HIGH-DOSE DOSIMETRY AT ANSTO: QUALITY ASSURANCE, CALIBRATION & TRACEABILITY

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Abstract

A overview of the techniques used by ANSTO's high-dose dosimetry laboratory is given, commencing with a description of the facilities operated and the nature of the services provided. The dosimetry systems used by ANSTO are detailed along with their applications. Techniques used for calibration of dosimeters and radiation sources are given, including traceability and measurement uncertainty considerations. Quality assurance aspects of the dosimetry service are discussed.

1. INTRODUCTION

The Radiation Technology Group at ANSTO is part of the Physics Division and provides services and advice in the areas of gamma irradiation and high-dose dosimetry.

The Group maintains and operates a number of irradiation facilities. The cobalt-60 used in the gamma irradiation facilities is produced in ANSTO's HIFAR research reactor. ANSTO's underwater facility consists of seven cobalt-60 sources configured in annular arrays with a range of activities and dose rates. The pond is approximately 5 m deep and is filled with de-ionised water. Water-tight stainless steel canisters with capacities of up to 30 litres are used in the processing of customer goods.

The main irradiation facility is GATRI – the Gamma Technology Research Irradiator – a research and small scale batch irradiator commissioned in 1969. The source is a cobalt-60 plaque source with a maximum capacity of 100 000 Ci. It is stored in a deionised water tank 5-m deep and is raised into a concrete shielded cell for irradiations.

Materials commonly irradiated at ANSTO include medical and other materials requiring processing for sterilisation or verification of sterilisation dose, items requiring decontamination and disinfestation for quarantine purposes, frozen bone and tissue samples for transplant surgery, monomers and polymers for modification of properties, virus samples, and Queensland fruit fly pupae used in the Sterile Insect Technique. The GATRI facility has been loaded with cobalt to provide the largest possible uniform radiation field, rather than for efficiency, so that we can provide the required doses as precisely as possible. We can offer irradiations at a range of dose rates and at frozen and elevated temperatures. During the past twelve months, client demand for target doses ranged from 10 Gy to 6000 kGy, at temperatures from -80 °C to 270 °C.

In order to provide a comprehensive irradiation service, Radiation Technology is licensed by Australia's Therapeutic Goods Administration (TGA) and the Australian Quarantine and Inspection Service (AQIS). Obtaining these licences meant implementing a Quality System complying with the ISO 9000 series of documents. In addition, the GATRI facility is required to comply with the National Health and Medical Research Council's (NH&MRC) Code of Practice for the Design and Safe Operation of Non-medical Irradiation Facilities. All radiation facilities are licensed by ANSTO's Safety Assessment Committee. An external regulatory

body, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), is proposed to be formed in 1998 and will also licence these facilities.

Radiation Technology makes and sells reference and transfer standard dosimeters which are purchased by users and suppliers of commercial irradiation services in Australia and the Asia-Pacific region. A calibration service is also provided for dosimeters made by or purchased from other organisations.

2. DOSIMETRY SYSTEMS

ANSTO's dosimetry practices are based on the standards published by the American Society for Testing and Materials (ASTM). Dosimetry systems in use are Fricke, ceric-cerous sulfate, Harwell Red and Amber Perspex and alanine/EPR.

2.1. Fricke

The Fricke dosimeter is used as a transfer standard to calibrate ANSTO's Underwater Calibration Facility with reference to the Secondary Standard Dosimetry Laboratory; for dose-mapping and calibration checks of self-shielded laboratory irradiators, such as blood irradiators; and to monitor irradiations for the Sterile Insect Technique and other low dose applications.

The methods used for preparation, measurement and calculation of results are essentially as described in ASTM Standard E 1026 [1], except that the solution is not air saturated and is dispensed into 5 mL polyethylene ampoules as required. These ampoules are conditioned prior to their initial use by irradiating them to a dose of approximately 1 kGy, and are reused many times. To avoid pre- and post-irradiation effects, the ampoules are filled immediately before use and are measured within one hour. The dose response of each new batch of dosimeter solution is verified before use by irradiation to several dose levels in the known radiation field of the Underwater Calibration Facility.

2.2. Ceric-Cerous sulfate

The ceric-cerous dosimeter is used by ANSTO during product dose mapping studies for critical process parameter determination; during sterilisation dose determination for product qualification studies; and for routine process control where a high degree of accuracy is required. These dosimeters are sold on a supply and measurement basis to users and suppliers of commercial irradiation services in Australia and the Asia-Pacific region wishing to verify the response of their routine dosimetry systems or confirm the dose delivered to their products. The dosimeters are also used as a transfer standard during the in-plant calibration of the routine dosimetry system used by Australia's only commercial irradiation company.

The methods used for preparation, measurement and calculation of results are essentially as described in ASTM Standard E 1205 [1] using the potentiometric method except for the following. A low range dosimeter is prepared and calibrated over the range 1-12 kGy using concentrations of 3.75×10^{-3} mol·L^{-1} ceric sulfate and cerous sulfate, and a high range dosimeter is prepared and calibrated over the range 10-35 kGy using concentrations of 0.01 mol·L^{-1} ceric sulfate and cerous sulfate. Each batch of dosimeters is calibrated by irradiating five samples to each of at least six dose levels in the known radiation field of the Underwater Calibration Facility. Following calculation of the dose using the Matthew's equation, a plot is made using curve-fitting software to determine the relationship between calculated dose and delivered dose. All subsequent measurements using this batch are then corrected according to this mathematical relationship.

2.3. Harwell Perspex

Harwell Red 4034 and Amber 3042 dyed Perspex dosimeters are used during dose mapping studies for relative dose determinations and for routine process control for non-critical items. They are calibrated in the Underwater Calibration Facility as described in ASTM Standard E 1276 [1].

2.4. Alanine-EPR

ANSTO has recently acquired a Bruker EMS104 EPR analyser and is in the process of developing protocols for the use and calibration of alanine dosimeters using this instrument for inclusion in our Quality System. It is not yet ready for routine use, but it is anticipated that it will be used as a transfer and reference standard.

3. CALIBRATION

All dosimetry calibrations performed at ANSTO either for internal use or for external clients are carried out in the known radiation field of the Underwater Calibration Facility (UCF). Calibration of this radiation field is described in section 4.

The source consists of 12 cobalt-60 pencils in an annular arrangement, stored at the bottom of ANSTO's underwater facility. All items for irradiation are loaded into a water-tight stainless steel canister which is in series with a continuous stainless steel roller chain driven by an electric motor which lowers it reproducibly into the centre of the source. The dosimeters for calibration are mounted onto a turntable fitted with a polyethylene holder with locations for up to 12 dosimeters. The turntable is sited in a fixed position within the irradiation canister and the dosimeters are continuously rotated to ensure an even dose.

The facility is controlled by a computer which provides for independent confirmation of irradiation time, irradiation temperature and rotation of the turntable. Temperature is monitored using a thermocouple.

4. TRACEABILITY

At ANSTO, measurement traceability to the national standard is obtained by the following approach. The Australian Standard for Absorbed Dose, formerly held by ANSTO but now residing in Melbourne at the Australian Radiation Laboratories, consists basically of a cobalt gamma source whose dose rate at a fixed point is measured using a graphite calorimeter. This primary standard is then disseminated by the Secondary Standard Dosimetry Laboratory or SSDL which is in the process of being re-established at ANSTO. The SSDL ionisation chamber is calibrated against the primary standard and this chamber is then used to calibrate a collimated beam from a teletherapy gamma source. ANSTO's Fricke dosimeters are then irradiated in this calibrated beam to a range of doses so that the response of this solution is well characterised. This dosimeter solution is then used to determine the dose rate in a fixed geometry on the turntable in the Underwater Calibration Facility in the pond. Routine and transfer standard dosimeters are then calibrated as required in the UCF, with the dose rate calculated according to the decay of the cobalt-60 source. Doses are routinely expressed in terms of the dose absorbed in water.

This process has a shortcoming that I suspect is common to other calibration labs around the world. That is, the calibrated collimated beams used in primary and secondary standard labs have very low dose rates because they are usually teletherapy units. Obviously, the dosimeters used in the traceability irradiations are selected because their response is as affected as little as possible by dose rate, but if it takes 12 or 24 hours to achieve a dose in the SSDL

that will take a couple of minutes to get in the calibration facility, then this is obviously far from ideal.

In conjunction with this calibration process, ANSTO has confirmed the dose rate in the UCF through irradiation of dosimeters supplied and measured by the National Physical Laboratories in the UK and via the IAEA's International Dose Assurance Scheme (IDAS). The dose rate measured in these instances agrees within 0.5% with ANSTO's calibrated dose rate.

5. MEASUREMENT UNCERTAINTY

As with the result of any analysis, the absorbed dose measurement obtained after reading a dosimeter is somewhat meaningless without an expression of the uncertainty associated with the result. In principle ANSTO follows the guidelines set out in ISO's 1993 "Guide to the Expression of Uncertainty in Measurement" and ASTM Standard E 1707 [1]. Uncertainties are reported as a percentage at the 95% confidence interval and are in the process of being fully incorporated into our Quality System.

6. QUALITY ASSURANCE

Radiation Technology performs all its functions according to the requirements of its ISO 9001 Quality System. This system requires that each dosimetry system, which includes the appropriate measuring instruments and written procedures for the system's use, is calibrated and maintained within specified accuracy limits. Extensive log books are maintained and stored to record such things as

- irradiation processes and dosimeter measurements,
- dosimeter batch preparation and calibration records,
- dose mapping details,
- calibration records for all measure and test equipment,
- maintenance records for facilities and
- non-conformances.

All services offered by Radiation Technology are initiated by completion of our Agreement for Service Work, which serves as an order form but also sets out ANSTO's Terms of Business and the responsibilities of both the customer and ANSTO according to Australia's Code of Good Manufacturing Practice.

Radiation Technology's activities are regularly audited by external regulatory bodies, by clients as part of their accreditation requirements and by ANSTO's Manager, Quality.

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REFERENCE

[1] American Society for Testing and Materials, Annual Book of ASTM Standards, Volume 12.02, West Conshohocken, PA (1997)