Retrospective Dosimetry Project for Dose Reconstruction in Industrial Radiography Accident

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Introduction
Radiation Accidents

Source from IAEA Training Material
Industrial Radiography Accidents

- Industrial radiography for NDT (Non-Destructive Test) can result in **overexposure to radiation workers**.
Retrospective Dosimetry

- Retrospective assessment of the radiation dose due to past human exposures when the conventional dosimetric data is not available.
Why is it necessary?

- History has demonstrated that **radiation accidents in a various of industries can occur** despite all precautions.
- Retrospective assessment of the radiation exposure is important to perform the **analysis of the radiation risk** and it is an essential part of **epidemiological studies after accidents**.
- **Alternative methods to routine dosimetry** for individual dose assessment are required under circumstances where exposed dose is significantly high. (e.g. greater than dose limits)
Available Techniques

- **Biological Dosimetry:** DCA, PCC, FISH, MN, etc.

- **Physical Dosimetry:** TL, OSL, EPR, etc.

- **Other Techniques:** Bioassay, Neutron activation analysis, Computational dosimetry (MC method), etc.
Key Parameters for Retrospective Dosimetry

- **Specificity to Ionizing Radiation Exposure**
- **Sensitivity** (Dose range, MDD, etc.)
- **Signal Stability** (i.e. Fading effect)
- **Turnaround Time to Get the Results**
Dosimetry Network

- **Dosimetry network** is essential for technical cooperation and intercomparison exercise to acquire the quality assurance of radiation dosimetry system.

- **Verification/Validation process** of the applied method is also required for accurate dose assessment.

- **Multiple and cooperative approach** will be necessary for effective response to large-scale radiation accidents.
KREDOS

Korean Retrospective Dosimetry Group (KREDOS)
Organized in 2016
To maintain national cooperation system
5 Working Groups
- WG1: Biodosimetry
- WG2: EPR Dosimetry
- WG3: TL/OSL Dosimetry
- WG4: Computational Dosimetry
- WG5: Reference Irradiation
Retrospective Dosimetry Project

- Launched in 2018 by the financial support of NSSC
- Four retrospective dosimetry techniques covered in the project

1. Biological Dosimetry (KIRAMS)
   - Chromosome Analysis (DCA, FISH, MN, etc.)
   - Application of Automatic Reading System

2. TL/OSL Dosimetry (KAERI)
   - Thermoluminescence/Optically Stimulated Luminescence
   - Target Samples: Glass, Register, IC Chip, etc.

3. EPR Dosimetry (KIRAMS)
   - Electron Paramagnetic Resonance (EPR) Spectroscopy
   - Target Samples: Tooth, Nail, Glass, etc.

4. Computational Dosimetry (KIRAMS)
   - Human Computational Phantoms
   - Application of Monte Carol Simulation Method
Retrospective Dosimetry Project

- EPR Dosimetry
- Computational Dosimetry
What is EPR Dosimetry?

- Absorption of ionizing radiation generates unpaired electrons.

- Electron spin flips of unpaired electrons occur at a specific microwave frequency within a variable magnetic field.
EPR Retrospective Dosimetry

- IAEA TEDOC-1331 on EPR Dosimetry
**EPR Spectrometer in KIRAMS**

- X-band EPR Spectrometer (Bruker ELEXSIS-II E500)
- Resonator: ER 4122SHQE
- Weak pitch sensitivity: S/N = 3000:1
- Number of Spins/G = $9.6 \times 10^8$ spins/G
Samples for Retrospective Dosimetry

- **Biological Samples**
- **Substitute Samples**
Dosimetry from EPR Measurements

**Dose Response Curve Method**

- Predetermined calibration curve
- No variation in the used sample
- Correction of background signal

**Additive Dose Method**

- No need of calibration curve
- Sample-specific estimation
- Not easy to correct BKG
Protection Films of Mobile Phones

- Touch Glass (TG) Film
- Polyethylene Terephthalate (PET) Film
- Thermoplastic Polyurethane (TPU) Film
Protection Films of Mobile Phones

◆ TG Film vs. TPU Film
Fingernail Samples

- The main component of human nails is the hard keratin. It is easier to collect the samples compared to other biological samples such as tooth and bone.
Fingernail–EPR Dosimetry Protocols

◆ Dose Response Curve Method
  - Sampling of Fingernail Samples
  - Dose Response Curve with Non-irradiated Samples
  - EPR Measurements using Irradiated Samples
  - Dose and Uncertainty Assessment

◆ Additive Dose Method
  - Sampling of Fingernail Samples
  - Addictive Dose Irradiation to Irradiated Samples
  - EPR Measurements using Additionally Irradiated Samples
  - Dose and Uncertainty Assessment
Local exposure accident occurred in semiconductor company using X-ray irradiation devices.

7 workers were exposed to X-ray beam.
Both two protocols were applied for dose assessment to a highly exposed worker.

Estimated MDD was about 2 Gy.

The other workers’ doses were evaluated to be below MDD.
Retrospective Dosimetry Project

- EPR Dosimetry

- Computational Dosimetry
General Dose Assessment

◆ Dose Measurement
  - Personal dosimeters
  - Physical phantom
  - Experimental measurements

◆ Computational Simulation
  - Radiation transport code
  - Human computational phantom
  - Monte Carlo technique
Application in Retrospective Dosimetry

New Approach by Dosimetry Guided Surgery

CT SCAN

FIRST EXERESIS (day 21)

Source

PHANTOM VOXELIZATION

DOSIMETRIC MAP

IAEA

1900 Gy
25 Gy
20 Gy
10 Gy
5 Gy
1 Gy

2000 Gy at skin surface
20 Gy at a depth of 5 cm

Courtesy: IRSN – HIA Percy (France)
ICRP Reference Phantoms

Reference Voxel Phantoms
(ICRP Pub 110)

Mesh-type Reference Phantoms
(being published soon)
Mesh–type Reference Phantoms

Mesh-type Reference Phantoms with Different Postures
(Source from Prof. C. Kim, Hanyang Univ.)
Development of Exposure Scenarios

- Survey of the past radiography accidents in Korea

- Scenarios resulting in overexposure to workers
Exposure Scenarios

- Location of Source Term (Isotopes: Ir-192 and Co-60)

Scenario 1

Scenario 2

Scenario 3

Scenario 4
Dose Coefficients (Scenario 1; 100 Cases)

◆ Conversion from source activity into dose rate (Unit: Sv Bq^{-1} s^{-1})

Scenario 1 (Kneeling Posture)

Scenario 1 (Squatting Posture)
Dose Coefficients (Scenario 2; 700 Cases)

- Conversion from source activity into dose rate (Unit: Sv Bq⁻¹ s⁻¹)

**Scenario 2**
(Standing Posture)

**Scenario 1**
(Walking Posture)
Dose Coefficients (Scenario 3; 410 Cases)

- Conversion from source activity into dose rate (Unit: Sv Bq\(^{-1}\) s\(^{-1}\))

Scenario 3 (Walking Posture)
Dose Coefficients (Scenario 3; 410 Cases)

- Conversion from source activity into dose rate (Unit: Sv Bq\(^{-1}\) s\(^{-1}\))

Scenario 3 (Squatting Posture)
Dose Coefficients (Scenario 4; 686 Cases)

- Conversion from source activity into dose rate (Unit: Sv Bq\(^{-1}\) s\(^{-1}\))

Scenario 4
(Standing Posture)

Anterior-Posterior
Right-Left
Conversion from source activity into dose rate (Unit: Sv Bq\(^{-1}\) s\(^{-1}\))

Scenario 4 (Squatting Posture)
Conclusions
Conclusions

- **Retrospective dosimetry project** performed by KIRAMS was introduced.

- **Rapid and accurate dose assessment** is necessary for management of exposed individuals with high dose level.

- **Various techniques** are available. In the future, the applied protocol will be optimized for the purpose of the rapid and accurate assessment.

- **National/International network** is essential for technical cooperation as well as intercomparison exercise.
Thank you for your attention.

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