patient treatment starts [2]. Audits should be also performed after major breakdowns of treatment units, after replacements of Co-60 sources and following requests by radiotherapy departments.

3. NATIONAL INFRASTRUCTURE OF RADIOTHERAPY

Each EAG should establish a national radiotherapy infrastructure database including information on the staff, equipment and procedures used at radiotherapy centres for treatment units. When needed, some clinical data should be included as well. An example of an infrastructure questionnaire to be sent out to radiotherapy centres is given in Appendix A.1.

The infrastructure database should be continuously updated by the EAG. Reasonable predictions on the evolution of the infrastructure should be made in order to make sure that future needs are met accordingly. The predictions should be supported by relevant data on national cancer incidence.

4. STRUCTURE OF THE EAG

The structure of the EAG in a specific country depends on the existing facilities and on the structure of the SSDL. Examples of the most common structures are shown in the following flow charts.

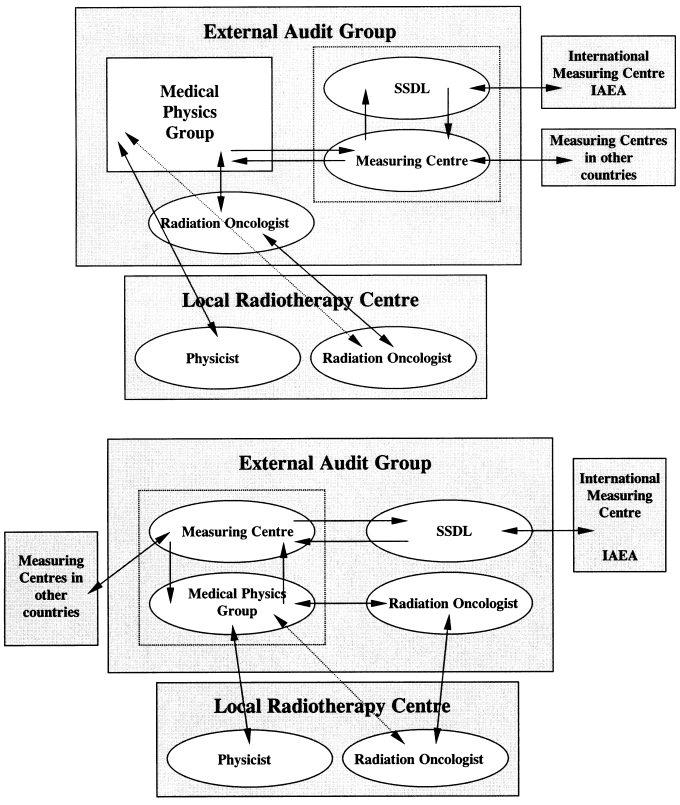

FIGURE 1: An example of two most common EAG structures

The partners of the EAG are the following:

The Measuring Centre (MC). The main tasks of the Measuring Centre are to provide reliable and accurate results traceable to existing standards of TL-dosimetry, to carry out TLD runs and to exchange information with other project partners. The MC can be part of the SSDL, connected to the SSDL or part of a medical physics department.

The SSDL maintains direct links with International Measuring Centres and, in particular, with the IAEA.

The Medical Physics Group (MPG) should be composed of one or several medical physicists with extensive experience in clinical dosimetry working full time at a radiotherapy department. The medical physicists can be a part of a medical physics department in a well-known hospital or they can work in different radiotherapy departments, if preferable.

One or more **radiation oncologists** should be associated with the EAG. One of their tasks should be reporting the audit results to the radiation oncologist of the Local Radiotherapy Centre in case of a confirmed major deviation, if this deviation can have a significant effect on patient treatments. The decision to stop the treatment of patients at the treatment unit where the deviation occurred should be taken by the radiation oncologist of the Local Centre, after discussing with the radiation oncologist of the EAG.

The Local Radiotherapy Centre (LC) can be any medical centre where a radiotherapy treatment unit is used for clinical practice. The external audit will be arranged with the physicist of the Centre, if available. In cases where there is no physicist, the audit should be arranged with the radiation oncologist who can delegate a radiotherapy technologist for the practical work. In case of a confirmed major deviation with possible significant effect on patient treatments, the radiation oncologist should be contacted directly by a radiation oncologist from the EAG.

The detailed structure of the EAG (SSDL or the MPG and the MC) shall be described in a Quality Manual with the corresponding organisational flow charts. The interaction between the members shall be clearly stated.

The distribution of tasks among the members of the EAG should be adapted to the specific situation in each country. One person should be responsible for each activity and should be consulted before a decision with respect to his task can be taken. The next person responsible should be indicated in case of absence.

TABLE 1. DISTRIBUTION OF TASKS AMONG DIFFERENT MEMBERS OF THE EAG.

SSDL	Measuring Centre	Medical Physics Group	Radiation Oncologist
Administrative management of the EAG (one member is nominated as a manager) Organisation of meetings between project partners INFORMATION EXCHANGE			
	Radiotherapy infrastructure questionnaires and data base		
		Choice and contacts with the Local Centres	
	Preparation of instructions and data sheets		
	Preparation of mailings		
	Data handling		
	Archiving		
	Data analysis and reporting		
	Organisation of on-site visits		
			Follow-up
			Organisation of corrective actions
			Liaison with national societies
			and other national related projects
Set up of TLD calibration procedures			
Internal calibrations of the TLD system (reader+powder)			
	Preparation of TLD		
	samples, reading		
	calculation of absorbed dose and		
	deviations		
	Analysis and interpretation of results		
Traceability to national standards,			
to IAEA, etc.			
	Interaction with MCs in other countries		
Internal Quality Control of the Process			

The desirable qualifications of the staff members for each activity should be stated although it is understood that in many instances the work has to be shared by the existing personnel and further on -the job - training will lead to achieving the required levels of expertise.

The responsibility levels should be clearly defined within the External Audit Group. The position of each co-worker and the relations between the individuals should be indicated, stating whether they are hierarchic or functional. An example for a MPG is given in the following flow chart.

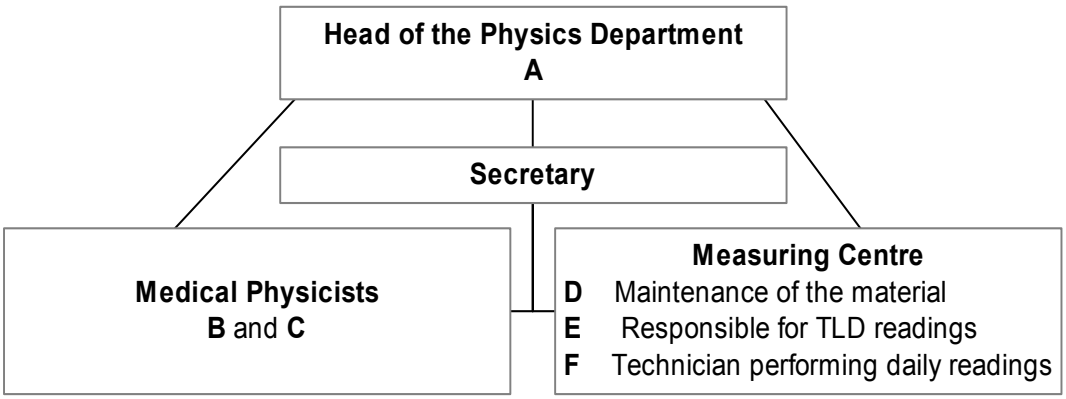

FIGURE 2. The structure of an MPG that includes the MC

A Chief Medical Physicist, PhD, 'x' years of experience; responsible for the internal organisation of the MPG, assigns tasks to the different staff members.

B Senior Medical Physicist, PhD, 'y' years of experience in clinical dosimetry; member of the EAG, responsible for the analysis of the results and communication with the physicists from LCs. Responsible for helping the physicists of the LC to find out the cause of the deviation and to decide on the corrective action. B is in contact with the LCs and, when necessary, with the radiation oncologist from the EAG.

C Physicist, junior or senior, with experience in clinical dosimetry. Member of the EAG, assumes the responsibilities of B when necessary.

D Engineer or physicist. Responsible for the maintenance of the dosimetry equipment of the MC.

E Physicist with experience in TLD responsible for the calibration procedures. Supervises the reading procedures; prepares the protocols for the calculation of dose from the readings; plans experiments to improve or extend the range of measurements (high energy X rays, electrons, non reference conditions). E is in contact with the SSDL and with other MCs to assure the quality of the measurements

F Technician trained in TLD readings. Performs the TLD readings under the supervision of E.

The Secretary is responsible for mailing the dosimeters, data sheets and other documents under the supervision of E and B. Results should not be mailed without the approval and signature of B (or C). B and E should review periodically the procedures and prepare together the reports to the EAG.

5. RESOURCES OF THE MC

As stated previously, the choice of the laboratory to carry out the TLD measurements in a specific country should be justified by the former experience of this laboratory in accurate TL-dosimetry. The MC has to be able to reach and maintain high accuracy in dose determination from TL-readings. Also its infrastructure with respect to equipment, manpower and financial resources should ensure high capability of large series of TLD measurements repeated in regular runs. It should preferably have demonstrated a good consistency in dose evaluation by carrying out comparisons with other standard dosimetry laboratories[1].

The selection of the TLD reader depends on the workload and the available human resources. When more than 50 beams per year have to be checked, a fast automatic reader is an obvious choice. However, if one can afford additional staff, a manual reader would do the same work in extended time. The ratio of the time spent on

[1] In those countries where national experience with TLD work is limited to personnel monitoring services, it is highly advisable to set up a separate MC (within the SSDL or at a radiotherapy centre) in order to meet the requirement of high accuracy in TL-readings at the therapy level.

loading and reading the same mass of TLD powder can reach up to 1:4 for an automatic to a manual reader.

It has been generally agreed that LiF exhibits suitable characteristics as a TLD material for the measurements of megavoltage beams in the typical dose range (Gy) used in radiotherapy. For Co-60 and photon beams of typical qualities used in radiotherapy, one can favourably use LiF of natural abundance. If problems with photoneutron contamination are expected, it is recommended to use LiF enriched in ^{7}Li, which shows a very low sensitivity to neutrons. The choice will depend on megavoltage units in a specific country and economical resources, since LiF of natural abundance is less expensive than ^{7}LiF. However, it is not recommended to use two different powders in the same project because of potential difficulties and mistakes, which can originate from improper handling of the powder, recording of the data, etc.

As it is good practice to anneal TLD powder in a high temperature oven before use, it is necessary to purchase an oven and associated equipment, including annealing containers, large tweezers, high temperature thermometer, etc. After annealing, the powder has to be sifted with a fine mesh sieve as to make the powder uniform to ensure good reproducibility of readings.

Further materials and equipment will include small tweezers, brushes, laboratory glass, powder dispenser (the type depends on the reader model), ultrasonic cleaning device for the cleaning of reading vessels, if applicable (the latter depends on the reader design) and high precision scales, if necessary.

For redundancy the reference dosimetry requires two ionisation chambers, preferably Farmer type, and an electrometer to be used for the dose measurements and for quality control of the applied procedures, a water phantom equipped with a precise chamber positioning system, a thermometer, a barometer, etc. The chambers and electrometers should have valid calibration certificates issued by an SSDL (or a PSDL). For the reference dose measurements the MC needs access to radiation beams, at least a Co-60 but also to high energy X-ray beams from accelerators. For on site dosimetry review visits, it is advisable to have a portable dosimetry system, which has a valid calibration certificate.

Protocols should be prepared for testing, evaluation, maintenance and repairing or replacement of equipment. The conditions stated in the protocols should be fulfilled before using the equipment for routine measurements. The results of equipment tests should be fully documented and approved by the responsible body.

An inventory of consumable items, such as LiF powder, TLD capsules and holders, etc. should be maintained. Steps to be followed for procurement of consumable items should be described so that required materials can be purchased and stocked well in advance without affecting the work to be carried out.

6. PROCEDURES

6.1 SETTING UP THE TLD SYSTEM

The reproducibility and precision of TLD readings depend on the quality of the TLD material, reader characteristics and proper adjustment of several parameters of the reader, including choice of preheating and heating cycles, choice of high voltage (HV) of the photomultiplier tube (PM) and the readout time. Specific parameters, which have to be defined and adjusted, depend on the design and operational functions of the reader. Adjustment of temperatures of preheating and heating cycles is associated with the readout duration and depends on the characteristics of a specific TLD material, especially on the temperature of the main dosimetric peak, but also on the mass of a single aliquot of powder to be read. Temperature and readout time should be studied together.

The PM response depends strongly on the applied HV. It is convenient to set the working voltage to ensure good signal stability independent of small voltage fluctuations.

To assure good reproducibility of the TLD system, the performance of the reader should undergo periodical quality control including daily checks of the reader's sensitivity, HV stability and the reproducibility of temperature cycles. During the readings, the shape of the glow curves should be observed. A distorted glow curve may be generated, if the reader's working parameters are unstable.

Long time stability tests, validity of the initial adjustments of preheating and heating cycles, the reading duration and high voltage settings should be repeated at least twice a year.

6.2 PREPARATION OF THE TL-DOSIMETERS

It is highly recommended to use LiF TLD powder but if another material gives satisfactory results, it can be adopted as well.

Before the first exposure, a virgin powder has to be preannealed in a high temperature oven following the annealing cycle recommended by the manufacturer.

Irradiated powder may be recycled after the cleaning and thermal treatment following the usual annealing procedure, which aims at erasing of the remaining signal from the previous irradiation, and makes the powder ready for the next use. It is advisable to sieve the powder after annealing with a fine mesh sieve (e.g. 70 – 80 μm) to eliminate the smallest grains. If a batch of powder is well sifted and mixed, the homogeneity of the powder allows testing a small sample from the batch to determine the radiation response characteristics representative of the whole batch.

The TL-detectors are made of LiF powder loaded into small plastic capsules.

For irradiation in water it is suggested to seal the capsule plugs with a suitable adhesive. If the powder is wet, the grains aggregate and make the readings uncertain.

6.3 TLD CALIBRATION PROCEDURES

6.3.1. Determination of absorbed dose to water

Before irradiating the capsules, absorbed dose to water should be measured with an ionisation chamber placed at the depth of the TL-detector. Dose to water at the position of the TL-detector should be calculated using the national dosimetry protocol, or the appropriate IAEA code of practice[2] [3, 4].

6.3.2. Calibration of the TLD system

In order to evaluate the absorbed dose to water from irradiated TL-detectors, a TLD system calibration has to be performed and the relevant correction factors determined: non-linearity dose response correction, beam quality correction and fading correction. The calibration characteristics have to be determined separately for each batch of powder, i.e. powder having the same history with respect to the manufacturer lot and previous annealing runs. Samples taken from the same TLD lot are considered to have consistent fading, dose response, and energy dependence characteristics.

A description of the calibration procedures is given in Appendix A.2.

When using the IAEA standard TLD holder in photon beams, it was observed [1, 10] that the holder influences the dose absorbed by the TLD. The dose calculated from the TLD signals should be corrected to correspond to the dose determined by an ionisation chamber. The magnitude of holder attenuation has been evaluated and holder corrections derived both for photon output and beam quality checks [8].

An analysis of uncertainties involved in the TLD dose determination has to be performed. Combined uncertainty of the dose calculation from TLD measurements is associated with the uncertainty of dose determination by ion chamber and the TLD system itself. The combined uncertainty should be expressed by quadratic summation of the uncertainties of the individual parameters used for calculation of absorbed dose from TLD readings. (see Appendix A.3)

6.4 ORGANISATION OF AUDITS FOR LOCAL CENTRES

The EAG prepares all necessary forms and documents for the audits (see Appendix A.4 “Examples of Technical Documents”) including

- instruction sheets describing the geometrical set up for the TLD irradiations and the irradiation procedures,
- data sheets for the clinical beams, where details concerning beam calibration and the TLD irradiations are reported by the participating hospitals, including the date of irradiation of the TL-dosimeters, the dose delivered to the dosimeters, the quality index for photon beams, the ion chamber calibration factor and its traceability, information on the dosimetry protocol used and date of the last external audit in which the centre has been involved, if any,
- forms for communicating the results of the external audit, in which the following information should be given: date of the check, identification of the treatment unit, specification of the audited beams, dose reported by the participant, dose evaluated

[2] TRS 398 Code of Practice [4] was published in 2000, after this document was created. Before TRS398, users were recommended to follow TRS277 [3]

from the TLD signal and the deviation of the results for each TLD capsule.

Every participant of the TLD audits is provided with instruction sheets and data sheets, a set of TLDs and a holder for their irradiation, together with control dosimeters to monitor the background, undesirable accidental irradiation, unexpected fading, etc.

An accompanying letter should contain specification on the modalities to be checked including information on the number of beams and a clear indication of the time window in which the TLDs should be irradiated in the radiotherapy department.

6.4.1. Reading of irradiated TLDs and calculation of the dose from the TL-signal

The readings of the irradiated TL-dosimeters after they have been returned from the participating centres to the MC should be carried out under a careful control of the daily fluctuation of the TLD reader. The calculation of absorbed dose to water from the TLD readings should follow the procedure proposed in Appendix A.2. It is convenient to prepare a worksheet for routine calculations of dose, in which all necessary corrections are included. An example of a worksheet organisation is given in a flowchart in Appendix A.2.

6.4.2. Analysis of the results of audit

The percentage relative deviation between the stated and the measured dose is defined as Dev = 100% x $(D_{stat} - D_{TLD})/D_{TLD}$ [7]. The measured dose D_{TLD} is an average of doses calculated by the MC from the readings of the TLD samples irradiated by the participant and D_{stat} is the dose stated by the participating centre.

A criterion for the acceptance of the audit results should be carefully chosen for a TLD network. The acceptance limit defines the maximum acceptable discrepancy between the stated and measured doses, which does not require any further investigations, since there is a high probability that the deviation is due to uncertainty in the TLD procedure [1] rather than in the dose stated by the user. It is convenient to set the acceptance limits at the level of 2 standard deviations (2 SD) of the combined uncertainty of the TLD system. This way the probability for an observed deviation to be found outside the acceptance limits due to the uncertainties in the measuring procedure will be only 5%.

It is suggested that the following levels are defined:

Acceptable results. The deviation is less than 2 SD of the uncertainty of the TLD system (most TLD networks adopt the acceptance limit of 5%).

Minor deviation. The deviation is more than 5% (or 2 SD) and less than 10%.

Major deviation. The deviation is more than 10%.

6.4.3. Reporting the audit results and the follow-up.

The experience has shown that especially when large deviations occur, serious misunderstandings on the meaning of a deviation and confusion between over- and underdosage of the patients occur. It is therefore strongly recommended that when communicating with physicists and radiation oncologists in local centres, the result of the TLD audit be expressed as the ratio D_{TLD}/D_{stat} of the dose D_{TLD} measured with the TLDs to the dose D_{stat} stated by the participating centre

It is recommended to put into the accompanying letter the advice of a group of experts [2], which states that *„the independent verification can never be used as a substitute for proper local output calibration, which must be carried out by the radiotherapy physicist associated with the centre”.... „The independent measurement must never be directly used either clinically or transferred to ionisation chamber.”*

It is suggested to analyse the statistical distribution of the general results and report it periodically to the participating centres. While the full distribution of the results is of limited interest itself, its parameters give some general information on the situation at a given time. The standard deviation of the distribution would reflect an average uncertainty in beam calibrations throughout the departments in a specific country. The evolution of the standard deviation for the different audits as a function of time can identify a progress in dosimetry at the national level. The mean of the distribution of D_{TLD}/D_{stat}, if it differs from 1.00, indicates a systematic error, which could occur either in the procedures of the MC or in the calibration procedure in the country.

It is important for the departments participating in a QA audit to have feedback from the EAG at the shortest possible time following TLD irradiations. If the results of a participating centre are outside the acceptance limits, the centre should be asked to identify the reason for the deviation and to take corrective action. In that case it is advisable not to

inform the centre about an actual magnitude of the deviation (blind conditions). It is suggested to offer assistance in error tracing to the centre and to help in corrective action, if necessary. A second TLD check should be performed. These points are discussed in a greater detail below.

Before reporting the results of the TLD audit to a participant, a careful review of the provided data should be performed by the EAG (MC and MPG). The user calculation of the dose to water from the ionisation chamber measurements should be verified by the EAG, including verification of the number of monitor units or the irradiation time given by the user for the TLD irradiation. If the dose recalculated by the EAG differs from the dose stated by the participant, an investigation is necessary, even if the dose measured with the TLDs and the stated dose are within the acceptance limits.

It is suggested that the following actions, based on D_{TLD}/D_{stat} ratio, should be taken after analysis of the results.

Acceptable results ($0.95 \leq D_{TLD}/D_{stat} \leq 1.05$). No further investigation is necessary, unless the dose recalculated by the EAG differs from the dose stated by the participant. The results of the audit should be mailed to the local radiotherapy physicist and radiation oncologist through the MPG. To avoid any confusion, the report should specify the basic information on the audit, including:

- identification of the centre by its code number,
- date of irradiation,
- identification of the radiation unit and specification of the beam (nominal accelerating potential and quality index for high energy X-ray beams),
- dose determined by each of the TLD capsules, followed by the mean measured dose,
- dose stated by the participant,
- percentage relative deviation between the stated and the measured dose
- ratio of measured to stated dose.

Minor deviation ($0.90 \leq D_{TLD}/D_{stat} \leq 0.95$ or $1.05 \leq D_{TLD}/D_{stat} \leq 1.10$)[3] The EAG contacts the centre and encourages the physicist to find and explain the origin of the discrepancy. The magnitude of the deviation is not reported to the participant. If considered helpful, the EAG assists the local physicist in solving the problems and the difficulties they encounter. The reason for the deviation has to be traced, explained and corrected. The centre should verify if the incorrect TLD result has affected clinical data used for patient treatments. It is advisable to ask the centre for a written report on the reason for the deviation, the corrective action taken and the consequences of the deviations for the patients. A second TLD check should be proposed to all beams in the centre to find out if the observed deviation is accidental or systematic. It has happened that multiple errors accidentally cancel each other for a particular machine [9]. This typically requires further investigation, including an on site visit with an ionisation chamber to verify the beam calibrations.

Major deviation ($D_{TLD}/D_{stat} < 0.90$ or $D_{TLD}/D_{stat} > 1.10$). Prompt action is necessary. The centre is requested to review immediately the beam calibration procedure and the TLD irradiation procedure. The assistance of the EAG has to be offered including an on site review, which provides an opportunity for the most rapid resolution of the discrepancy. One should carefully investigate if the TLD results translate to a misadministration of doses received by patients. If so, the radiation oncologist should be immediately informed (preferably, by the EAG radiation oncologist) in order to ascertain if the patients have been treated with the wrong dose. After the origin of a major deviation has been explained, the TLD checks must be repeated with the shortest possible delay. A written report by the centre is required.

6.5 CONFIDENTIALITY

The results of the TLD audit are communicated to individual participants by a written report (see Appendix A.4.4). Each centre will receive only its own results. When providing the centres with a general report on the overall results of the audit, the report will be written so that individual centres cannot be identified. It is of the utmost importance that strict confidentiality is assured. The data are not transferred to administrative or governmental authorities without written permission from LCs, unless the national regulatory authorities require another mode of reporting of the TLD results.

It is very useful to prepare a database of the results to facilitate the operation of audits in an efficient manner; especially this would be

[3] a percentage relative deviation (see 6.4.2) of 10% corresponds to a ratio $D_{TLD}/D_{stat} = 0.91$ (Dev=-10% corresponds to $D_{TLD}/D_{stat} = 1.11$). To simplify communication with the local centre it is recommended to set the limits at 0.90 and 1.10.

required for the follow-up actions. However, this database should be independent of the database on the infrastructure of radiotherapy to assure confidentiality. All necessary actions should be taken to avoid unwanted access to this database.

Contacts with the centres, where deviations occur should be carried out in a manner that encourages close collaboration between the local staff and the EAG team. Usually the local physicists are highly motivated to find the causes of any deviations, and value the external assistance, provided that the experience and qualifications of the EAG staff guarantees rapid resolution of the discrepancies and that the investigation process is kept confidential. Under these conditions, the external assistance may be very helpful and efficient. On the other hand, experience in some countries has shown that it could have a negative effect if there is a lack of confidence in the efficiency of the MPG or their investigation is too heavy-handed. Moreover, the EAG should encourage LCs to appeal for continuous assistance in the resolution of dosimetry problems, whenever necessary. It is always advantageous for radiotherapy departments if EAG stimulates close co-operation between radiation oncologists and physicists.

7. PROCESS CONTROL

It is necessary for EAG to verify that the procedures described in Section 6 are correctly followed. A person responsible for ensuring compliance of the written procedures with the day-to-day practice should be identified. Each step has to satisfy the conditions specified in the written protocols and instructions as they appear in the operational procedures for audits.

The records of results of the test procedures should be documented and made available to the staff member responsible for carrying out the TLD measurements. The application of the methodology for TL-dosimetry should be checked regularly by internal quality control and external audits.

The reproducibility of the Co-60 reference dose should be monitored with an ionisation chamber, which has a valid calibration certificate. The linearity of the TL calibration curves (dose and energy response) should be tested.

External checks should be conducted regularly both for the external audit of the beam calibrations and for the checks of the calibration of the MC TLD systems. The beam calibration can be verified through the IAEA/WHO TLD audit programme for SSDLs. For the check of the MC's TLD system calibration, the IAEA offers a set of reference irradiations. The dosimeters are prepared by the MC and read-out upon their return from the IAEA. The performance of the MC on this test should agree with the IAEA at the level of twice the uncertainty of the TLD system in order for the LCs to be confident in the measurements of the MC.

Any unusual occurrences such as malfunctioning of any component of the system should be investigated by the responsible person. Necessary corrective measures should be carried out immediately so that entire TL dosimetry procedure meets the specifications defined in the quality manual prepared by the centre.

A register of complaints should be kept (including internal and external complaints) and explanations should be given. Appropriate corrective action should be taken, whenever required.

REFERENCES

[1] Dutreix A., Derreumaux S., Chavaudra J., van der Schueren E.: Quality control of radiotherapy centres in Europe: beam calibration. Radiother. Oncol. 32, 256-264, 1994

[2] Dutreix A., Hanson W.F., Jarvinen H., Johansson K.A., Thwaites D.I.: Recommendations for an independent verification of the initial output calibration of megavoltage radiotherapy unit. Radiation dose in radiotherapy from prescription to delivery. Proceedings of the Interregional Seminar for Europe, the Middle East and Africa organised by the IAEA/ESTRO, Leuven, 16-20 Sept. 1991, IAEA-TECDOC-734, 385-386, 1994

[3] IAEA: Absorbed Dose Determination in Photon and Electron Beams. An International Code of Practice. Tech. Rep. No 277, IAEA Pub. Vienna 1987

[4] IAEA: Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry based on Standards of Absorbed Dose to Water. Tech. Rep. No 398, IAEA Pub. Vienna 2000

[5] ISO/IEC Guide 25: 1990 General requirements for the calibration and testing laboratories, International Organisation for Standardisation, Geneva 1990

[6] ISO 9004 - 1: 1994, Quality management and quality system elements, Part 1: Guidelines, International Organisation for Standardisation, Geneva 1994

[7] ISO: 1995, Guide to expression uncertainty of measurement, International Organisation for Standardisation, Geneva 1995

[8] Izewska J., Novotny J., Dutreix A., Van Dam J., van der Schueren E.: The influence of IAEA standard holder on dose evaluated from TLD samples, Phys. Med. Biol., 41, 1-9, 1996, 41: 465-473, 1996

[9] Izewska J., Novotny J., Gwiazdowska B., Kindlova A., Kontra G., Van Dam J., Dutreix A., van der Schueren E.: Quality Assurance network in Central Europe. External audit on output calibration for photon beams, Acta Oncol. 34: 829-838, 1995

[10] Nyström H., Bera P., Nette P.: Beam Quality Dependence of the IAEA TL-dosimeters in a Standardised Geometry. Measurement Assurance in Dosimetry, Proceedings of a Symposium, Vienna, 24-27 May 1993, 527-539, IAEA-E2-SM-330/72, Vienna 1994

APPENDICES

All appendices are available on request from the Dosimetry and Medical Radiation Physics Section of the IAEA (dosimetry@iaea.org) or can be downloaded from the web page

http://www-naweb.iaea.org/qamanual.html

A.1. Radiotherapy infrastructure questionnaire

A.2. TLD calibration procedures

A.2.1. Determination of absorbed dose to water from the TL-readings

A.2.2. Flow chart for dose calculation from TL-readings

A.3. Uncertainties of the TLD system

A.4. Examples of Technical Documents:

A.4.1. TLD postal audit for megavoltage X-rays and Co-60 g - beams (Instruction Sheet)

A.4.2. TLD postal audit for Co-60 g - beams (Data Sheet)

A.4.3. TLD postal audit for megavoltage X-ray beams (Data Sheet)

A.4.4. Report of the TLD audit results to the participants

STANDARDIZED QUALITY AUDIT PROCEDURES FOR ON-SITE DOSIMETRY VISITS TO RADIOTHERAPY HOSPITALS

Report of the IAEA Consultants' Meeting, IAEA, Vienna, 27 September – 1 October 1999; revised in 2001.

Scientific Secretary: Joanna Izewska
Dosimetry and Medical Radiation Physics Section, Division of Huma Health, IAEA

Contributors: A. Dutreix, D. S. Followill, A. Nisbet, J. Novotny, P. Sipila, J. Van Dam

1. INTRODUCTION

Since 1969 the International Atomic Energy Agency (IAEA), together with the World Health Organization (WHO), has performed postal TLD audits to verify the calibration of radiotherapy beams in developing countries. The IAEA over the past 30 years, has verified the calibration of more than 3500 clinical photon beams at approximately 1000 radiotherapy hospitals. Detailed follow-up procedures have been implemented since 1996. When the TLD result of a participating institution falls outside the acceptance limits of ±5%, the institution is initially informed that there is a discrepancy and requested to try to identify the reasons why it occurred. The institution is not informed of the actual magnitude of the discrepancy (blind conditions) but is offered a second TLD audit. If the deviation cannot be resolved by the local radiotherapy institution or the national SSDL, then an on-site visit is suggested which, if accepted, is made by an IAEA expert in clinical dosimetry. The on-site visit includes a review of the dosimetry data and techniques, corrective measurements and ad-hoc training. The reasons for the discrepancy are then traced, explained, corrected and reported. Until the discrepancies are resolved and changes have been implemented by hospitals to ensure that the discrepancies do not reoccur, the safe and effective delivery of radiation doses to patients is questionable.

This document provides a standardised set of procedures for resolving discrepancies during on-site visits to radiotherapy hospitals by the IAEA experts. The table below summarises the acceptance criteria to be used by the IAEA experts for dosimetry and mechanical parameters of the hospital treatment units. If some of the parameters are outside the acceptance criterion, it will not be possible for an institution to assure the adequate quality of the dosimetry practices in radiotherapy. The criteria are based on analyses of clinical data and the measurement uncertainties for various dosimetry and mechanical parameters.

TABLE 1.PARAMETERS AND ACCEPTANCE CRITERIA FOR ON-SITE VISITS

Parameter	Criterion
Beam calibration	±3%
Relative measurements (e.g. tray, wedge factors, %DD)	±2%
Mechanical parameters	±3 mm/±2°

2. THE PREPARATION OF VISIT

The IAEA is in charge of the organization of the visit, including the contacts with the expert and the institution to be visited. The IAEA recommends the on-site visit to the institution indicating clearly that the visit is a consequence of an unresolved discrepancy in dosimetry detected during TLD audits. Upon confirmation that the institution wishes to receive an expert, the IAEA contacts the expert and provides him/her with a set of the data available on the institution's radiotherapy and dosimetry equipment and staff (the IAEA data base and TLD data sheets). These data are confidential and should not be distributed outside the authorised individuals, i.e. the IAEA staff involved in the TLD programme, the expert and the relevant WHO office. At this stage, arrangements are made for the practical aspects of the visit, including a request for the local staff to assist the expert (see Appendix 1). In addition, data collection forms to be used during staff interviews (Appendix 2) are made available to the expert prior to the on-site visit.

The expert will be equipped with reference publications [1-4] and a standard instrumentation kit (a minimum set), which contains the following items of equipment:

- electrometer with 2 Farmer-type ion chambers along with calibration certificates
- triax cable
- barometer, thermometer (preferably 2 thermometers)
- water phantom (NE2528/3A)
- spirit level
- ruler

- calipers
- multimeter
- simple tools (screwdrivers), adaptor plug
- scotch tape
- 5 verification films (prepacked)
- survey meter
- electronic personal dosimeter
- graph paper (millimetre scale)
- spare batteries
- telescopic distance indicator for distance and isocentric checks
- stopwatch
- 2 TLD sets and a TLD holder along with the instruction and data sheets.

The dosimetry equipment is calibrated at the Dosimetry Laboratory of the IAEA and its calibration factors are traceable to BIPM. The Dosimetry Laboratory of the IAEA provides the quality assurance and maintenance of the expert's equipment. It is the expert's responsibility to complement this equipment with additional items which may be needed during the visit, such as a pocket calculator (or a laptop), etc.

3. INTERVIEW OF THE INSTITUTION STAFF

It is essential that the expert interviews the appropriate staff from the local institution before any measurements are performed. The purpose of this interview is to understand the dosimetry practices of the institution, collect missing data and compare the institution's dosimetry data to the standard data for the specific treatment unit.

This interview should cover, as a priority, the questions which may be useful in resolving the TLD discrepancy (Appendix 2.6).

The second step is to review the dosimetry data available at the institution in order to compare them with standard sets of data for the same treatment unit make and model (Appendix 5).

The expert should also review the patient treatment charts in order to understand the different radiotherapy techniques used in the institution. He/she should get familiar with the typical field sizes used for different treatments including the use of accessories, such as blocks and wedges. This is needed to ascertain that the necessary dosimetry data are available and that the test dose calculations performed with the expert's assistance correspond to the typical treatments actually performed at the institution.

4. SAFETY AND MECHANICAL TESTS

4.1. Safety Tests

Before conducting any tests on the treatment unit, the expert should conduct, as a minimum, the following safety tests to ensure safe working conditions:

- door interlock operational
- radiation warning light operational
- emergency on/off switches operational
- manual means to shut off the machine
- exposure within the room with treatment unit in "beam off" condition.

The expert shall wear a personnel radiation monitoring device and, if available, a radiation survey meter with an active alarm option.

4.2. Mechanical Tests

The mechanical tests are designed to evaluate the geometrical accuracy and functionality of the treatment unit prior to the determination of the machine output under reference conditions. The confirmation of the geometrical integrity of the treatment unit is necessary to ensure proper set-up conditions for the calibration of the unit as well as the positioning of patients for daily treatments. To meet the IAEA acceptance criterion for the mechanical tests, the parameters measured or calculated by the expert and those used by the institution must agree within ±3 mm (2° for angle indicators). Any differences noted between the expert's measurements and the institution's values may provide the expert with additional information in determining the reason for the output discrepancy measured with the TLDs. The minimum list and order of the mechanical tests to be performed by the expert is given below.

- **Collimator Axis of Rotation** The mechanical axis of rotation of the collimator should be determined using the telescopic distance indicator or institution's mechanical distance indicator if available.
- **Collimator Angle Indicator** The collimator angle indicator should be compared at 90° intervals.
- **Gantry Axis of Rotation** The mechanical axis of rotation of the gantry should be determined using the telescopic distance indicator (or the institution's mechanical distance indicator if available). This is

accomplished by varying the gantry angle and placing the distance indicator as close as possible to the axis of rotation for each gantry angle attempting to converge on the axis of rotation. A reference pointer should be used to follow the axis of rotation at each gantry angle. A distance from a fixed point on the treatment head (e.g. the bottom surface of the tray holder) to isocenter should be measured and recorded.

- **Gantry Angle Indicator** The gantry angle indicator should be compared at 90° intervals using the spirit level.
- **Field Size Indicator** The field size indicator should be compared to the light field at the nominal treatment distance for three field sizes (5 cm x 5 cm, 10 cm x10 cm, 20 cm x 20 cm) using the millimetre graph paper.
- **Light/Radiation Field Coincidence** The light field and radiation field agreement should be evaluated using film for a 10 cm x 10 cm at the nominal treatment distance.
- **Lasers** The congruence of the lateral lasers and the isocenter horizontal plane, 20 cm on either side of the isocenter, at the nominal treatment distance should be measured.
- **Optical Distance Indicator** (if available) The congruence of the optical distance indicator (ODI) and the mechanical isocenter should be measured. In addition, the ODI at –10 cm, and +10 cm from the mechanical isocenter should also be measured. If the ODI is not available, then the institution's mechanism for determining the distance should be verified by the expert.
- **Travel of Treatment Couch** The congruence of the table indicators for vertical and lateral displacement with the measured displacement from isocenter, i.e. -10 cm and +10 cm, should be measured.

Once the above measurements have been performed and the comparisons made, the expert should discuss the findings with the institution's responsible physicist/personnel to correct any parameter found outside of the acceptance criteria. The expert is encouraged to assist the institution to perform the mechanical tests by making further confirmatory measurements. Any parameter found outside of the acceptance criteria may require the institution to alter its clinical treatments to account for the corrective actions taken by the institution's physicist or personnel. Once the expert believes that the geometrical and functional integrity of the treatment unit are acceptable, he/she should proceed to make the dosimetry measurements outlined in the next section. If the integrity of the treatment unit is not acceptable, the expert may wish to consider extending the visit, to allow the personnel at the institution to repair the treatment unit in a timely fashion before making the dosimetry measurements. If the unit cannot be repaired, the expert is still encouraged to make as many measurements and collect as much data as possible to resolve the TLD discrepancy.

5. DOSIMETRY EQUIPMENT COMPARISON

Before performing the beam output calibration, it is necessary for the expert to perform the following comparisons:

- comparison of the institution's and the expert's dosimetry systems
- comparison of the institution's and the expert's barometer and thermometer.

The aim of the above comparison is to verify the constancy of the local dosimetry system response, with reference to the calibration certificate.

If the standard local procedures involve the control measurements in a Sr-90 check source, these measurements should be performed prior to any other quality control tests and measurements. If the measured value is within ±1 % of the expected one, the result is considered acceptable. In case of a larger deviation, which cannot be explained, the local dosimetry system must be carefully checked for the chamber leakage, cable connection, humidity influence, electrometer stability, etc.

The standard method for comparison of the institution's ionisation chamber and electrometer with the expert's dosimetry system is to position both chambers in sequence in a water phantom, preferably in the NE 2528 box phantom and compare their readings in a Cobalt-60 beam. If an institution's chamber is non-typical and cannot be placed in the NE 2528 phantom, it is necessary to perform the reading comparison in air, with both chambers equipped with the appropriate build-up caps.

If no cobalt unit is available at the institution, the comparison should be performed at the

accelerator with the lowest megavoltage photon beam available.

The two readings should be converted to the same physical quantity, i.e. air kerma or absorbed dose to water (preferably that used by the local SSDL) and compared, with the acceptance level of 2%. If the difference observed can account for the discrepancy detected in the TLD audit, it is necessary for the institution to request recalibration of their dosimetry system at the local SSDL, or at the IAEA Dosimetry Laboratory.

The differences between the local and the expert's barometer and thermometer readings should be within 1.0% and 0.5 deg., respectively.

6. DOSIMETRY CALIBRATIONS AND MEASUREMENTS

6.1. Beam output calibration

Under the observation of the expert, the local medical physicist should calibrate the beam output according to the local institution's standard procedure. This procedure may include calibration in air, or in a water or plastic phantom at dmax or at the reference depth (e.g. 5 cm or 10 cm). The expert should follow carefully the whole procedure step by step and try to understand the local procedure completely. However, when an error is noticed, no remark should be made to the local physicists until he/she has completed the calibration procedure. The reason for this is that the expert may better identify possible reasons for the TLD discrepancy that pertain to the local calibration procedure or set-up.

The expert will perform a beam output calibration according to IAEA TRS-398 protocol [4] and compare the measured output to the institution's specification. The calibration may be performed using either:

1) the small water phantom (20 cm x 20 cm x 10 cm, model NE 2528) from the expert's kit or,

2) the water phantom belonging to the local institution.

In either case the measurements should be performed for the field size of 10 cm x10 cm at the nominal treatment distance and with whatever set-up method (SSD/SAD) is used at the institution.

The shutter correction for cobalt-60 units should be measured. In addition, the time indicated by the timer of the Co-60 unit and the time indicated by the stopwatch should be compared. The linearity of the treatment unit's timer should also be verified within the minimum and maximum treatment times used at the institution.

In the case of a linear accelerator, the ion recombination correction for the chamber should be determined. The quality index for high energy X-ray beams should be estimated prior to the dose measurement using the standard data provided for the make/model of the accelerator.

The Excel spreadsheet or printed worksheets for TRS-398 [4], prepared by the IAEA, should be used for calculation of the absorbed dose rate to water under reference conditions.

A comparison of the beam output determined by the institution's physicist and by the IAEA expert should be performed to identify any possible reasons for the TLD discrepancy. If the local beam calibration was not performed according to the TRS 398 protocol [4], the expert should convert the local beam output value to that consistent with TRS-398 [4]. The difference between the two beam output measurements should be carefully analysed and discussed with the local physicists or other relevant staff.

After the careful analysis of the difference between the institution's and the expert's values it is necessary to compare the deviation observed during the TLD audit with the present deviation in the output measurements to ascertain whether the TLD discrepancy can be fully explained by the differences in beam output measurements.

As a quality control check of his/her beam output determination the expert will irradiate the set of TLDs provided by the IAEA and will demonstrate the IAEA's standard TLD audit methodology to the institution's staff.

6.2. Additional measurements

The expert is encouraged to make a number of additional measurements, which are designed to verify that the institution's use of basic clinical dosimetry data is appropriate. The extent of these additional measurements will depend on the mission time available to the expert. If a large water phantom is not available at the institution, the expert may consider making the appropriate adjustments to the NE2528 water phantom to allow for measurements at a depth of 10 cm.

The following additional measurements are suggested to provide more complete assessment of the institution's clinical dosimetry practices (the standard data set may be required):

- verification of the dose variation with field size at d_{max} and at the depth of measurement
- verification of the institution's clinical wedge and tray transmission factors (if time does not allow for measurement of all wedges, the expert should, as a minimum, verify the two wedges with the largest wedge angles used clinically),
- verification of the beam output for non-standard SSDs used clinically.

If the differences between the expert's measured and the locally used clinical values exceed the tolerance levels (±3% for the beam output determination and ±2% for the relative measurements), a detailed analysis and possibly additional measurements should be carried out in order to explain the differences.

7. CLINICAL DOSIMETRY

At this stage the expert should have knowledge of the clinical techniques routinely used at the institution. The expert should therefore concentrate his/her efforts on the relevant clinical dosimetry data.

7.1. Basic Dosimetry Data

The expert should examine the beam data tables available, determine if the data are measured or based on published data, and obtain copies of appropriate data (if possible) to enable an independent review by the IAEA staff.

The expert should confirm the validity of the basic beam dosimetry data used by the institution by comparison with the standard data [1]. The expert should ascertain how the basic dosimetry data set is used by the treatment planning system (TPS) or the in-house software.

7.2. Monitor Units / Time Set Calculation

The expert should evaluate the institution's method used routinely to calculate the number of monitor units or time set for patient treatments. For this the local physicist should be requested to determine monitor units or time set for the clinical dosimetry tests as described below. Also the expert should independently calculate the monitor units/time set for the same standard dosimetry tests using the output value that he/she has measured and the standard data supplied. The expert's results should be compared with those determined by the institution. A detailed analysis of any differences in calculation should be performed.

Standard clinical tests should be performed for a simple water phantom (20 cm x 20 cm x 10 cm) irradiated with a single field. Monitor units or time set should be calculated to deliver 2 Gy at the various points of interest. The following set-ups are recommended:

- Field size 10 x 10 cm. Depth 5 cm. With and without wedge
- Field size 10 x 10 cm. Depth 10 cm
- Field size 7 x 15 cm. Depth 5 cm. With and without wedge
- Field size 7 x 15 cm. Depth 10 cm.

If blocks are used at the institution, the expert and the local physicist should calculate monitor units or time set for a typical blocked field used at the institution.

The ion chamber measurements described in section 6.2 should be used to demonstrate how to verify the dose calculations.

7.3. Check of treatment planning system

The expert should perform a set of tests to verify the following parameters of the treatment planning system (TPS):

- Confirm that the field sizes on printouts and the entered field sizes match within ±1 mm.
- Confirm that the depth doses are correct e.g. check isodose values at 5 cm and 10 cm depth and compare to the measured data.
- Confirm the wedge isodose values by measuring doses in three points at a 5 cm depth for a 10 cm x 10 cm field size, i.e. one point on the central axis and two additional off-axis points, 2.5 cm on each side of the central axis. The latter two measurements will involve moving the phantom laterally.

8. TRAINING OF LOCAL STAFF

An important part of the IAEA expert mission is to provide training to the local physicists to improve their clinical dosimetry practices. This educational process will be an ongoing one, starting from the initial interview, and continuing throughout the mechanical checks, instrument comparisons, beam output calibration, analysis of the expert's measured values with respect to the institution's clinical values and possible explanations of any deviations observed. In

addition to the above processes, the clinical dosimetry measurements and tests, as outlined in the sections 6.2 and 7, also have an important educational value for the institution's physicists or other staff involved in the daily treatment of patients. The expert should leave a copy of his/her signed and dated measurements, calculations, report of results and a copy of the TRS 398 [4] with the local physicist prior to departing the institution. These data and information will provide the institution's physicist with a set of independently measured reference data that can be used later to compare his/her own measurements for possible future dosimetry changes.

The goal of TLD irradiation performed by the IAEA expert at the end of the beam calibration is twofold. The first is to provide a confirmation of the expert's ionisation chamber measurements, and the second, to train the institution's staff on the IAEA methodology of the TLD irradiation procedure.

The expert should make every effort to explain to the institution's staff any recommendations for changes in the local dosimetry practices. The local physicist should be encouraged, prior to introducing any changes, to understand the new procedures and to perform his/her own confirmatory measurements.

9. REPORTING AND RECOMMENDATIONS

At the end of his/her visit, the expert should present to the local physicist and, if possible, to the chief of the radiotherapy department (director of the hospital) a preliminary report of the measurements performed during the mission using the report form in Appendix 4. Any records left at the institutions should be clearly marked "preliminary".

The end-of-mission report to the IAEA should contain the following data and information for further quality control and processing:

- summary of the tests and measurements performed by the expert
- results of the measurements
- results of clinical dosimetry
- analysis of the results of the measurements
- the expert explanation of the reason for the discrepancy
- the impact of the discrepancy on patient treatments
- recommendation to the institution: general and specific
- recommendation to the IAEA/WHO TLD postal dose audit programme.

The relevant forms, spreadsheets and worksheets, given in the Appendices, should be used for reporting measured data. All forms should be properly dated and signed.

It is of utmost importance that the radiotherapy personnel understand the consequences of the observed discrepancies and how they affect patient treatments. The discrepancies relevant to patient treatments should result in a number of specific recommendations by the expert to the local staff. The expert may be required to explain any important changes in dosimetry practices to the radiation oncologist particularly if these changes might have a significant impact on the clinical outcome of patient treatments.

REFERENCES

[1] British Institute of Radiology, Central axis depth dose data use in Radiotherapy, Brit. J. Radiol. Supplement no. 25, The British Institute of Radiology, London (1996)

[2] FAO/IAEA/ILO/OECD(NEA)/PAHO/WHO, International Basic Safety Standards for protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series no. 115, IAEA, Vienna (1996)

[3] International Atomic Energy Agency, Design and implementation of a radiotherapy programme: Clinical, medical physics, radiation protection and safety aspects, IAEA-TECDOC-1040, IAEA, Vienna (1998)

[4] International Atomic Energy Agency:: Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry based on Standards of Absorbed Dose to Water. Tech. Rep. No 398, IAEA Pub. Vienna 2000

APPENDICES

All appendices are available on request from the Dosimetry and Medical Radiation Physics Section of the IAEA (dosimetry@iaea.org) or can be downloaded from the web page http://www-naweb.iaea.org/qamanual.html

1. Information form "A typical on-site dosimetry review visit"
2. Staff interview data collection forms
2.1. DIRAC questionnaire
2.2. Instrumentation
2.3. Co-60 unit data
2.4. Accelerator data (photons)
2.5. Clinical dosimetry
2.6. TLD discrepancy interview record
3. Measurements records and forms
3.1. Safety and mechanical measurements
3.2. Dosimetry equipment comparison
3.3. Dose determination records
3.3.1. IAEA dose calculation spreadsheets
3.3.2. Dose measurements record
3.3.3. Beam output reporting form
3.4. Clinical dosimetry
4. Expert report form
5. Standard data set for Co-60 and high energy photon beams.

REASONS FOR DEVIATIONS OUTSIDE THE ACCEPTANCE LIMITS IN THE IAEA/WHO TLD AUDITS FOR RADIOTHERAPY HOSPITALS

Stanislav Vatnitsky and Joanna Izewska

Dosimetry and Medical Radiation Physics
Section, Division of Human Health
IAEA

The main purpose of the IAEA/WHO TLD postal dose audit programme for dosimetry in radiotherapy [1] is to provide an independent verification of the dose delivered by treatment machines in radiotherapy hospitals. The results of the TLD audit are considered acceptable if the relative deviation between the participant's stated dose and the TLD determined dose is within ±5%. The goal of this note is to draw the attention of participants of the TLD programme to some of the common reasons for deviations outside the acceptance limits. Armed with this knowledge, other participants may avoid similar problems in the future.

The analysis of deviations presented here is based on the results of TLD audits of the calibration of approximately 1000 Co-60 beams and 600 high-energy X-ray beams performed in the period 1996-2001.

A total of 259 deviations outside the ±5% limits have been detected, including 204 deviations for Co-60 beams (20% of all Co-60 beams checked) and 55 for high-energy X-ray beams (10% of all X-ray beams checked). It is worth mentioning that the percentage of large deviations (beyond 10%) is also higher for Co-60 beams than for high-energy X-ray beams.

Some problems may be caused by obsolete dosimetry equipment or poor treatment machine conditions. Other problems may be due to insufficient training of staff working in radiotherapy. The clinical relevance of severe TLD deviations detected in the audit programme was confirmed in many cases, but, fortunately, not all-poor dosimetric results reflect deficiencies in the calibration of clinical beams or machine faults. Sometime it happens, that the TLDs are irradiated with an incorrect dose due to misunderstanding of the instructions on how to perform the TLD irradiation. Such dosimetry errors would have no direct impact on actual dose delivered to a patient. The deviations that occur most frequently in the IAEA/WHO TLD programme are shown in figure 1 and discussed below.

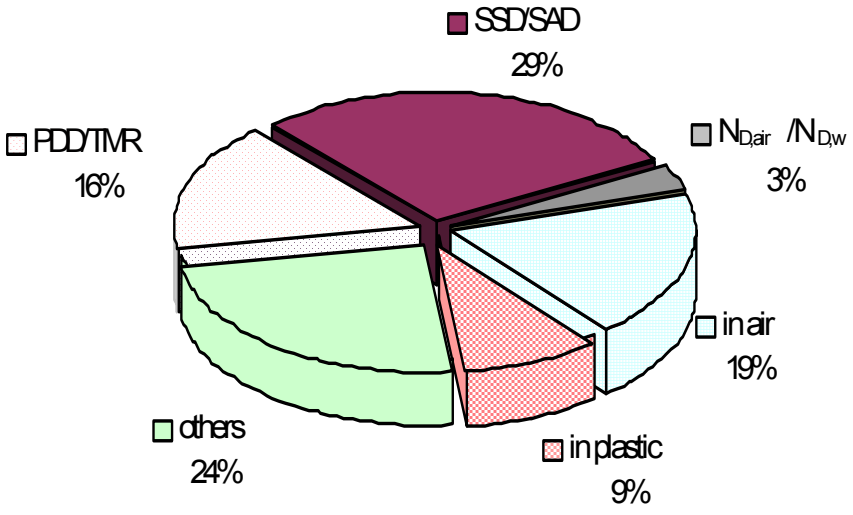

Figure 1. The frequency of occurrence of deviations outside the acceptance limits of ±5% grouped according to the cause of deviation, indicating confusion about a specific factor or parameter

PDD/TMR ERROR: MAGNITUDE 18 – 25%

In this error, the TLD is placed properly at a depth of 5 cm, but the irradiation time or the number of monitor units, (MU) is calculated as if the TLD were at the depth of dose maximum, without using the percentage depth dose (source skin distance, SSD, setup) or the tissue maximum ratio, TMR (source axis distance, SAD, or isocentre setup). The discrepancy between the stated and measured doses ranges from 18% to 25 %, depending on beam quality.

Tip to hospital staff: *double-check the calculated time/MU for the TLD irradiation. Remember that the TLD is placed at 5 cm depth not at the depth of dose maximum.*

SSD/SAD ERRORS: MAGNITUDE 10 – 17 %

In this error, the beam output is given for the SSD setup, but the TLDs are irradiated in the SAD setup or vice versa, yielding a discrepancy between the stated and measured doses of about 10 – 17 %, depending on the values of SSD/SAD (60 – 100 cm).

Tip to hospital staff*: make sure that the output used for the TLD irradiation is defined for the same beam geometry as the TLD setup; do not confuse SSD with SAD.*

MISINTERPRETATION OF ION CHAMBER CALIBRATION FACTORS: MAGNITUDE 10 – 13%

Two types of errors may occur:

(i) The absorbed dose to water calibration factor, $N_{D,w,}$ is used instead of the absorbed dose to air factor, $N_{D,air}$ when calculating the beam output from the ion chamber measurements following TRS 277 [2],

(ii) The direct Gray-scale readings are used to measure the absorbed dose to water in Co-60 beams, although the calibration factor in terms of air kerma, N_K, is in the electrometer memory; as a result, N_K is used as if it were $N_{D,w}$.

These cause a discrepancy between the user's stated dose and the TLD measured dose of about 10-13 %, depending on the photon beam quality.

Tip to hospital staff*: make sure to use a consistent set of data in the dose calculation formalism: either the N_K based dosimetry protocol, such as TRS-277 [2] with the $N_{D,air}$ (formerly N_D) chamber factor, or the $N_{D,w}$ based protocol, such as TRS-398 [3] with the $N_{D,w}$ chamber factor. Check which type of chamber factor is stored in the memory of the electrometer: when the direct Gray-scale reading for the measurement of absorbed dose to water is used in a Co-60 beam, the $N_{D,w}$, factor should be in the memory. In case of doubts, contact the calibration laboratory.*

ERRORS IN CONVERSION OF EXPOSURE TO ABSORBED DOSE TO WATER: MAGNITUDE UP TO 5-8%

In this error, an inconsistent set of data is used for the determination of absorbed dose to water from the exposure measurements in air based on the old N_X based dosimetry protocols in Co-60 beams. This yields deviations up to 5-8%.

Tip to hospital staff: *make sure to convert exposure to the dose in a mini-phantom and then to use (i) tissue air ratio, TAR, for the SAD setup or (ii) a backscatter factor and PDD for the SSD setup to convert the dose from mini-phantom to full-scatter phantom.*

ERRORS IN CONVERSION OF THE ABSORBED DOSE TO PLASTIC TO THE DOSE TO WATER: MAGNITUDE UP TO 7%

In this error, corrections for the stopping power ratio of plastic/water are ignored and/or the depth scaling is not applied when using plastic phantoms for beam calibration measurements. This yields errors in the beam output up to 7%.

Tip to hospital staff: *make sure to correct the ion chamber readings in plastic to obtain the absorbed dose to water, e.g. following the procedure proposed by AAPM [4].*

CRITICAL ERRORS

Two examples of serious problems detected with TLDs are given, where the doses to radiotherapy patients differed significantly from those prescribed:

(i) TLD measured dose divided by the user stated dose, D_{TLD}/D_{stat} = 1.79. An error in the measurement of output was made by an inexperienced physicist after a Co-60 source replacement. Patients were irradiated with significantly higher doses during a period of one

month. This caused the deaths of approximately 90 patients and severe injuries to many others [5].

(ii) The ratios of D_{TLD}/D_{stat} varied from 0.61 to 1.20 in subsequent audits, due to erratic functioning of the Co-60 shutter system attributable to poor maintenance of the machine. No output measurements had been done for a few years and several patients treated with this machine may have been affected.

ANECDOTAL CASES

A few extreme deviations were observed that were caused by communication problems but, fortunately, these had no direct clinical relevance.

Due to an error in data transfer, a Co-60 timer was set to 157 s instead of 15.7 min. The error in time setting yielded a ratio of the TLD measured dose to the user stated dose of $D_{TLD}/D_{stat} = 0.17$.

Due to misunderstanding of the TLD irradiation instructions**,** very large deviations occurred in a few hospitals.

(i) TLDs were irradiated twice, resulting in the ratio of $D_{TLD}/D_{stat} = 1.99$.

(ii) TLDs were irradiated with 2 Gy 'fractions', four days in sequence, resulting in the ratio of $D_{TLD}/D_{stat} = 4.02$.

(iii) TLDs were irradiated in air, due to the lack of a water phantom. Each TLD capsule was irradiated with a different photon beam. The TLD readings were not evaluated.

REFERENCES

[1] J. Izewska, P. Andreo, The IAEA/WHO TLD postal programme for radiotherapy hospitals, Radiotherapy and Oncology 34 65-72 (2000).

[2] IAEA: Absorbed Dose Determination in Photon and Electron Beams: An International Code of Practice (IAEA Technical Reports Series No. 277, Second Edition).

[3] IAEA: Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry based on Standards of Absorbed Dose to Water (IAEA Technical Reports Series No. 398).

[4] AAPM American Association of Physicists in Medicine, Task Group 21: A protocol for the determination of absorbed dose from high-energy photon and electron beams, *Med. Phys.* 10 (1983) 741-771.

[5] Accidental Overexposure of Radiotherapy Patients in San José, Costa Rica. IAEA Special Publication Series (IAEA-STI/PUB/1027).

HOW TO JOIN

THE IAEA/WHO TLD POSTAL DOSE AUDIT PROGRAMME

During last 32 years more than 1200 hospitals have participated in the IAEA/WHO TLD postal dose audit. This cost-free audit service provides checks of the calibration of high energy photon beams in radiotherapy hospitals in Africa, Asia, South America and, South and Eastern Europe.

We believe that participation in the TLD postal dose audit programme is valuable to hospitals since it may contribute to improving the accuracy of their clinical dosimetry which in turn would benefit many cancer patients.

The technical aspects of the TLD service are carried out at the IAEA Dosimetry and Medical Radiation Physics Section in Vienna, whereas the WHO (PAHO in Latin America) managers the distribution of the TLDs. In order to join the IAEA/WHO TLD network, a request should be sent to the WHO Office in Geneva, PAHO office in Washington or directly to the IAEA :

WHO: fax +41 22 791 4836, e-mail ingolfsdottirg@who.ch
PAHO: fax +1 202 974 3610, e-mail borrasca@paho.org
IAEA: fax +43 1 26007 21662, e-mail dosimetry@iaea.org

HOW TO JOIN

EQUAL - THE ESTRO TLD QUALITY ASSURANCE PROGRAMME

The IAEA/WHO TLD network closely co-operates with the TLD network of the European Society for Therapeutic Radiology and Oncology (ESTRO) who offers the TLD service to the ESTRO members mainly in the European Union. The ESTRO TLD Quality assurance programme (EQUAL), provides photon and electron beam checks in reference and non-reference conditions:

- *For photon beams, the EQUAL programme checks the reference beam output, the percentage depth doses, the beam output variation for open and wedged fields and the wedge transmission factor. The programme has recently been extended to include dose checks for photon MLC fields on axis. Reference field and five other fields with shapes and dimensions defined by the MLC are checked*

- *For electron beams the programme checks the output for five different field sizes.*

In accordance with the Memorandum of Understanding between the IAEA and ESTRO-EQUAL, the EQUAL service for dose audits for photon MLC fields and electron beams is now being offered to the neighbouring countries, where this type of service is not available through national QA networks.

The application forms can be downloaded from: www.estro.be, or a request can be made to: ESTRO-EQUAL Laboratory in Villejuif, France: Fax 33/1/42.11.52.99, e-mail : equal@igr.fr.

COMPARISON OF CALIBRATIONS OF A WELL TYPE IONIZATION CHAMBER BETWEEN THE IAEA AND THE SSDL OF FINLAND

H. Tölli, Dosimetry and Medical Radiation Physics Section, Division of Human Health
IAEA

P. Sipilä, A. Kosunen, SSDL
Radiation and Nuclear Safety Authority (STUK)
Finland

1. INTRODUCTION

Since 1996, the IAEA has maintained standards for Low Dose Rate (LDR) brachytherapy dosimetry. These standards consist of two ^{137}Cs sources, calibrated at the National Institute of Standards and Technology (NIST), USA. Detailed data are shown in Table 1.

TABLE 1. IAEA ^{137}Cs LDR STANDARDS FOR BRACHYTHERAPY DOSIMETRY

Source	Capsule		Active	K_R
	Length (mm)	Diameter (mm)	Dimensions[4] (mm)	(01-05-96) (μGy / h)
CDCS J5	20	2.65	13.5	190.5
CDC1100	8.0	3.2	2.2	339

As with all calibrations, maintaining our knowledge and confidence in of the standards at the highest possible level is essential. One way of verifying the quality of our calibrations is by means of a comparison with another SSDL. The purpose of this report is to describe such a comparison.

2. PROCEDURE FOR THE COMPARISON

A comparison was performed between the IAEA and the SSDL of Finland (STUK). A well type chamber, HDR 1000Plus (Standard Imaging, USA) was calibrated at the IAEA Dosimetry Laboratory and sent to STUK. After calibration by STUK the chamber was returned to the IAEA and a check of the chamber's response was made. This was done in order to verify that the chamber calibration had not been altered as a result of the transportation.

2. MATERIALS

The well type chamber was calibrated at the IAEA Dosimetry Laboratory using both the sources shown in Table 1. The uncertainty in the calibration at the IAEA has been analysed in TECDOC-1079 [1] and is 1.2% (k=1). The corresponding uncertainty in the calibration performed by STUK is 1.6% (k=1). STUK uses one ^{137}Cs LDR source for their calibration service, namely model CDC700 from Amersham.

3. RESULTS

The results of the comparison are shown in the Table below.

TABLE 2. RATIOS BETWEEN STUK AND IAEA CALIBRATIONS

Source	Ratio STUK/IAEA
CDCS J5	0.996
CDC1100	0.989

4. DISCUSSION

None of the ratios in Table 2 are significant since both quotients shown have the relative uncertainty of 2% (k=1). The ratios are different due to the different geometries of the sources. It must be mentioned that neither of the IAEA standards is identical with the source, CDC700, used by STUK. The data available for this source is that its geometry resembles more that of the CDC1100 source rather than CDCS J5. However, the exact geometry of the CDC700 source was not possible to find out in spite of contacts taken with Amersham.

This unclear geometry complicates the interpretation of the results. An additional source of uncertainty in the interpretation of the results is due to the periodic variation of the response of the IAEA brachytherapy standards, as has been reported previously [2].

REFERENCES

[1] Calibration of Brachytherapy Sources: Guide-lines on standardized procedures for the calibration of brachytherapy sources at Secondary Standard Dosimetry Laboratories (SSDLs) and hospitals. IAEA TECDOC-1079, (1999)

[2] SSDL Newsletter 44, pp. 20 – 23, (Jan.2001)

[4] The CDCS J5 source consists of 9 active pellets, each with a 1.5 mm diameter. The CDC1100 consists of a single active pellet with 2.2 mm diameter.

UPDATE OF TECDOC-1079 ON CALIBRATION OF BRACHYTHERAPY SOURCES

TECDOC-1079 on calibration techniques of brachytherapy sources has been updated. The new report is:
TECDOC-1274: Calibration of photon and beta ray sources used in brachytherapy: Guidelines on standardized procedures at Secondary Standards Dosimetry Laboratories (SSDLs) and hospitals.

TECDOC-1274 has a wider scope than its precursor and includes calibration techniques for all the most commonly used brachytherapy sources. Parts of the TECDOC-1079 that described calibration techniques for ^{192}Ir, ^{137}Cs and ^{60}Co brachytherapy sources are included in the new report with only some minor editing. Calibration methods for both ^{125}I and ^{103}Pd are given in TECDOC-1274. Included in the updated report are guidelines for calibration of beta ray sources used in ophthalmic applications and in endovascular brachytherapy.

Besides its wider scope, TECDOC-1274 includes a description of a large number of different detector systems that can be used in calibration procedures. Tables are given that classify the different detectors according to their suitability for calibration of different types of brachytherapy sources.

In order to be able to state the overall uncertainty in a given calibration, it is necessary to know all the component uncertainties, i.e. at the PSDL and at the SSDL. In as far as it has been possible, the uncertainty in the calibration by the PSDL is given in TECDOC-1274.

The report also gives guidelines on quality control of the equipment used in the calibrations. Recalibration intervals of well type chambers are given. Clear acceptance limits are stated for the constancy checks of well type chambers in the case where the constancy is checked using a photon source (e.g. ^{137}Cs) or a beta ray source (e.g. ^{90}Sr). During a constancy check, if the chamber's response deviates from the expected result by more than given by the limits, a recalibration is recommended.

A PDF-version of the TECDOC-1274 can be downloaded from:

http://www-naweb.iaea.org/nahu/external/e3/publications.asp

A cost-free hardcopy of TECDOC-1274 can be ordered from the Dosimetry and Medical Radiation Physics Section using the address given in this Newsletter.

PILOT STUDY TO VERIFY THE CALIBRATION OF ELECTROMETERS

P. Becker, National Laboratory for Metrology of Ionizing Radiation, IRD
Brazil

A. Meghzifene, Dosimetry and Medical Radiation Physics Section, Division of Human Health
IAEA

The main detector used for standardization of the quantities used in measurements of ionizing radiation is the ionization chamber. The interaction of the radiation with this detector produces electrical charge, usually, in the range of pC to nC. The instrument used to measure such small charges (or currents) is the electrometer. As part of a good practice, the measured charge (current) must be traceable to a primary or secondary standard.

Some calibration laboratories can only provide a system calibration coefficient, i.e. a calibration coefficient for the combination of electrometer plus ionization chamber (Gy/scale division). This practice is acceptable, but it can impose a limitation to the automation of their calibration procedures (using computerized application for the acquisition of current/charge). Not all models have the possibility of a connection to a computer and in the case of those that don't have this capability, automation is not possible without the development of a specific interface. In addition, end-users receive a calibration coefficient, which is only valid for the set ion chamber and electrometer. In case of a broken chamber, the end-user cannot connect another chamber to their electrometer without knowing its calibration coefficient. If the calibration laboratories had the capability of calibrating the chamber separately from the electrometer, for example, using an electrometer calibrated in terms of charge, all the chambers could be calibrated using this electrometer. The laboratory can also benefit from the automation of the measurements. This requires that the laboratory must be able to cross-calibrate the electrometers (associated to the chambers) also in terms of charge (Coulombs).

Electrical charge is standardized by the use of a standard air capacitor and a standard voltage source (Q=CV) and the National Laboratory for Metrology of Ionizing Radiation (IRD) in Brazil has also adopted this procedure.

Since the Brazilian National Laboratory for Electrical Measurements has not yet developed its capability for the standardization of small electrical charge produced by DC, the IRD is trying to verify its standardization procedures of the electrical charge through a comparison programme. This subject was discussed with a major electrometer manufacturer that has offered to provide free of charge, three of their electrometer calibration standards for a pilot run. The model to be provided consists of four calibrated resistors and two calibrated capacitors, covering the charge/current range of interest. For producing charge or current a standard DC voltage must be applied to these components. Since practically all-modern electrometers measure using virtual ground, this methodology is viable.

The IRD, in collaboration with the IAEA, wishes to invite interested laboratories to participate in this pilot comparison programme. This exercise is expected to be useful for all participants and will hopefully open the way for the establishment of routine comparisons in this area. The results will be discussed and published in an appropriate journal.

Interested institutions should contact directly Mr. Paulo H. B. Becker through e-mail (pbecker@ird.gov.br) or fax +55 21 24421950 informing him of the model and manufacturer of the electrometer to be used for the pilot study and discuss all practical details.

AN OVERVIEW OF THE FACILITIES OF THE IONIZING RADIATION LABORATORY, SOUTH AFRICA

J.C. Mostert

Ionising Radiation Laboratory
CSIR-National Metrology Laboratory
South Africa

1. INTRODUCTION

The Ionising Radiation Laboratory (IRL) of the CSIR-National Metrology Laboratory (NML) in South Africa was recently accepted as a member of the IAEA SSDL network. This article gives a very brief overview of the services and facilities provided by this laboratory.

The NML has the responsibility to realize and maintain the national measuring standards in South Africa. In the field of ionizing radiation, this function is performed by the IRL.

The IRL provides traceability through its calibration and measurement services for regulatory authorities, institutions providing radiation therapy services such as hospitals and other oncology centres, radiation protection service providers such as the South African Bureau of Standards (SABS), the radiation protection industry in general and to companies providing industrial quality assurance services. These services also extend to a number of countries in the Southern African Development Community (SADC) which do not currently have metrology facilities of their own.

2. FACILITIES

2.1 Standards for radiation therapy

The IRL maintains the South African national measurement standards for air kerma in Co-60 radiation and X-rays as well as for absorbed dose to water in Co-60 radiation. These standards are based on measurements made with a secondary standard that consist of an electrometer and ionization chamber whose calibration coefficients are traceable to the National Physical Laboratory (NPL) in the UK.

The ionization chamber is used to calibrate a set of working standards, in accordance with accepted quality assurance principles, which in turn are used to calibrate secondary standards belonging to the different radiation therapy centres.

2.2 Standards for radiation protection

Air kerma standards are used to calibrate radiation beams from Cs-137, Co-60 and Am-241 sources. These calibrated fields are then used to calibrate gamma ray survey meters and personal dosimeters used in the radiation protection field. The calibrated fields are also used to irradiate TLD's to specific doses for institutions operating TLD based radiation protection services, such as the SABS.

The IRL also maintains a set of neutron sources that are calibrated in terms of fluence rate at the NPL. These are used to calibrate neutron sensitive devices and to irradiate neutron sensitive TLDs to specific doses.

In addition to gamma and neutron radiation standards, a beta irradiation facility with two standard sources with traceability to the NPL is maintained. This is used primarily for the irradiation of TLDs.

2.3 Activity standards

In addition to the dosimetry standards maintained by the IRL, a set of surface activity standards and a radon progeny activity concentration standard are maintained.

The surface activity standards consist of a set of four extended area sources (Am-241, Sr-90, Cl-36 and C-14) of which the surface emission rates are traceable to the NPL. These are used to calibrate other extended area sources in terms of surface emission rate using a gas flow window counter. Calibrated extended area sources are used to calibrate contamination monitors that are used primarily in the radiation protection field.

A large radon chamber houses a radon progeny sampling and measuring system. This facility is used for the calibration of radon progeny measuring devices that are used in radiation protection. These monitors are used extensively in South African gold mines to monitor radon and radon progeny levels.

3. COMPARISONS

As part of the NML's comparison programme, the IRL participates regularly in international and regional comparisons to ensure it's continuing competence and equivalence to other international facilities. The laboratory recently participated in the Asia-Pacific Metrology Program (APMP)

comparison for absorbed dose to water and several other comparisons are currently in progress.

4. QUALITY SYSTEM

Due to the importance of accurate and traceable calibrations of ionizing radiation equipment, the IRL is currently in the process of implementing ISO/IEC 17025 guidelines. The conclusion of this process will be an assessment by the South African National Accreditation Service (SANAS), during which the technical activities of the laboratory will be subjected to review by international experts. This process is expected to be completed by the end of 2003.

5. MORE INFORMATION

More information on the activities and capabilities of the CSIR-NML and the IRL may be obtained from the world wide web at www.csir.nml.co.za

CALIBRATION FACTOR OR CALIBRATION COEFFICIENT?

A. Meghzifene & K. R. Shortt

Dosimetry and Medical Radiation Physics, Division of Human Health
IAEA

The IAEA/WHO network of SSDLs was set up in order to establish links between SSDL members and the international measurement system [1]. At the end of 2001, there were 73 network members in 63 Member States. The SSDL network members provide calibration services to end-users at the national or regional level. The results of the calibrations are summarized in a document called calibration report or calibration certificate [2]. The IAEA has been using the term calibration certificate and will continue using the same terminology.

The most important information in a calibration certificate is a list of calibration **factors** and their related uncertainties that apply to the calibrated instrument for the well-defined irradiation and ambient conditions. The IAEA has recently decided to change the term calibration **factor** to calibration **coefficient**, to be fully in line with ISO [ISO 31-0], which recommends the use of the term **coefficient** when it links two quantities A and B (equation 1) that have different dimensions. The term **factor** should only be used for k when it is used to link the terms A and B that have the same dimensions

$$A = k.B \qquad (1)$$

However, in a typical calibration, an ion chamber is calibrated in terms of a physical quantity such as air kerma, dose to water, ambient dose equivalent, etc. If the chamber is calibrated together with its electrometer, then the calibration refers to the physical quantity to be measured per electrometer unit reading. In this case, the terms referred have different dimensions.

The adoption by the Agency of the term **coefficient** to express the results of calibrations is consistent with the "International vocabulary of basic and general terms in metrology" [4] prepared jointly by the BIPM, IEC, ISO, OIML and other organizations. The BIPM has changed from **factor** to **coefficient**.

The authors believe that this is more than just a matter of semantics and recommend that the SSDL network members adopt this change in terminology.

REFERENCES

[1] International Atomic Energy Agency, the SSDL Network Charter, IAEA, Vienna, (1999)

[2] International Atomic Energy Agency, Calibration of Dosimeters Used in Radiotherapy, TRS-374, IAEA, Vienna, (1994)

[3] International Organization for Standardization, Quantities and Units-Part 0: General Principles, International Standards 31-0, ISO, Geneva, (1992)

[4] International Vocabulary of Basic and General Terms in Metrology, BIPM, ISO, IEC, IFCC, IUPAC, IUPAP, OIML, (1994)

ANNOUNCEMENT

INTERNATIONAL SYMPOSIUM ON STANDARDS AND CODES OF PRACTICES IN MEDICAL RADIATION DOSIMETRY

25-28 November 2002

Vienna, Austria

The Symposium will provide a forum where advances in radiation dosimetry during the past decade, not only in external beam radiotherapy but also in other areas of radiation medicine, can be disseminated and scientific knowledge exchanged. It will include areas that have been developed recently (e.g. intravascular therapy and hadron dosimetry), together with classic areas where the standardization of dosimetry may not have reached a mature stage (e.g. diagnostic radiology and nuclear medicine). It will also summarize the present status and outline future trends in medical radiation dosimetry and identify possible areas for improvement. Its conclusions and summaries should lead to the formulation of recommendations for the scientific community.

The Symposium will give an opportunity for scientists in medical institutions, research centers and standards laboratories (Secondary Standards Dosimetry Laboratories and Primary Standards Dosimetry Laboratories) to meet for discussions covering the entire dosimetry chain. The Symposium is addressed to a broad spectrum of medical physicists and other scientists working in radiation dosimetry with responsibilities in the following fields: radiation metrology, external beam radiotherapy with photons, electrons and hadrons, brachytherapy including intravascular techniques, diagnostic radiology including CT, mammography and interventional procedures, and nuclear medicine

Additional information and details on participation can be found on the Internet:

www.iaea.org/worldatom/Meetings/2002/infcn96.shtml

The submission for Extended Synopsis (2 pages, deadline: 15 March 2002) can be done through the Internet**:**

www-naweb.iaea.org/nahu/symposiumsubmission.asp

However, the original documents (extended synopsis, participation form, grant form) must be sent to the IAEA through the official governmental channels. Authors whose extended synopsis has been accepted for oral or poster presentation at the Symposium will be informed in **June** at the time of announcing the final programme. By **early September**, presenters must submit the 5-page paper for refereeing by the chair and co-chair of the appropriate session. Each 5-page submission for the proceedings should be in electronic format ready for final editing during the symposium.

COURSES AND MEETINGS TO BE HELD DURING 2002

Regional Training Course on clinical dosimetry, Caracas, Venezuela, 21 January-1 February 2002 (RLA/6/032),

Regional training course for technicians and technologists on quality assurance and quality control in mammography 4-8 February 2002, Havana, Cuba (RLA/6/043)

Regional Workshop on quality assurance in radiotherapy: physical and technical aspects, Dar-es-Salam, Tanzania, 15-19 April 2002 (RAF6027)

Regional Workshop on the implementation of TRS-398, Tunis, Tunisia, May/ 2002 (RAF6027)

Regional Workshop on quality assurance for treatment planning systems, Rabat, Morocco, 3-8 June 2002 (RAF6027)

ESTRO courses under RER/6/012

Radiotherapy Treatment Planning: Principles and Practice, Dublin, Ireland, 10-14 March

Dose Determination in Modern Radiotherapy: Beam Characterization, Calculation and Verification, Perugia, Italy, 21-25 April 2002

Basic Clinical Radiobiology (regular version), Uppsala, Sweden, 5-10 May

Modern Brachytherapy Techniques, Lisbon, Portugal, 16-20 June

Imaging for Target Volume Determination in Radiotherapy, venue to be decided, 23-27 June

Basic Clinical Radiobiology, St. Petersburg, Russia, 25-29 August

Physics for Clinical Radiotherapy, Leuven, Belgium, 25-29 August

Evidence Based Radiation Oncology: Methodological Basis for Clinical Application, Tenerife, Spain, 10-16 November

Meetings

Technical Meeting on the Evaluation of and Recommendations on the Dosimetry Programme (10th Meeting of the SSDL Scientific Committee, the SSC-10), 25 February-1 March 2002, 25 February – 1 March 2002

Programme Committee Meeting for the 2002 International Symposium on standards and codes of practice in medical radiation dosimetry, 8-10 May 2001, 25 February – 1 March 2002.

Final Research Coordination Meeting on implementation of TRS-398, 18-22 November 2002, IAEA Headquarters, Vienna

International Symposium on Standards and Codes of Practice in Medical Radiation Dosimetry, 25-28 November 2002, IAEA Headquarters, Vienna. (www-naweb.iaea.org/nahu/symposiumsubmission.asp)

MEMBER LABORATORIES OF THE IAEA/WHO NETWORK OF SSDLS[1]

Country	City	Contact person	Fax	E-mail
ALGERIA	Algiers	Mr. M. Arib	+213 21 43 4280	amehenna@altavista.fr
ARGENTINA	Buenos Aires	Ms. M. Saravi	+54 11 4379 8228	saravi@cae.cnea.gov.ar
AUSTRALIA	Menai	Mr. D. Alexiev	+612 9717 3257	dax@ansto.gov.au
AUSTRIA	Vienna	Mr. C. Schmitzer	+43 2254 7802502	hannes.stadtmann@arcs.ac.at
BANGLADESH	Dhaka	Mr. Abdul Jalil	+88 2 863051	inst@bangla.net
BELARUS	Minsk	Ms. Valeri Milevski	+375 17 2130938	belgim@belgim.belpak.minsk.by
BELGIUM	Ghent	Mr. H. Thierens	+32 92646699	hubert.thierens@rug.ac.be
BOLIVIA	La Paz	Mr. Ismael Villca	+591 2 433063	ibten@caoba.entelnet.bo
BRAZIL	Rio de Janeiro	Ms. M. de Araujo	+552 14421605	mmaraujo@ird.gov.br
BULGARIA	Sofia	Mr. Z. Bouchakliev	+359 2 443114	ivan_dim@techno-link.com
CANADA	Ottawa	Mr. Brian R. Gaulke	+1 613 9578698	brian_gaulke@hc-sc.gc.ca
CHILE	Santiago	Mr. Oyarzún Cortes	+56 2 27318723	coyarzun@gopher.cchen.cl
CHINA*	Beijing	Mr. Gan Zeuguei	+86 10 444304	
CHINA	TaiYuan, Shanxi	Mr. Chen Mingjun		
CHINA	Shanghai	Mr. Liu Shu-lin	+86 2164701810	simtt@stn.sh.cn
CHINA	Beijing	Mr. Li Kaibao	+86 10 62012501	kbli@lih1.nrmpin.ac.cn
CHINA	Hong-Kong	Mr. C.L. Chan	+852 29586654	cchan@ha.org.hk
CHINA	Beijing	Mr. Guo Wen	+86 1 69357178	rmcssdl@iris.ciae.ac.cn
COLOMBIA	Santafe de Bogota	Ms. M.E. Castellanos	+57 1 3153059	ecastell@ingeomin.gov.co
CUBA	Cuidad Habana	Mr. J. Morales Monzón	+537 579571	tony@cphr.edu.cu
CYPRUS	Nicosia	Mr. S. Christofides	+357 2 801 773	cstelios@cytanet.com.cy
CZECH REP. *	Prague	Mr. Kodl	+4202 738330	
CZECH REP.	Prague	Mr. P. Dryák	+4202 67008466	pdryak@cmi.cz
CZECH REP.	Prague	Mr. D. Olejár	+4202 67311410	hzackova@suro.cz
DENMARK	Herlev	Mr. K. Ennow	+45 44 543450	klaus.ennow@sis.dk
ECUADOR	Quito	Mr. H. Altamirano	+593 2 253097	comecen@comecenat.gov.ec
EGYPT	Cairo	Mr. H.M. Eissa	+20 2 3867451	
ETHIOPIA	Addis Ababa	Mr. S. Mulugeta	+251 1 620495	nrpa@telecom.net.et
FINLAND	Helsinki	Mr. H. Jarvinen	+358 9 75988450	hannu.jarvinen@stuk.fi
FRANCE	Le Vesinet	Mr. J.F. Lacronique	+33 1 39760896	opri@opri.fr
GERMANY	Oberschleissheim	Mr. D.F. Regulla	+49 8931872517	regulla@gsf.de
GERMANY	Freiburg	Mr. Pychlau	+49 761 4905570	ptw@ptw.de
GHANA	Legon-Accra	Mr. C. Schandorf	+233 21 400807	rpbgaec@ghana.com
GREECE	Paraskevi-Attikis.	Mr. C.J. Hourdakis	+30 1 65 33 939	khour@eeae.nrcps.ariadne-t.gr
GUATEMALA	Guatemala C. A.	Mr. B. Baldizon	+502 4762007	byronbaldizon@tutopa.com
HUNGARY*	Budapest 126	Mr. I. Csete	+36 1 2120147	icsete@omh.hu
HUNGARY	Budapest XII	Mr. G. Kontra	+36 1 2248620	kontra@oncol.hu
HUNGARY	Paks	Mr. M. Orbán	+36 1 3551332	orbanmi@npp.hu
INDIA	Bombay	Mr. V.V. Shaha	+91 22 5505151	vvshaha@apsara.barc.ernet.in
INDONESIA	Jakarta Selatan	Mr. Susetyo Trijoko	+621 217657950	
IRAN	Karaj	Mr. M. Gavahi	+98 21 411106	mghafoori@seai.neda.net.ir
IRAN	Teheran	Mr. H. Gharaati	+98 21 6428655	hgharat@yahoo.co.uk
IRAQ[**]	**Baghdad**			
IRAQ[**]	**Baghdad**			
IRELAND	Dublin 14	Mr. S. Somerville	+353 12697437	ssomerville@rpii.ie
ISRAEL	Yavneh	Mr. B. Shlomo	+972 8 9434696	bsholomo@hotmail.com
KOREA, REP	Seoul	Ms. Heon-Jin Oh	+82 2 3513726	radjin@kfda.go.kr

Country	City	Contact person	Fax	E-mail
LIBYA	Tripoli	Mr. Ben Giaber	+218 21 3614142	BenGiaber@yahoo.com
MADAGASCAR	Antananarivo	Mr. Andriambololona	+261 20 2235583	instn@dts.mg
MALAYSIA	Kajang	Mr. Taiman Bin Kadni	+60 3 8258262	taiman@mint.gov.my
MEXICO	Mexico, D. F.	Mr. V. Tovar Munoz	+52 53297302	abv@nuclear.inin.mx
NIGERIA[**]	**Lagos**			
NORWAY	Osteras	Mr. H. Bjerke	+47 67147407	Hans.Bjerke@nrpa.no
PAKISTAN	Islamabad	Mr. Salman Ahmad	+92 51 9290275	salman.pins@dgcc.org.pk
PERU	Lima	Mr. Tony Benavente A.	+51 1 2260024	tbenavente@ipen.gob.pe
PHILIPPINES*	Diliman, Quezon	Ms. E.S. Caseria	+63 9201646	escaseria@pnri.dost.gov.ph
PHILIPPINES	Sta. Cruz, Manila	Ms. Nieva O. Lingatong	+632 711 6016	apperalta@co.doh.gov.ph
POLAND	Warsaw	Mr. Bulski	+48 22 6449182	w.bulski@rth.coi.waw.pl
PORTUGAL	Sacavem	Mr. A.F de Carvalho	+351 21 9941995	aferroc@itn1.itn.pt
PORTUGAL	Lisbon	Mr. Paulo M.S. Ferreira	+351 217229877	radfisica@ipolisbloa.min-saude.pt
ROMANIA	Bucharest	Mr. C. Milu	+40 1 3123426	cmilu@ispb.ro
RUSSIA	St. Petersburg	Mr. V.I. Fominykh	+7 812 113 0114	trof@dosmet.vniim.spb.su
SAUDI ARABIA	Riyadh	Mr. A. Al-Haj	+9661 4424777	Abdal@kfshrc.edu.sa
SINGAPORE*	Singapore	Mr. Eng Wee Hua	+ 65 7384468	
SINGAPORE	Singapore	Mr. S. Chong	+65 2262353	sckmipil@pacific.net.sg
SINGAPORE	Singapore	Mr. Chua Eu Jin	+65 2228675	trdcej@nccs.com.sg
SLOVAK REP.	Bratislava	Ms. V. Laginová	+4217 52923711	vlaginov@ousa.sk
SOUTH AFRICA	Pretoria	Mr. B. F. Denner	+27 12 8412131	nml@csir.co.za
SUDAN[**]	**Khartoum**			
SWEDEN	Stockholm	Mr. J-E. Grindborg	+46 87297108	jan.erik.grindborg@ssi.se
SYRIA	Damascus	Mr. M. Takeyeddin	+963 116112289	atomic@net.sy
TANZANIA	Arusha	Mr. W.E. Muhogora	+255 272509709	nrctz@habari.co.tz
THAILAND*	Bangkok	Mr. K. Bhadrakom	+66 2 5806013	
THAILAND	Bangkok	Mr. S. Srimanoroth	+66 2 9511028	siri@dmsc.moph.go.th
THAILAND	Bangkok	Ms. W. Thongmitr	+66 2 5613013	wimann@oaep.go.th
TURKEY	Istanbul	Mr. A. Turer	+90 212 5482230	yasard@cnaem.nukleer.gov.tr
TUNISIA	Tunis	Ms. L. Bouguerra	+216 1 571630/653	sadok-mtimet@rns.tn
URUGUAY	Montevideo	Ms. B. Souto	+598 2 9021619	dntnpsr@adinet.com.uy
VENEZUELA	Caracas	Mr. F. Gutt	+58 2 5041577	fgutt@ivic.ivic.ve
VIET NAM	Hanoi	Mr. Dang Duc Nhan	+84 4 9424133	ddnhan@mail.vaec.gov.vn
YUGOSLAVIA	Belgrade	Mr. M. Kovačević	+381 11 455943	milojko@rt270.vin.bg.ac.yu

[**] **Provisional Network members**

* SSDL Organization

[1] Kindly notify the Dosimetry and Medical Radiation Physics Section if the information here is incorrect or changes.

COLLABORATING ORGANIZATIONS ASSOCIATED WITH THE IAEA/WHO NETWORK OF SSDLs

International Bureau of Weights and Measures (BIPM)
International Commission on Radiation Units and Measurements (ICRU)
International Electrotechnical Commission (IEC)
International Organization of Legal Metrology (IOML)
International Organization of Medical Physics (IOMP)

AFFILIATED MEMBERS OF THE IAEA/WHO NETWORK OF SSDLS

Bundesamt für Eich und Vermessungswesen (BEV)	Vienna, AUSTRIA
Australian Radiation Laboratory (ARL)	Melbourne, AUSTRALIA
National Research Council (NRC)	Ottawa, CANADA
Laboratoire de Metrologie des Rayonnements Ionisants (LMRI)	Saclay, FRANCE
Physikalisch-Technische Bundesanstalt (PTB)	Braunschweig, GERMANY
National Office of Measures (OMH)	Budapest, HUNGARY
Ente per le Nuove Tecnologie L'Energia e L'Ambiente (ENEA)	Rome, ITALY
Electrotechnical Laboratory (ETL)	Tsukuba, JAPAN
Rijks Institut voor Volksgesundheid (RIVM)	Bilhoven, NETHERLANDS
National Radiation Laboratory (NRL)	Christchurch, NEW ZEALAND
Scientific Research Institute for Physical-Technical and Radiotechnical Measurements (VNIIFTRI)	Moscow, RUSSIAN FEDERATION
Laboratory of Ionizing Radiation, Slovak Institute of Metrology (SIM)	Bratislava, SLOVAK REPUBLIC
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)	Madrid, SPAIN
National Physical Laboratory (NPL)	Teddington, UNITED KINGDOM
National Institute for Standards and Technology (NIST)	Gaithersburg, USA