Dosimetry Standards and Dissemination Systems for Radiation Processing in China

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Founded in 1955, National Institute of Metrology (NIM) is the national metrology institute of China, subordinate to General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ), China. It is the nation’s highest technical authority in the field of metrology, and responsible for providing metrology services of the highest accuracy and reliability to customers.
NIM’s main tasks

- Research, establish, maintain and improve national primary standards & national standards
- Participate in international comparisons to ensure traceability and international equivalence of national standards;
- Disseminate values to its clients through verification and calibration services, ensure all unit values are traceable and reliable within the nation;
- Carry out fundamental and frontier research in metrological science, study measurement theory and technique; develop value disseminating and tracing methods, etc.

Div. of Metrology in Ionizing radiation:

Three section: Radioactivity, Dosimetry, Accelerator and Neutron

- Primary standards: 18 (1 for radiation processing)
- Secondary standards: 15 (4 for radiation processing)
- Comparison: 34 (1 for radiation processing)
- CMCs: 195 (8 for radiation processing)
In 1983, a project of high dose standardization was initiated in China.

- To establish the high-dose standards system for $\gamma$-rays and EB irradiation.
- To establish the dissemination of high-dose value through intercomparison, calibration and verification.
- Implementation of NDAS using alanine/EPR dosimetry system.
- To Calibrate routine dosimeters and measure radiation field dose mapping of radiation processing facility.
- To train the technical personal in dosimetry for irradiation facilities and to help them to set up their own routine dosimetry system.
- To enact administrative regulation and technical standards concerned absorbed dose for radiation processing.
In 1986, the high-dose standards and dissemination system has been established at NIM.

- **Primary standard**: Fricke liquid chemical dosimeter
- **Transfer standards**: Ceric-cerous sulfate liquid chemical dosimeters, Dichromate liquid chemical dosimeters, Alnine/EPR dosimeter

<table>
<thead>
<tr>
<th>Absorbed dose range</th>
<th>Fricke dosimeter</th>
<th>Silver Dichromate dosimeter</th>
<th>Potassium Dichromate dosimeter</th>
<th>Alanine/EPR Dosimeter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gy</td>
<td>40~400</td>
<td>0.4~5</td>
<td>5~40</td>
<td>0.1~40</td>
</tr>
<tr>
<td>kGy</td>
<td></td>
<td>4%</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>Uncertainty at k=2</td>
<td>2.0%</td>
<td>4%</td>
<td>4%</td>
<td>4%</td>
</tr>
</tbody>
</table>
liquid chemical dosimeter Standards at NIM

A type of Cary 4E Uv/vis spectrophotometer has been used for measuring optical absorbance of dosimetric solution, the pre-irradiation absorbance: Ao and the post-irradiation absorbance: Ai.

$$\Delta A = |A_i - A_o|$$
The Fricke dosimetry system

as primary standard to measure the absorbed dose in water of $^{60}$Coγ-rays in processing level with uncertainty of less than 2% (k=2).

- The absorbed doses are calculated as follows:

$$D_W = 1.004 \ D_F = 1.004 \ K_F \cdot \Delta A$$  \hspace{1cm} (1)

$$K_F = \frac{1}{\varepsilon \cdot G \cdot l \cdot \rho} = 279 \ (\text{GyAbs})$$  \hspace{1cm} (2)

--- $K$ is the dose-response conversion factor.
--- $G$ is radiation chemical yield
  ($=1.61 \times 10^{-6} \text{ mol}\cdot\text{J}^{-1}$, ICRU 34# report)
--- $\varepsilon$ is molar linear absorption coefficient of Fe$^{3+}$
  ($=219.2 \pm 0.3 \text{ m}^2\text{mol}$)
--- $l$ is optical pathlength of the dosimetric solution in the cuvette
  ($=10.0\text{mm}$)
--- $\rho$ is density of the dosimetric solution,
  ($=1.024 \text{ g/cm}^3$)
Dosimetry system for high-dose

Alanine/EPR dosimetry system

It has been developed as a transfer standard used for NDAS program similar to IDAS of IAEA, and used to unify quantity of absorbed dose for irradiation at radiation processing dose level with uncertainty of less than 4% (k=2).

Alanine/EPR dosimetry system at NIM
Routine (working) dosimeters

The Fricke, potassium/silver dichromate, several kinds of radiochromic films (RCD), cellulose triacetate (CTA) and PMMA dosimeters have been recommended as routine dosimeters for radiation processing in China.
Dosimetry system for high-dose

The schema of dosimetry tractability to national standards for radiation processing in China

**FIG 1. The schema of dosimetry tractability to national primary standards for Y-rays**
Dosimetry system for high-dose

γ-rays reference irradiated facility

- The pool $^{60}$Co source with an activity of 770 TBq on Oct 1st, 2016 opened beam and barrel source
- The source was calibrated in terms of absorbed dose to water by a set of Fricke dosimeter. The K of transfer standard and routing dosimeter are calibrated through the Fricke dosimeter standard at the dose rate of about 2 kGy/h in this irradiation field, respectively.

$^{60}$Coyrays high-dose irradiation facility at NIM
**EB reference irradiated facility**

- **Nominal energy of EB:** 9, 10, 11, 12 MeV
- **Maximum power of electron beam:** 10 kW
- **Repetition rate of EB current pulses:** 50, 100, 150, 300 1/s
- **Scanning length in 100 cm from extraction window:** 60cm
- **Speed of conveyor system:** 10-200mm/s
- **Minimum absorbed dose (50 Hz, 200mm/s):** 40 Gy

*linear electron accelerator*  
*conveyor system*  
*Graphite and polystyrene calorimeter*
In 1998 and 2008, NIM’s Fricke dosimeter participated in CCRI (I)-S2 comparisons of standards for absorbed dose to water in $^{60}$Co $\gamma$-rays at radiation processing dose levels using alanine/EPR dosimeters of the NIST and the NPL as the transfer dosimetry.

Results in 1998

Results in 2008
From 1988, the project of NDAS was initiated by using NIM alanine/EPR and dichromate dosimeters transfer standards in China, which is used to unify value of absorbed dose for $^{60}\text{Co}$-$\gamma$-rays radiation processing all over China.

- a set of 3～5 dosimeters with information sheet every six months by mail.
- Irradiation dose in the range of 0.5 to 40 kGy.
- Up to now, more than 70% $\gamma$-rays or EB radiation facilities used for food processing and sterilization participated in the NDAS program in China.

From 2007 to 2016, altogether 988 dose checks have been carried out. 929 of 988 dose checks fall on the deviation range less than $\pm$ 5%.
• **Characterization of the irradiation facility and Validation process**
  
  • *Dose Mapping in simulated product units:* to determine location of $D_{\text{min}}$ and $D_{\text{max}}$ and timer setting for achieving the desired $D_{\text{min}}$ for actual product.
  
  • *For EB:* to measure beam and depth profiles, and to determine conveyor speed, beam current, electron energy, scan width for $D_{\text{min}}$ and maximise the beam penetration capability.

• **Routine product processing**

  • *To Control, monitor and document the operating parameters to ensure that each process load that passes through the irradiator is processed in accordance with specifications.*
  
  • *To place dosimeters either within or on the selected process load at predetermined locations of $D_{\text{min}}$ (and $D_{\text{max}}$ if a prescribed limit) or at the reference positions to provide an independent check that absorbed dose is still within the desired $D_{\text{min}}$ and $D_{\text{max}}$ during the processing.*
In order to guaranteeing the product quality of radiation processing, General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) has issued 20 national standards or technical norms concerned to the field of radiation processing with reference to ISO /ASTM Standards since 1990.

Include as follows:

- GB 139-2008 Standard method for using the ferrous sulfate (Fricke) dosimeter to measure absorbed dose in water.
- GB/T 16639-2008 Alanine-ESR dosimetry system for radiation processing.
- GB/T 15053-2008 Standard method for using the radiochromic film and PMMA dosimeters to measure absorbed dose.
- GB/T 16334-2008 Practical guide of dosimetry in a gamma irradiation facility for food processing.
The *Dosimetry Standards and Dissemination Systems for Radiation Processing* has already provide a useful method to ensure the routine dosimeters tracing to the national standard and take an important role to control quality of radiation processing in China.
Thanks for your attention!