IAEA/WHO NETWORK OF SECONDARY STANDARD DOSIMETRY LABORATORIES

SSDL NEWSLETTER

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EDITORIAL NOTE

This issue of the SSDL Newsletter starts with a summary article on the International Symposium on Standards and Codes of Practice in Medical Radiation Dosimetry held at the IAEA Headquarters in November 2002. The Symposium was very successful. It was attended by about 250 scientists from 62 Member States. A total of 140 presentations were delivered covering a broad range of topics in medical radiation dosimetry. One of the recommendations of the Symposium is to hold the next meeting in 6 years.

The second article is a short note on the new IAEA programme related to the standardization of radioactivity measurements. This new initiative was introduced following positive feedback from many SSDL members and their interest in this activity. This new project is being led by Brian Zimmerman, who joined the IAEA in March 2003. SSDL members with existing radioactivity measurement capabilities that are interested in participating in this new initiative are encouraged to contact him for more information, as are laboratories wishing to submit proposals to participate in the new Coordinated Research Project focussed on radionuclide metrology. Laboratories wishing to develop the capability to prepare and disseminate radioactivity standards should consider submitting a proposal to the Agency's Technical Co-operation Programme. The deadline for proposals for new projects is 31 December 2003. Additional information is available on the IAEA web site:

http://www-tc.iaea.org/tcweb/tcprocedures/projectproposals/default.asp

The third article, from the School of Applied Physics- Kebangsaan University in Malaysia, is a short technical note on errors that could arise if dosimetry codes of practice are not implemented correctly. Such errors were detected through IAEA comparison and audit services and advertised among SSDL members to avoid similar mistakes.

The fourth article, from the SSDL in Pakistan, is also a technical note on a comparison of calculated absorbed dose to water calibration coefficients determined with air kerma based protocols and the so-called direct absorbed dose to water calibration coefficient (traceable to a primary standard). The main conclusion of this article is consistent with previous findings, namely that in the case of patient treatments there is no significant difference between air kerma based and direct absorbed dose to water calibration coefficients for the most commonly used ionization chambers in a Co-60 beam.

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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 Low Dose Rate (LDR) brachytherapy.	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/

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SUMMARY NOTE ON THE INTERNATIONAL SYMPOSIUM ON STANDARDS AND CODES OF PRACTICE IN MEDICAL RADIATION DOSIMETRY

The International Symposium on Standards and Codes of Practice in Medical Radiation Dosimetry was organised by the Agency in Vienna from 25 to 28 November 2002 to foster exchange of information and highlight recent advances in research in this field.

Over 250 scientists attended the Symposium from 62 Member States. A total of 140 presentations were delivered covering a broad range of topics in medical radiation dosimetry.

A key issue addressed by the Symposium was knowledge of the accuracy of radiation doses delivered to patients, which is essential for the safe and effective diagnosis and treatment of disease. Such accuracy in dose measurement is an integral part of a comprehensive Quality Assurance (QA) programme to ensure that the technology is used properly and has the intended effect on patients.

1. CO-SPONSORING AND COLLABORATING ORGANIZATIONS

The co-sponsoring organizations of the Symposium were the European Commission (EC), the European Society for Therapeutic Radiology and Oncology (ESTRO), the International Organization for Medical Physics (IOMP) and the Pan American Health Organization (PAHO).

The collaborating organizations were the American Association of Physicists in Medicine (AAPM), the European Federation of Organisations for Medical Physics (EFOMP), the International Society for Radiation Oncology (ISRO), the International Commission on Radiation Units and Measurements (ICRU) and the World Health Organization (WHO). Ten companies participated in a scientific exhibition of equipment relevant to medical radiation dosimetry and the treatment of cancer. One of these companies arranged for the display of a cobalt therapy machine, which was located in the rotunda of the Vienna International Centre during the symposium.

2. A SPECIAL PLENARY SESSION ON CANCER MANAGEMENT

A special plenary session entitled “Meeting the Needs” focussed attention on the impending crisis in cancer management. A speaker from the International Agency for Research on Cancer indicated that cancer incidence within developing countries is expected to increase from 5 million new patients per year in 2000 to 10 million in 2015, primarily due to population aging. In the discussion following this special session, representatives of the manufacturers participating in the equipment exhibition, invited speakers and delegates tried to identify appropriate and affordable technologies and to define possible roles for the Agency to help in transferring equipment and developing local expertise required to meet the needs arising because of this crisis.

3. FINDINGS AND RECOMMENDATIONS

Recommendations from the Symposium sessions were presented for discussion and approval by participants in the final session. Although many of these recommendations concern the scientific community, some are directed to governments and industry as these affect the practical application of nuclear technology in the health care sector in both developing and developed countries. Several themes appear consistently throughout the various recommendations, which are in accord with the recommendations of the International Conference on the Protection of Patients in Diagnostic and Interventional Radiology, Nuclear Medicine and Radiotherapy organised by the Agency in Malaga, Spain, 26-30 March 2001. As emphasised at Malaga, the education and training for health care workers required to diagnose and treat patients safely and effectively is of utmost importance.

In addition, The Symposium recognised that:

- appropriate and affordable equipment is required to meet the needs, particularly of developing countries, with manufacturers as partners in the process of technology transfer,
- it is essential for treatment methodologies to be supported by infrastructural services in medical physics and diagnostic radiology, and
- programmes in quality control and assurance should provide the necessary auditing tools to demonstrate the safe and effective application of nuclear technology in the patient realm.

Explicitly within the field of medical radiation dosimetry, the Symposium made recommendations:

- for the development of physical standards, and
- performance comparisons, and participation in audits within the sub-fields of nuclear medicine, brachytherapy, proton therapy and clinical dosimetry.

There are recommendations for primary and secondary standards dosimetry laboratories:

- to develop further their standards for absorbed dose to water and air kerma,
- to refine the assessment of their corresponding uncertainties, and
- to participate in comparison exercises in order to build confidence in their measurement capabilities.

A recommendation was made to enhance the application of the Agency's dosimetry code of practice (TRS-398) for external beam therapy and to complete the development of the new code for diagnostic radiology.

The full text of the symposium recommendations is reproduced at the end of this note.

4. RESPONSE OF THE AGENCY

The refereeing and editing process of the symposium proceedings has been completed. The proceedings will comprise about 85 papers and will include the recommendations of the Symposium. The Agency plans to publish the proceedings before the end of this year.

The Agency convened a Technical Meeting in June 2003 to prepare an action plan in response to the recommendations of the Symposium. Representatives of PSDLs, SSDLs and international organizations together with Agency staff developed a draft action plan. Other organizations are invited to review this plan and make whatever contributions they find to be appropriate.

CONCLUSIONS AND RECOMMENDATIONS OF THE INTERNATIONAL SYMPOSIUM ON STANDARDS AND CODES OF PRACTICE IN MEDICAL RADIATION DOSIMETRY

Recommendations following the papers and discussion were prepared by the chairs, co-chairs and rapporteurs of each session and presented to the participants of the Symposium in the final session for their approval.

Although many of these recommendations concern the scientific community, some are directed to governments and industry as these affect the practical application in developing countries. However, as was pointed out during the final session, some of the developed countries would also benefit from following these latter recommendations. The IAEA would obviously be a good choice to take the lead in many of these actions.

SESSION 1: SETTING THE SCENE

After the description of the operation of the mutual recognition arrangement (MRA), it was clear that the developing countries would benefit from being included in the MRA comparisons and declaring their calibration and measurement capabilities (CMCs) as this would encourage them to clarify their methods and uncertainties. As it is a matter for individual countries to decide whether they should sign the MRA, the Symposium simply recommends that:

1.1 SSDLs holding national dosimetry standards for signatories of the MRA should be encouraged to participate in comparisons and declare their CMCs through their regional metrology organization (RMO).

To support the SSDLs in this dosimetry work, it is recommended that:

1.2 additional RMO comparisons should be developed and participation in these comparisons by Member States should be encouraged.

For more than thirty years the IAEA has developed dosimetry codes of practice pertinent to external beam therapy and has arrived at a situation now where all forms of dosimetry measurements are linked together in one coherent protocol. Consequently, the Symposium recommends that:

1.3 the IAEA dosimetry Code of Practice TRS-398 should be maintained and updates released as necessary

1.4 the use of TRS-398 should be encouraged throughout all the Member States

1.5 the translation of TRS-398 should be encouraged.

Through maintenance and support of the IAEA/WHO SSDL Network, it is recommended that:

1.6 the dissemination of dosimetry standards and expertise throughout the developing world should continue

1.7 the consistency and quality of dosimetry standards should be maintained and developed through comparisons.

SESSION 2: STANDARDS OF ABSORBED DOSE TO WATER

Absorbed dose to water is the necessary quantity for dosimetry measurements for radiotherapy. Many papers were presented on the different methods of determining absorbed dose to water using primary methods. However, there are many issues relating to this that need to be addressed by the primary standards laboratories in the national metrology institutes. The Symposium recommends that:

2.1 absorbed dose to water should be derived from as many independent methods as possible

2.2 direct comparison of water and graphite calorimeters should be encouraged

2.3 uncertainties assigned to absorbed dose to water primary standards should be examined in detail, preferably in a

working group of the international Consultative Committee (CCRI) in order to rationalize any apparent discrepancies

2.4 research should be supported for all forms and new applications of calorimetry, e.g. in brachytherapy

2.5 absorbed dose standards for electron beams should be developed further

2.6 development of absorbed dose to water standards for kV X rays should be encouraged

2.7 more PSDLs should participate in the high energy X ray comparison piloted by the BIPM.

SESSION 3: AIR KERMA STANDARDS FOR PHOTONS

Currently, most dosimetry measurements are made in terms of air kerma. However, as all these measurements are related to a common primary method using cavity ionization chambers, it is particularly important that the physical constants used in the measurement equations, and the corrections necessary for cavity ionization chambers are well understood. Consequently, the Symposium recommends that:

3.1 primary standards laboratories and the ICRU, as appropriate, should address the unresolved issues pertaining to air kerma dosimetry standards, including the re-evaluation of

- k_{wall} and k_{an} (including the BIPM standard)
- W_{air} values and uncertainties
- stopping power ratios
- type B uncertainties related to Monte Carlo methods, taking account of the underlying interaction coefficients.

SESSION 4: MEETING THE NEEDS

During this session, the WHO clearly presented the dramatic increase that is likely in the number of cancer patients in developing countries within the foreseeable future. Since nuclear technology in the form of radiotherapy will remain central for the treatment of cancer in both developed and developing countries within the same time frame, the Symposium feels that:

4.1 the IAEA, WHO and PAHO should be proactive in assisting developing Member States in addressing their current and future needs for cancer treatment.

It is clear that cobalt teletherapy and brachytherapy source trains will be the mainstays of radiotherapy for most developing countries in the foreseeable future. To support these therapies, the Symposium feels that:

4.2 appropriate staffing — medical, technical, nursing and scientific — is crucial for the treatments to be effective

4.3 treatment equipment must be accompanied by the appropriate techniques for diagnosis, tumour localization and staging, immobilization, shielding, treatment simulation and planning, clinical dosimetry (including displays), treatment verification and follow-up

4.4 appropriate dosimetry equipment must be made available for equipment commissioning and continuing quality control.

With regard to therapy and supporting diagnostic equipment, the Symposium felt that a number of issues could be addressed. There were particular concerns raised during the final discussion session that low dose rate brachytherapy equipment was no longer being produced, whereas this was considered by some radiation oncologists to be better or less expensive than high dose rate brachytherapy. Consequently, the Symposium recommends that the equipment industry should be:

4.5 encouraged to recommence the production of low dose rate brachytherapy equipment and also to strive to make high dose rate brachytherapy equipment more affordable

4.6 made aware of the future needs of the Member States regarding the increasing demands for cancer services.

Whilst collaboration between industry and government was seen as useful for developing countries, concern was expressed that voluntary organizations often donated equipment without taking account of consequent needs. Understanding that this is the domain of the WHO and PAHO in particular, the Symposium felt that:

4.7 WHO advice that provides guidance to organizations donating technologies to the developing countries should be disseminated widely

4.8 supporting guidance covering all factors required to implement such radiation technologies for safe and effective diagnosis and therapy should be developed.

Where the necessary infrastructure and expertise for maintaining linacs are missing, cobalt therapy may be much safer and more reliable for the patients than linacs. Hence the Symposium felt that:

4.9 manufacturers should be encouraged to continue production of cobalt therapy units.

The current lack of properly trained radiotherapy personnel is as serious as the lack of equipment in many developing — and, indeed, in some developed — Member States. It was noted that optimizing the use of existing equipment through the proper use of personnel could sometimes be more cost-effective than simply adding new equipment. Consequently, the Symposium recommends to the IAEA, WHO, PAHO, EC, ISRO, EFOMP, ESTRO and IOMP that, in view of the current lack of and future need for trained personnel:

4.10 training programmes should be implemented on a large scale for professional staff working in radiotherapy not just to follow the basic curricula but also to comply with a requirement for continuing professional development

4.11 national or regional centres of excellence for training should be developed and supported in co-operation with international organizations.

SESSIONS 5, 6 AND 8B: DOSIMETRY PROTOCOLS AND COMPARISONS

The Symposium felt very strongly that radiotherapy dosimetry within a given country should be consistent. To achieve this, ideally the same dosimetry protocol should be used in all radiotherapy centres of that particular country. Keeping in mind that some countries have developed their own national dosimetry protocol (e.g., TG-51 in the USA), for those countries that prefer to use TRS-398, the Symposium recommends that:

5.1 when adopting the IAEA international Code of Practice for Radiotherapy Dosimetry, TRS-398, this should be done initially at the national level in collaboration with the national scientific societies and the SSDLs

5.2 training and education on TRS-398 should be encouraged prior to the implementation of the code by users

5.3 the differences expected with the practical implementation of TRS-398 should be disseminated

5.4 the necessary changes in QA procedures should be assessed before the adoption of TRS-398

5.5 both TRS-398 and the previous code should be used in parallel for a short time and differences between the codes outside those expected should be explained

5.6 a specific date should be chosen for the adoption of the new code by all hospitals in the country

5.7 independent dosimetry checks in co-operation with peers should be encouraged

5.8 external audits should be performed if available

5.9 the practical aspects of the adoption of TRS-398 for kV X rays should be

studied and a pilot study should be encouraged for the adoption of the kV code in the clinic.

It is recognized that several PSDLs and many SSDLs do not have their own accelerators for the purpose of calibrating secondary standards for the clinics. It has been suggested that the SSDLs could use hospital equipment (out of normal operating hours) for this purpose. However, the setting up of a facility for calibration takes time and the uncertainties associated with setting up may be larger than the uncertainties associated with using a protocol's calculated values. Consequently, the Symposium recommends that:

5.10 a feasibility study (including the assessment of uncertainties) should be carried out so that SSDLs can disseminate experimentally determined $N_{D,w}$ calibrations — traceable to primary standards laboratories — to radiotherapy centres for both megavoltage photon and electron beams.

Further recommendations concerning the dissemination of dosimetry protocols are that:

5.11 primary standard laboratories should be encouraged to measure k_Q factors and these should be compiled in a single document

5.12 clinical electron dosimetry (at the hospital level) should be based, in order of preference, on:

i) ionization chamber calibrations in electron beams based on a standard traceable to a primary standards laboratory, or

ii) cross-calibration in an electron beam against a ^{60}Co calibrated reference chamber, or, if no other option is possible,

iii) direct ^{60}Co calibrations.

SESSIONS 7 AND 8A: DOSIMETRY ISSUES FOR DIAGNOSTIC RADIOLOGY

A large number of quantities have been used for dosimetry measurements in diagnostic radiology, in particular for dosimetry in computed tomography. This has caused considerable confusion, so it is strongly recommended that:

7.1 the quantities used for these purposes should be harmonized

7.2 new codes of practice for dosimetry in diagnostic radiology should use the agreed quantities

7.3 the determination of diagnostic reference levels, a process in which image quality also needs to be assessed, should use the agreed quantities.

Some SSDLs have established or are in the process of establishing calibration services for dosimetry in diagnostic radiology. The number of laboratories that can provide these services is not sufficient to meet national needs. The Symposium recommends that:

7.4 SSDLs develop these services to be able to cover their national needs

7.5 a set of recommendations be developed to provide an interim approach to traceability for countries with no access to an SSDL that is undertaking the calibration of diagnostic dosimeters.

The Symposium noted that computed tomography could deliver significant doses to the patient although these were not always simple to assess, and that interventional radiology had caused irreversible skin damage to some patients. The discussions provoked the recommendations that:

7.6 appropriate methods for quality assurance and quality control in digital and interventional radiology should be developed urgently

7.7 new dosimetry methods should be developed to meet the needs of current and future X ray diagnostic methods

7.8 dosimetry audits to check the performance of calibration laboratories and of end users should be developed and implemented for these diagnostic radiology techniques.

It was further noted that new skills for those performing the diagnostic radiology measurements needed to be acquired.

Consequently, the Symposium recommends that:

7.9 education and training programmes should be developed for physicists and technical staff working in clinical diagnostic radiology.

SESSION 9: NUCLEAR MEDICINE

During this session, a number of concerns were expressed about the state of radionuclide measurements and patient dosimetry in nuclear medicine. The use of unsealed sources for radiotherapy is increasing but there does not seem to be a concerted effort to improve the quality of the therapies although standardization is becoming increasingly important, especially in view of multi-national trials. The Symposium summarized their concerns by making recommendations that:

9.1 clinical radioactivity measurements should be traceable to national or international activity standards in each country in which nuclear medicine is practised

9.2 PSDLs should be encouraged to focus on establishing reliable procedures for measuring low energy gamma emitters, beta emitters, low energy electron emitters and alpha emitters

9.3 quality assurance/quality control programmes should be established and implemented, particularly for quantitative dosimetry analyses in nuclear medicine; guidance for such programmes should be developed.

With reference to patient dosimetry, the Symposium recommends that:

9.4 the use of current dosimetry models should continue with the collection of adequate data to obtain good dose estimates, using as many patient-specific modifications as possible

9.5 the dissemination of better dosimetric models, particularly those based on patient images in voxel format, should be encouraged so that internal dose calculations can be more accurate and detailed and able to provide better correlations of calculated dose and observed effect

9.6 comparison programmes for quantification of radioactivity should be established, especially for in-phantom measurement and for calculation of organ doses from multiple image sets

9.7 the development of standardized and well documented software programs for traditional dose calculation methods, and for implementing newer, voxel-based methods, should be encouraged.

Finally, in this session, the Symposium recommends that:

9.8 a standardized code of practice for simple and for more complicated dosimetry calculations should be developed.

SESSIONS 10 AND 12A:BRACHYTHERAPY

Although brachytherapy has been practised for decades, it is a many faceted area in which the dosimetry is neither always clear nor always practised well. The Symposium considered that the time had come to take definite steps to improve the situation. Consequently, it is recommended that:

10.1 PSDLs should establish dosimetry standards for brachytherapy sources that SSDLs then disseminate using an internationally agreed method

10.2 dosimetry comparisons between PSDLs and SSDLs should be developed and implemented

10.3 dosimetry audits for clinical end users should be developed and implemented

10.4 research efforts should be focused on dosimetry standards based on absorbed dose to water for photon emitting brachytherapy sources

10.5 beta dosimetry for brachytherapy should be improved, in particular for Ru-106/Rh-106 sources

10.6 quality assurance programmes for brachytherapy dosimetry should be developed and implemented

10.7 education and training programmes should be developed for SSDL staff and for clinical personnel.

SESSIONS 11 AND 12B: QUALITY ASSURANCE AND QUALITY AUDITS IN RADIOTHERAPY DOSIMETRY

Quality assurance and quality audit of a number of areas in the radiotherapy process were covered in these sessions and this has resulted in a large number of recommendations. In particular, to set the scene, the Symposium feels that:

11.1 radiotherapy at levels 1 (basic) and 2 (advanced) should be strengthened through education and training, equipment provision and expert support, while at level 3 (developmental) it should be advanced through research programmes.

The Symposium strongly expressed the view that quality assurance and quality audits are a very effective way to ensure the correct delivery of the radiation dose to the patient and to enable the therapeutic outcome to be assessed in a consistent manner. Consequently, it is recommended that:

11.2 quality assurance (QA) programmes for radiotherapy equipment, dosimetry and processes should be promoted, implemented and strengthened to ensure accurate reproducible dose delivery to each radiotherapy patient

11.3 QA programmes should cover the medical aspects of radiotherapy as well as the physics and technical aspects

11.4 audit should be encouraged for all levels of radiotherapy.

The many facets of dosimetry audit were considered and the Symposium recommends that:

11.5 dosimetry audit should be included within the scope of clinical audit, as assured dosimetry is required to enable assured clinical practice

11.6 an external audit should be available to all radiotherapy centres for all clinically used external beam treatment units, as recommended internationally (e.g. International Basic Safety Standards, the EC Medical Exposure Directive 97/43/Euratom)

11.7 the level of external audit should be appropriate to the level of the radiotherapy department and the national expertise (see also 11.11)

11.8 as a minimum external audit for radiotherapy beam dosimetry, each beam dose output should be measured independently of the institution procedures, e.g., using a mailed TLD from an external laboratory, at least once every two years.

It was agreed that nationally adopted QA programmes provided consistency for radiotherapy practice and consequently, the Symposium recommends that:

11.9 the development of national QA programmes should be encouraged and supported, especially in developing countries

11.10 national programmes should include guidelines on QA procedures for radiotherapy centres and also for audit networks or audit systems at the national level

11.11 national audit systems for radiotherapy dosimetry should be operated by qualified groups involving co-operation between SSDLs and clinical medical physicists.

The Symposium understood that complex radiotherapy techniques required significantly increased effort for their safe and effective implementation and use. Consequently, it recommends that:

11.12 the development of QA recommendations and programmes should be promoted for complex treatment situations (e.g. total body irradiation, stereotactic radiosurgery, intensity modulated radiotherapy)

A range of audit tools has been developed by several audit programmes, including that successfully run by the IAEA, for dosimetry audit. Postal dose audit based on TLD is widely used and well-established. However, it

was noted that other systems (e.g. alanine) are being considered at the research level. The Symposium recommends that:

11.13 support should be given, through research programmes, to the development and evaluation of audit methodologies suitable for the various radiotherapy levels.

Appreciating the particular importance of audit when it is used to assure the dosimetry of patients from more than one country entered into co-operative clinical trials, the Symposium recommends that:

11.14 activities in quality audit should be co-ordinated internationally and different audit systems should be compared.

SESSION 13: PROTON AND HADRON DOSIMETRY

The Symposium noted that the number of treatment facilities using proton beams and heavier ion beams (mostly carbon-12) was growing, with 24 currently operational and another 20 planned worldwide over the next five years. There is still a divergence of opinion internationally and even nationally about the dosimetry methods to use for these therapy beams. However, the results presented indicate that the adoption of TRS-398 would provide a coherent approach. Consequently, the Symposium felt that the dosimetry of these beams should be in keeping with conventional radiotherapy beam dosimetry and recommends that:

13.1 proton and heavier ion beam dosimetry should be based on absorbed dose to water standards

13.2 comparisons based on absorbed dose to water calibrations should be organized between centres.

For ion dosimetry, the Symposium felt that considerable research was still needed to improve knowledge on basic physics data for dosimetry and consequently recommends that:

13.3 research projects on ion dosimetry techniques should be supported.

SESSION 14: CLINICAL RADIOTHERAPY DOSIMETRY

At the clinical level, two areas of concern were discussed, these being dose measurements and dose calculations. The practicalities of dosimetry systems were evidently a problem and the Symposium recommends that:

14.1 industry should be encouraged to develop affordable systems for practical use in QA and dosimetry (e.g. tissue equivalent materials, phantoms that are easy to use, equipment that is robust and reliable)

14.2 gel dosimetry methodology should be developed to evaluate its potential for routine use in radiotherapy centres

14.3 in vivo dosimetry should be promoted, including its use in developing countries

14.4 alternative methods of clinical dosimetry should be tested and compared with traditional techniques.

With regard to dose calculations, the Symposium recommends that:

14.5 advanced computing methods for dose calculation should be encouraged where appropriate expertise is available

14.6 guidelines should be developed as to which QA tests of treatment planning systems should be performed by manufacturers, user groups and individual users.

Recognizing that errors in treatment monitor units and treatment time calculations have caused accidents, the Symposium also recommends that:

14.7 all radiotherapy institutions should implement an independent monitor unit or time calculation protocol for each patient.

SESSION 15: REVIEW AND CONCLUSIONS

Some additional discussion points were raised during the round-up session. In particular, concern was expressed at the lack of

understanding of the role of the medical physicist, specifically regarding dosimetry for the patient. The Symposium recommends that:

15.1 during the training of administrators, the different roles of professionals working in radiotherapy should be clearly identified

15.2 national, regional and international professional societies such as the IOMP should be encouraged to work together to register the profession of medical physicist with the International Labour Organization

15.3 medical physicists should involve themselves in the education and training of clinical practitioners.

Views were also exchanged on the lack of medical physics staff currently available and the need for more staff in the future. Evidence for the lack of staff currently employed, even in developed countries, can be seen in the report commissioned by a UK government department on the need for "nuclear skills" http://www.dti.gov.uk/energy/nuclear/skills/nsg.shtml. The Symposium recommends that:

15.4 national, regional and international professional societies should work towards promoting the profession of medical physics to university undergraduates.

In conclusion, the Symposium was greatly appreciated by all the participants and each felt personally involved with the recommendations. The view was expressed that the time interval since the last Symposium had been too long. In spite of the heavy organizational burden on the staff of the Dosimetry and Medical Radiation Physics section, it is strongly recommended that:

15.5 a further dosimetry symposium should be held in six years' time.

ESTABLISHING RADIOACTIVITY MEASUREMENT CAPABILITIES FOR NUCLEAR MEDICINE IN MEMBER STATES

B. Zimmerman

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The International Atomic Energy Agency (IAEA), in response to a growing need for measurement quality assurance for radionuclides used in nuclear medicine, particularly in developing countries, is establishing a new radioactivity standardization programme in the Dosimetry and Medical Radiation Physics section. The short-term (3-5 years) goals of this project are to:

- Develop capabilities within the IAEA to prepare and distribute calibrated solution sources of medically relevant radionuclides, traceable to international standards, to Member States for use in calibrating instrumentation. Traceability will be established through comparisons with primary National Measurement Laboratories, as well as with the International Reference System for activity measurements of the BIPM. Ultimately, the goal will be for the Agency to be able to distribute standard sources of the most relevant radionuclides to Member States that require them as part of a secondary standards radioactivity laboratory network. The laboratories in the network will then provide calibration and auditing services to nuclear medicine clinics on a national or regional basis. Formation of the laboratory network is ongoing.
- Assist Member States in the development of quality assurance networks for nuclear medicine clinics in their countries. This could be accomplished through Technical Cooperation projects at the national and regional levels and will take the form of personnel training and consultations to develop appropriate quality assurance and audit systems, and in some cases, donation of appropriate instrumentation. Further, a Coordinated Research Project has recently been approved to develop a uniform code of practice for clinical radioactivity measurements. Formation of the research group will begin in early 2004.

THE –10% AND +13% ERRORS ARISING FROM MIS-INTERPRETATION OF THE TWO IAEA PROTOCOLS TRS-277 AND TRS-398: CAUSES AND PREVENTION

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Presently IAEA provides two protocols for determining the absorbed dose to water, D_w. If M_u is the corrected electrometer reading, N_D the absorbed dose to air chamber coefficient and L a quantity derived from the multiplication of several chamber coefficients, the IAEA TRS 277 protocol [1,2] calculates D_w as

$$D_{w\text{-}TRS277} = M_u\, N_D\, L \qquad (1a)$$

On the other hand, if $N_{D,w}$ is the absorbed dose to water calibration coefficient, the IAEA TRS 398 protocol [3] calculates D_w as

$$D_{w\text{-}TRS398} = M_u\, N_{D,w} \qquad (2)$$

If a user at a hospital uses either one of the protocols at a time, he or she will only have to deal with either N_D or $N_{D,w}$. On the other hand, some users will need to deal with both N_D and $N_{D,w}$ at the same time. In this case, IAEA, in two different documents [3,4] made a strong recommendation to SSDLs scientists and hospital users that they should be careful not to confuse the two symbols $N_{D,w}$ and N_D. If this confusion should occur, then

(i) An error of –10% could arise in quoting $N_{D,w}$ [4]. Call this Error I.

(ii) An error of +13% could arise in the dose delivered to a patient [3]. Call this Error II.

The confusion that led to Error I has in fact occurred among two SSDLs during the IAEA comparison programme [4]. To avoid further possibility of this error, IAEA issued a notice to all SSDLs in 1995, not to report values of $N_{D,w}$ to hospitals [4,5]. Error II, however, was mentioned in the most recent IAEA document [3], but only very briefly, and without detailed explanation. That is to say, between equations (1a) and (2), this document does not say which equation is responsible for Error II. It is clearly of interest among SSDL scientists and hospital users to understand how these Errors I and II could occur. The purpose of this letter is to provide the most likely answer to this.

We consider that there is inevitably a risk of confusion when a symbol such as N does not always appear with the same number of subscripts (as in equations (1a) and (2)). If both N_D and $N_{D,w}$ are encountered, then the implication is that the second, absent, subscript in N_D must be replaced by a "default" value. If the intended default is "*air*" and the user supplies the subscript "*air*", then all is well. If the user supplies the subscript "*w*" for water, then an error will occur. Conversely, if someone has been carrying out measurements with water as the only medium, then it might seem reasonable to omit the second subscript and regard the default as "*w*". When another person sees the symbol N_D, however, it may appear that the more reasonable assumption is that the missing subscript is "*air*", and this again leads to an error. In short, this problem of unequal numbers of subscripts on N is the cause of the two errors. To overcome this, the IAEA has made a recommendation [3,6] that another subscript, "*air*", should be added to N_D of equation (1a), so that the existing TRS-277 formula now becomes

$$D_{w\text{-}TRS277} = M_u\, N_{D,air}\, L \qquad (1b)$$

The purpose of the recent IAEA recommendation on the use of equation (1b) is clearly to prevent the second subscript ever being dropped, so that a user will never need to choose the default. Errors

due to incorrect assumptions should then not arise, although nothing can be done to insure against errors in reading the symbols. (We note that "*air*" in the Malay language means "*water*" in English, but to the best of our knowledge this particular error has not been reported in practice.)

Both Errors I and II reported by IAEA can therefore be explained by the insertion of an incorrect default subscript into the symbol N_D.

The values reported, –10% and +13%, are in fact approximate values. Accurate error values can only be obtained if we know the exact $N_{D,air}$ and $N_{D,w}$ values of the ionisation chamber in use. As an example Table 1 gives the values for our three chambers. Here Error I gives the result of assuming that N_D refers to $N_{D,air}$ when $N_{D,w}$ was intended. Error II gives the result of assuming that N_D refers to $N_{D,w}$ when $N_{D,air}$ was intended. We used equations (1a) or (1b) to calculate Error II.

Table 1: The result of mistakenly supplying the missing subscript in N_D.

Symbols, assumed values and error formula	NE 2581	NE 2571A	NE 2571
$N_{D,air}$ mGy/nC (=Y)	50.81±0.37	40.23±0.25	40.68±0.26
$N_{D,w}$ mGy/nC (=Z)	57.49±0.13	44.87±0.10	45.29±0.10
Error I [=100%(Y–Z)/Z]	(–11.6±0. 7)%	(–10.3±0.6)%	(–10.2±0.6)%
Error II [=100%(Z–Y)/Y]	(+13.2±0.9)%	(+11.5±0.7)%	(+11.3±0.7)%

We have therefore reproduced the errors quoted by IAEA (although both numbers do not occur for the same chamber), and confirmed that s (1a) or (1b) are the cause of Error II. Notice that the results of Errors I and II show some evidence of a systematic difference between NE 2571A and NE 2571 (which have graphite walls) and NE 2581 (which has tissue-equivalent walls).

We noticed that the points that we raised here have not been published in the earlier issues of this SSDL newsletter, and we considered that a discussion of the two causes of error should be combined in a single article.

ACKNOWLEDGEMENT

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COMPARISON OF CALCULATED ABSORBED DOSE TO WATER CALIBRATION AND DIRECT ABSORBED DOSE TO WATER CALIBRATION COEFFICIENTS OF FARMER TYPE IONIZATION CHAMBERS

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ABSTRACT

Results of the calculated absorbed dose to water calibration coefficients using air kerma calibrations and direct absorbed dose to water calibration coefficients $N_{D,W}$ for eight Farmer Type ionization chambers were compared using Co-60 radiation quality and following the dosimetry Codes of Practice (TRS-277 [1], TRS-381 [2] and the new International Code of Practice, TRS-398 [3]). The percentage deviation in the results of calculated and direct absorbed dose to water calibration coefficients for NE-2571 type chambers ranged from -0.33 to -0.65. No significant difference was found in the results of calculated and direct absorbed dose to water calibration coefficients for these chambers following the new International Code of Practice [3].

1. INTRODUCTION

The quantity of direct interest to the medical physicists in radiotherapy institutes is absorbed dose to water. However, at present due to many technical difficulties and practical limitations, a primary standard of absorbed dose to water is not available in many countries of the world. Reference dosimetry is therefore based upon air kerma standards and the use of dosimetry protocols to establish absorbed dose to water in clinical radiotherapy beams.

In IAEA dosimetry protocols [1,2] prior to TRS-398, the formalism is based on the use of an ionization chamber calibrated in terms of air kerma. These protocols provide the necessary methodology for the accurate determination of the absorbed dose to water from radiation beams used in radiotherapy. However their application from the perspective of medical physicist is not simple and may negatively affect the accuracy of clinical dosimetry as a result of mistakes.

The main objective of the present work was to evaluate the possibility of providing calibration of ionization chambers in terms of absorbed dose to water. This would be provided to medical physicists according to new trends of clinical dosimetry of radiotherapy beams. Absorbed dose to water for Co-60 gamma rays was determined with eight different Farmer ionization chambers using air kerma and direct absorbed dose to water calibration coefficients.

2. MATERIAL AND METHODS

Eight Farmer type ionization chambers were calibrated by comparison with the working standard of the laboratory both in terms of air kerma and absorbed dose to water. The working standard of the laboratory [4] consists of a measuring assembly type NE-2560 S. No. 173 and ionization chamber type NE-2561 S. No. 200 and was calibrated at the IAEA Dosimetry laboratory (Seibersdorf, Austria) in terms of air kerma and absorbed dose to water. The characteristics of the ionization chambers used in the present work are given in Table 1.

Table 1: Characteristics of the ionization chambers used in this work

Ionization chamber type & Sr. No.	Wall material	Cap	Internal radius (mm)
NE-2571 # 1905	Graphite	Delrin	3.15
NE-2571 # 1213	Graphite	Delrin	3.15
NE-2571 # 1148	Graphite	Delrin	3.15
NE-2571 # 595	Graphite	Delrin	3.15
NE-2571 # 1211	Graphite	Delrin	3.15
NE-2581 # 237	A-150	Poly-styrene	3.15
NE-2581 # 815	A-150	Poly-styrene	3.15
PTW-30004 # 0070	Graphite	PMMA	3.05

In the first step, air kerma calibration coefficients for the ionization chambers connected to a Unidos measuring assembly were determined in a Co-60 beam by the substitution method using the laboratory reference standard. The distance from the source to the center of the chamber (SCD) was 1.0 meter and the field size at the chamber position was 10 cm. x 10 cm. The experimental setup for the air kerma calibrations of the ionization chambers is shown in Figure 1.

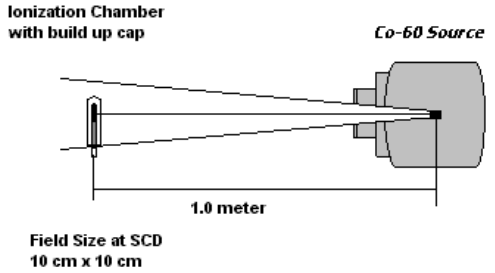

Figure 1. Experimental set up for the air kerma calibration of ionization chambers.

In the second step, absorbed dose to water calibrations were performed in an IAEA standard water phantom with dimensions 30 cm. x 30 cm. x 30 cm. and that had a provision to place the chambers at a fixed position with the chamber center at a reference depth of 5 cm in water using a 3.45 mm thick PMMA sleeve . The distance from the source to the center of the chamber was 1.0 meter and the field size at the chamber position was 10 cm x 10 cm.

Determination of absorbed dose to water calibration coefficient

For the determination of absorbed dose to water calibration coefficient, the formalism given in IAEA dosimetry protocol TRS-277, was followed. According to the protocol, the absorbed dose to water at the effective point of measurement is

$$D_w(P_{eff})=MN_{D,air}(S_{w,air})P_u \quad (1)$$

where, M is the dosimeter (electrometer plus ionization chamber) reading in charge mode corrected for influence quantities,

$N_{D,\ air}$ is the absorbed dose to air chamber calibration coefficient for the ionization chamber,

$S_{(w,air)Co\text{-}60}$ is stopping power ratio of water to air at Co-60 radiation quality, and

P_u is a perturbation coefficient at Co-60 radiation quality to take into account the non-water equivalence of the wall of the ionization chamber during the measurement in water

$$N_{D,air} = N_K \,.\, (1\text{-}g) \,.\, k_m\, k_{att} \quad (2)$$

where, N_K is the air kerma calibration coefficient for the ionization chamber,

g is the fraction of the energy of the secondary electron lost to bremsstrahlung in air,

k_{att} is a coefficient that takes into account attenuation and scattering of photons in the chamber wall and the build-up cap and

k_m corrects for the non- air equivalence of the material of the ionization chamber wall.

Since the design of the IAEA standard water phantom allows placing the ionization chamber only at fixed positions at depth increments of 2.5 cm in water, the centers of all of the ionization chambers were placed at the depth of 5 cm. The absorbed dose to water at the effective point of measurement and at the

center of the chamber was related by the displacement correction coefficient, P_{dis}

$$D_W(5cm.)=D_W(P_{eff}).P_{dis} \quad (3)$$

Where P_{dis} = 1 - 0.004 r, with r being the inner radius of the ionization chamber in mm [5]. This coefficient takes into account the displacement of the volume of water replaced by the chamber cavity.

Experimental set-up for the determination of absorbed dose to water calibration coefficients is shown in Figure 2.

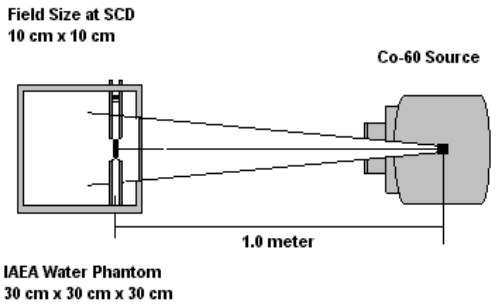

Figure 2. Experimental set-up for the determination of absorbed dose to water

The absorbed dose to water calibration coefficient $N_{D,W}$ was obtained from

$$N_{D,w}=D_W(5cm)/M \quad (4)$$

Equation (4) was also used for obtaining direct absorbed dose to water calibration coefficients for the Farmer ionization chambers.

3. RESULTS AND DISCUSSIONS

The results of air kerma calibration coefficients for ionization chambers determined using the reference standard are given in Table 2.

Table 2: Air kerma calibration coefficients for the ionization chambers used in this work

Ionization chamber type & Sr. No.	Air kerma calibration coefficient (mGy/nC)
NE-2571 # 1905	41.64
NE-2571 # 1213	41.20
NE-2571 # 1148	41.35
NE-2571 # 595	41.57
NE-2571 # 1211	41.07
NE-2581 # 237	50.89
NE-2581 # 815	52.27
PTW-30004 # 0070	47.59

The values of the absorbed dose to water calibration coefficients ($N_{D,W}$) determined using air kerma calibration coefficient and TRS-277, and direct absorbed dose to water calibration coefficient of the reference standard are presented in Table 3.

Table 3: Absorbed dose to water calibration coefficients $N_{D,w}$ based on air kerma and TRS-277, and direct $N_{D,w}$.

Ionization chamber type & Sr. No.	Absorbed dose to water calibration coefficient $N_{D,w}$ (mGy/nC)		
	Calculated using Air kerma calibration coefficient (TRS-277): A	Direct absorbed dose to water calibration coefficient: B	Percentage deviation [A-B/B] *100
NE-2571 # 1905	45.31	45.57	-0.57
NE-2571 # 1213	44.84	45.06	-0.48
NE-2571 # 1148	45.00	45.24	-0.53
NE-2571 # 595	45.24	45.51	-0.59
NE-2571 # 1211	44.70	44.84	-0.32
NE-2581 # 237	54.79	55.31	-0.94
NE-2581 # 815	56.27	57.15	-1.53
PTW-30004 # 0070	51.79	52.09	-0.58

Comparison of the results of absorbed dose to water calibration coefficients presented in Table 3, reveal that differences in calculated $N_{D,W}$ and direct absorbed dose to water calibration coefficients as much as -0.6 % for the ionization chambers Type NE-2571. For the tissue equivalent ionization chambers Type NE-2581, the difference between calculated and direct absorbed dose to water calibration coefficients was higher -- as much as -1.5 %. Since TRS -277 did not include k_{cel} in the equation for computing $N_{D,air}$, no correction for k_{cel} was applied in the calculation of $N_{D,w}$.The value of P_{cel} was taken to be equal to 1.

Following the recommendations of the new International Code of Practice [3] based on standards of absorbed dose to water, the $N_{D,W}$ was calculated for the ionization chambers using the following equations;

$$N_{D,w,Co\text{-}60}=N_{D,air(Sw,air)Co\text{-}60}P_{Co\text{-}60} \quad , \qquad (5)$$

where $P_{Co\text{-}60}$ is the overall perturbation coefficient at Co-60 radiation quality, given by:

$$P_{Co\text{-}60}=[P_{dis}P_{wall}P_{cav}P_{cel}]_{Co\text{-}60} \qquad (6)$$

$$N_{D,air}=N_K(1\text{-}g).k_m k_{att} k_{cel} \qquad (7)$$

The values of these correction coefficients were taken from TRS-398 [3]. The meaning of these coefficients has been described in detail in the protocol.

Results of the absorbed dose to water calibration coefficients $N_{D,w}$ calculated using above equations (5-7) according to TRS-398 [3] and direct $N_{D,W}$ are presented in Table 4.

The results presented in Table 4 reveal a good agreement between calculated absorbed dose to water ($N_{D,W}$) and direct absorbed dose to water calibration coefficients. It should be noted that the value used for k_{cel} is equal to 1.006 for the NE-2571 chamber with a 1 mm diameter aluminium central electrode as given in TRS-381 [2]. For P_{cel} , the value used was 0.993 as recommended in TRS-398 (3). The net contribution of the product {k_{cel} , P_{cel} } was almost unity and therefore no appreciable difference between the calculated and direct absorbed dose to water coefficients was found.

Table 4: Absorbed dose to water calibration coefficients $N_{D,w}$ calculated based on air kerma and TRS-398 and direct $N_{D,w}$.

Ionization chamber type & Sr. No.	Absorbed dose to water calibration coefficient $N_{D,w}$ (mGy/nC)		
	Calculated using Air kerma calibration coefficient (TRS-398): A	Direct absorbed dose to water calibration coefficient: B	Percentage deviation A-B/B *100
NE-2571 # 1905	45.32	45.57	-0.55
NE-2571 # 1213	44.83	45.06	-0.50
NE-2571 # 1148	44.94	45.24	-0.65
NE-2571 # 595	45.24	45.51	-0.60
NE-2571 # 1211	44.69	44.84	-0.33
NE-2581 # 237	55.12	55.31	-0.34
NE-2581 # 815	56.61	57.15	-0.94
PTW-30004 # 0070	51.63	52.09	-0.89

4. CONCLUSION

It is concluded that there is no significant difference between calculated and direct absorbed dose to water calibration coefficients when data from the previous dosimetry Codes of Practice [TRS-277 and TRS-381] is used, for chambers type NE-2571 and NE-2581.

The use of direct absorbed dose to water calibration coefficient for routine clinical dosimetry of radiotherapy beams is very simple for medical physicists. Although the use of a calculated absorbed dose to water calibration coefficient from an air kerma calibration coefficient is not recommended, the use of a calculated $N_{D,W}$ calibration coefficient could be continued for an interim period until the direct $N_{D,W}$ calibration coefficient is available from the standards laboratories.

It should be noted that the calculated absorbed dose to water calibration coefficient $N_{D,W}$ is not

traceable to any primary standard of absorbed dose to water.

5. ACKNOWLEDGEMENT

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COURSES, MEETINGS AND CONSULTANCIES TO BE HELD DURING 2003

Courses and workshops

Regional Training Course on Quality Assurance of Physical and Technical Aspects in Radiotherapy, Argonne National Laboratory, Illinois (USA), 12-23 January 2003

Regional Workshop on Dosimetry of Therapeutic X-ray Beams, Accra, Ghana, 7-11 July 2003 (RAF/6/027)

Regional Training Course on Mould Room Technology, Immobilization and Treatment Planning, Sao Paulo, Brazil, 6-10 October 2003 (RLA/6/046 and RLA/6/049). *This course will be repeated again in 2003, dates of repeated course yet to be fixed.*

Regional Workshop on Acceptance Testing and Commissioning of Radiotherapy Equipment, Tripoli, Libya, 12-19 October 2003 (RAF/6/027)

Workshop on the Implementation of the International Code of Practice for Radiotherapy Dosimetry, IAEA TRS-398, Chiang Mai, Thailand, 17-21 November 2003

Regional Training Course on Evidence-based Radiotherapy, Tlalpán, Mexico City, Mexico, 24-28 November 2003 (RLA/6/046 and RLA/6/049)

Regional Training Course on Stereotactic Radiotherapy (SRT), Sao Paulo, Brazil, 3-6 December 2003 (RLA/6/046)

Regional Workshop on Internal Dosimetry, Rio de Janeiro, Brazil, 12-23 January 2004 (RLA/9/049, ARCAL LXXVIII).

ESTRO courses under RER/6/012

Training Course on Radiotherapy Treatment Planning: Principles and Practice, Dublin, Ireland, 9-13 March 2003

Training Course on Dose Determination in Radiotherapy: Beam Characterization, Dose Calculation and Dose Verification, Barcelona, Spain, 6-10 May 2003

Training Course on Physics for Clinical Radiotherapy (Russian Edition), Moscow, Russia, 25-29 May 2003

Training Course on Imaging for Target Volume Determination in Radiotherapy, Nice, France, 8-12 June 2003

Training Course on Physics for Clinical Radiotherapy, Leuven, Belgium, 31 August – 4 September 2003

Training Course on Evidence-Based Radiation Oncology: Methodological Basis and Clinical Application, Tenerife, Spain 9-14 November 2003

Meetings and consultancies

Second Research Co-ordination Meeting on the Development of an International Code of Practice in X-ray Diagnostic Radiology, IAEA Headquarters, Vienna, 13-17 January 2003

Consultancy to finalize the Agency's Medical Physics Syllabus, IAEA Headquarters, Vienna, 24-28 February 2003

Joint TCPC/NAHU Thematic Planning Meeting on Diagnostic Radiology, IAEA Headquarters, Vienna, 26-30 May 2003

IAEA/ICRU Inaugural Meeting of the ICRU Subcommittee on Proton Therapy, "Prescribing, Recording and Reporting Proton Beam Therapy", IAEA Headquarters, Vienna, 29-31 May 2003

Second and Final Research Co-ordination Meeting on the Development and Dissemination of Absorbed Dose to Water Calibration Techniques for SSDLs, Oslo, Norway, 23-27 June 2003

Action Plan Meeting in response to the Recommendations arising from the 2002 International Symposium on Standards and Codes of Practice in Medical Radiation Dosimetry, IAEA Headquarters, Vienna, 30 June – 1 July 2003

OIOS Evaluation Meeting of the Agency's Activities in Dosimetry, IAEA Headquarters, Vienna, 29 Sept. – 3 Oct. 2003

Consultants' Meeting on Development of Procedures for the Physical and Biological Evaluation of Treatment Planning Calculations, IAEA Headquarters, Vienna, 13-17 October 2003

Consultants' Meeting on Development of the Methodology for TLD-based Quality Audits for Radiotherapy Dosimetry in Non-reference Conditions, IAEA Headquarters, Vienna, 20-24 October 2003

Consultancy to review the IAEA quality manual, IAEA Headquarters, Vienna, 1-5 December 2003

Consultants' Meeting on Development of Procedures for "*in vivo*" Dosimetry, IAEA Headquarters, Vienna, 8-12 December 2003

RAF6027 and RAF6024 (AFRA II-4) Project Coordinators' Meeting on Medical Physics and the Management of the Most Common Cancers in Africa, Bangkok, Cairo, Egypt, 13-17 December 2003

Task Group Meeting on Strengthening Medical Physics in the Asia & Pacific Region, place and dates to be decided

Task Force Meeting on upgrading medical physics in Africa, Cairo, Egypt, 15-18 December 2003

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* SSDL Organization

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

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