Development and prospects on dosimetry at radiotherapy levels in the Secondary Standard Dosimetry Laboratory of Cuba.

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Abstract. The Secondary Standard Dosimetry Laboratory of Cuba (SSDL) undertakes calibrations in all fields of photon radiation dosimetry in the country. In this way, reference measurements throughout it have metrological links to the international measurement system. The calibration service was introduced into the Quality Assurance System of SSDL which meets the requirements of the ISO/IEC 17025 standard. The internal quality control programme, as one of the basic tasks of the Quality System, set up the long-term stability test of reference and working standards as well as stability tests by checking source measurements and the control of the charge measuring assembly. All these tests together with the intercomparison exercises with other laboratories of the same or higher metrological level enabled the study of metrological properties of the reference standards in order to apply for its official recognition as the Cuban National Standard in the field of dosimetry at radiotherapy level. Regarding the new trends in this matter, the SSDL has implemented recently a calibration service based on standards of absorbed dose to water. The SSDL has collaborated with the end-users providing not only the calibration certificates for therapy chambers but also by TLD irradiation service used by the National Audit Group for a pilot quality audit of clinical beams. The Cuban governmental bodies are interested in ensuring the metrological subjects relevant to the patient under oncology treatments. The SSDL staff was asked for this work regarding their experience both in the successful implementation of legal marks for radiation protection dosimetry and on their advanced works in the field of radiotherapy dosimetry. The preliminary proposal of legal metrology standardization in this field is commented. This paper presents the results and prospects of the work of SSDL in the field of radiotherapy dosimetry.

I. Introduction

The Secondary Standard Dosimetry Laboratory (SSDL) of Cuba was established in the year 1995 at the Center for Radiation Protection and Hygiene (CPhR) and since then it has been joined to the network of SSDLs belonged to International Atomic Energy Agency (IAEA) and World Health Organisation (WHO). Its construction was finished under support of the IAEA project. In this way, Cuban reference measurements throughout it have metrological links to the international measurement system. The Laboratory basically was equipped with the standards for photon dosimetry (chambers, electrometers) at radiotherapy and radiation protection levels, the $^{137}$Cs and X-ray units, two calibration benches with laser positioning systems and radiation safety systems (TV circuit, protection barriers, etc). Later, during the year 1999 the $^{60}$Co unit for calibration of the therapy dosimeters was installed.

Membership in the Network has helped the laboratory on the improvement of accuracy in radiation dosimetry in Cuba. It provides us either the periodic calibration of the reference standards through the Agency Dosimetry Laboratory, the quality audits to the service and the training to the laboratory staff with financial support of the IAEA.

The SSDL has not only followed the technical recommendation of the Agency but also it has participated in the co-ordinated research projects to develop new trends in the Network.

This paper presents the results and prospects of the work of SSDL in the field of radiotherapy dosimetry.
2. Current status and future on radiotherapy dosimetry.

2.1 Calibration service for therapy dosimeters.

The secondary standard system of the SSDL for calibration of the dosimeters used in external beam radiotherapy is contained by the following components:

- Cylindrical ionization chamber model NE 2561 s/n 323 for calibration at medium energy X rays (above 80 kV), \(^{60}\)Co gamma radiation,
- Plane-parallel ionization chamber model PTW 23344 s/n 748. For calibration at low energy X rays.
- Measuring assembly (electrometer) model NE 2590 s/n 626 calibrated in terms of charge per scale division.

The calibration service for therapy dosimeters was based on standards of air Kerma. At the first time, some calibrations of the radiotherapy dosimeters at \(^{60}\)Co beam were done in the users units because of the lack of \(^{60}\)Co units in the SSDL. This way of calibration had the disadvantages of the transportation of SSDL standards that increased the probability of damage in the instrumentation, the difficulties for organization of the calibration programme in all radiotherapy hospitals, lost of precision and consistency and the large time spent on the process, etc. Much later, in 1999, the SSDL acquired the Theratronics \(^{60}\)Co unit that enabled the implementation of the calibration service in the SSDL installations.

For X ray qualities the situation stated different. Since 1995, the laboratory mounted the X-ray unit model PANTAK HF-160 in which were established the low and medium energy X-ray qualities (up to 150kV).

The service has been extended to calibration in terms of absorbed dose to water. The new service was implemented in the year 2002 because of the request of the Cuban medical physics community for implementation of the new code of practice TRS 398 [1] for dosimetry at clinical beams based on absorbed dose standards.

The laboratory has calibrated ionisation chambers from Cuba, Costa Rica, Dominican Republic and Nicaragua.

As an additional collaboration with the end users, the SSDL has been provided the irradiation service of postal dosimeters used in dose comparisons for medical institutions in Cuba. The SSDL integrate the National Audit Group whose aim is to ensure adequate precision in the dosimetry of clinical beams. In this way, the SSDL specialists participated in the IAEA Co-ordinated Research Programme (CRP) "Development of Quality Assurance Programmes for Radiation Therapy Dosimetry in Developing Countries"; and at this moment, the specialists participate in the new IAEA CRP “Development of a TLD based Quality Audit Programme for Radiotherapy Dosimetry in Non-Reference Conditions”. The last one is intended to extend the scope of activities of external audits group from reference to non-reference audit measurements.

2.2 Quality Assurance Programme.

Since the establishment of SSDL, his staff associated the calibration service with the development of a Quality Assurance System (QAS) according to the requirements of ISO/IEC guide 25 [2]. This guide was identified as a way for increasing the user’s confidence into the quality of SSDL works. Our SSDL is a pioneer on this scope. In 1996, its QAS was documented and in 1997 it was accredited by National Accreditation Bureau of the Standardising National Office. The SSDL was re-accredited in the year 2001 by the same entity for meeting the requirements of the new ISO/IEC 17025 standard. The QAS cover all of the works of the laboratory, starting from internal quality controls (checks of
the standards, radiation beams and equipment, record keeping, etc) and ending with external controls that include the IAEA/WHO TLD and ion chamber irradiation programmes, intercomparisons and accreditation audits. The results of these external controls are shown in figures 1 and 2.

The ability of the SSDL to transfer the chamber calibration to determination of absorbed dose to water under reference conditions has been demonstrated with the results of these audits (see figure 1). All results were inside the Agency’s 3.5 % action level.

The first 5 values of absorbed dose to water stated by CPHR-SSDL were based on measurements made with ionization chamber calibrated in terms of air Kerma. The last values are based on measurement directly in terms of absorbed dose to water.

The 15 intercomparison exercises of the therapy level secondary standards of the CPHR-SSDL with 5 foreign SSDLs were organised. The transfer chamber from the CPHR was the thimble ionisation chamber model NE2571/1881. The comparison comprised the quantities air kerma at $^{60}\text{Co}$ and several X-ray therapy qualities and the absorbed dose to water only at $^{60}\text{Co}$. The figure 2 shows the intercomparison of the ion chamber calibration factors with the laboratories from the Norwegian Radiation Protection Authority (NRPA, Norway), Laboratoire Central de Industrie Electriques (LCIE, France), Instituto Venezolano de Investigaciones Científicas (IVIC, Venezuela), Swedish Radiation Protection Authority (SSI, Sweden) and the IAEA. The statistic $E_n$ is internationally recommended [3] for evaluation of performance of participants in the comparisons. $E_n$ numbers are calculated as follows:

$$E_n = \frac{x - X}{\sqrt{U_{\text{lab}}^2 + U_{\text{CPHR}}^2}} \quad (1)$$

Where “$x$” is the participant’s value, “$X$” is the reference assigned value of CPHR-SSDL, $U_{\text{lab}}$ is the uncertainty of “$x$” and $U_{\text{CPHR}}$ is the uncertainty of “$X$”. If $|E_n| \leq 1$ the result of the intercomparison is considered satisfactory, if $|E_n| > 1$ the result is unsatisfactory.

Figure 1. Results of the IAEA/WHO postal TLD dose audits of SSDL in the period 1997-2003 at $^{60}\text{Co}$ beam.

Figure 2. Results of the ion chamber intercomparisons. The value 1 of the $E_n$ number is considered as an action level.
Only one result unsatisfactory at 50 kV X-ray quality was encountered. The investigation to find the cause for the unsatisfactory result is discussed in [4]. In this investigation no reason were found for the problem, so it was organised other intercomparison at the same quality with LCIE, France. It was obtained a very good agreement for the air kerma calibration factor at 50 kV energy X-ray quality by both laboratories (see figure 2).

![Graph showing measured vs reference values over time](image)

*Figure 3. Results of long-term stability test of reference standard using the $^{90}\text{Sr}$ check source.*

The internal quality control programme, as one of the basic tasks of the Quality System, set up the long-term stability test of reference and working standards using the $^{90}\text{Sr}$ check source. The SSDL reference standard has been tested during a period of 5 years. The action level for this test is the value of $\pm 0.5\%$ of the reference measurement. The results of these measurements are shown in the figure 3. In 5 years no measurement were found outside of the action level limits. This test together with the control of the charge measuring assembly and the intercomparison exercises enabled the study of metrological properties of the reference standards [5] in order to apply for its official recognition as the Cuban National Standard in the field of dosimetry at radiotherapy level.

From 1996 to 1999 the SSDL participated in the Co-ordination Research Project (E2.10.02) on the development of a quality assurance programme for secondary standard dosimetry laboratories of the network. During these years in the laboratory was developed a computer data base application “GESCAL” designed for quality assurance information control, planning and system revision. This software is a very helpful complement for laboratory’s works. It provides the fast planning and report of quality assurance activities and the automatic revision of the quality controls results. With the use of GESCAL software quality assurance activities became faster process.

### 2.3 Legal mark proposal for radiotherapy dosimetry.

It has been demonstrated the utility of legal metrology framework in the creation of a credible system of measurements in a society. In 1999 this system was first implemented in Cuba for the ionising radiation by the establishment of legal verification service for X and gamma measuring instrument used for radiation protection [6]. This service offering in the SSDL, is supported by a new Cuban standard [7] in this scope. Due to the obligation for annual verification of the instruments, the detection of wrong operation of some of them has been facilitated. In the case of the calibration of radiotherapy dosimeters no legislation is approved at the moment. Several radiotherapy dosimeters were found with unacceptable long-term stability parameters regarding the large changes in calibration coefficient during the time, but no restriction were applied to its use because of the lack of legislation. Only the re-calibration of the chambers was carried out as a corrective action. This situation derived the claims of the Cuban users to manufacturer and the
IAEA investigation. The SSDL results were confirmed and the manufacturer reported the use of non-aged material in the construction of the chamber that affected the long-term stability in the first period of use. Because the Cuban governmental bodies are interested in ensuring the metrological subjects relevant to the patient under oncology treatments, the SSDL staff was asked for the extension of the legislation to dosimeters used in radiotherapy.

The standard on preparation is based on the IEC 60731 [8] and IAEA Technical Report Series 374 [9]. According with the use and accuracy of measurements, the dosimeters are classified in Reference-class and Field-class. The Reference-class is supposed to be used for beam calibration, reference measurements in the user beam and for internal calibration of the Field-class dosimeters. For this reason the performance requirements for Reference class are but demanding. At the moment, in the legal framework will be partially verified the performance of the Reference dosimeters only. Every time the ionisation chamber should be presented together with the electrometer. These reference’s systems are proposed to be re-calibrated and tested for long term stability and repeatability parameters every two year. In addition, when the dosimeter is verified for the first time, after its purchase or repairing, it will be included the tests for dependence on radiation quality and non-linearity over the measuring scale. The legislation will not cover the use of Field-class instruments. The Field-class is normally used for routine measurements and the user decide the periodicity for re-calibration at the SSDL.

3. Conclusions.

The CPHR-SSDL is actively contributed to the improvement of accuracy of dosimetry at radiotherapy level in Cuba. The participation in the IAEA/WHO Network allows the maintenance of the traceability to the international measurement system by calibrating their reference standards against standards of the Agency Dosimetry Laboratory. The SSDL provide the calibration services not only to Cuban users but also to other countries in the Latin American region. This service was normally based on air Kerma standards but actually it was extended to terms of absorbed dose to water regarding the new trends in radiotherapy dosimetry.

The Laboratory had successfully participated in several quality audits under IAEA/WHO TLD and ion chamber irradiation programmes. The good results in these audits together with the international intercomparisons and internal controls as a part of the principal tasks of the accredited Quality Assurance System are in agreement with the carefully work carried out during these years.

For the near future, the legal framework in the metrology applied to radiotherapy dosimetry will be established. This action will help to better performance control of the instrumentation used for measurements at clinical beams and in this way will decrease the possibility of mistakes on the dose determination to be applied to the patients.

4. References


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