10th EURADOS Winter School (AM2017)
"Internal Dosimetry for Radiation Protection and Medicine"
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Internal dosimetry in emergency situations: challenges and recent developments

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Internal dosimetry in emergency situations: challenges and recent developments

- **Radiation emergency exposures** may occur

  - ✓ during the operation of a planned situation
  - ✓ from a malevolent act
  - ✓ from any other unexpected event

  requiring urgent action to prevent or reduce unwanted health effects.

- One priority is **to quickly identify internal exposures and to quantify the doses received by the exposed people**:
  - ✓ nuclear site workers
  - ✓ Emergency workers (including first responders)
  - ✓ population

Internal dosimetry in emergency situations

- First challenge: **to establish an efficient individual monitoring program**
  - ✓ according to the intake scenario and the source term,
  - ✓ with appropriate in vivo and/or in vitro bioassay techniques for a large number of individuals
  - ✓ For a rapid interpretation of monitoring data for dose assessment.

- Initial main concern: **quick identification of people at highest risk (Triage)**
  Second phase: **more reliable dose investigation for the identified individuals with highest exposure**.

Transfer the dosimetric data to decision makers to support **actions**
- **to reduce the risk of stochastic effects,** based on EFFECTIVE DOSE (Sv)
- **to avoid or minimize deterministic effects ,** based on ABSORBED DOSE(Gy)

Internal dosimetry in emergency situations

- According to **EC Council Directive 2013/59/EURATOM:**
  - ✓ emergency occupational exposure must remain if possible below the **limit on the effective dose for occupational exposure (20 mSv/y).**
  - ✓ for situations where this is not feasible, Reference Levels for emergency occupational exposure must be set below an **Effective Dose of 100 mSv.**

- According to **ICRP 109** when the emergency scenario may result in **effective doses >100 mSv,** or when the resulting exposures are very **strongly dominated by the irradiation of a single organ** (e.g. radioiodine in thyroid) ICRP advices to provide reference levels in terms of **organ doses.**

- In case of exposure to a high dose that might lead to deterministic effects, the **absorbed dose weighted by the appropriate Relative Biological Effectiveness (RBE)** should be calculated as defined by ICRP 103

➢ Emergency INTAKE SCENARIO:

✓ early phase: acute intake through inhalation

- Volatile elements including iodine (^{131}I, ^{132}I, ^{133}I, ^{134}I, ^{135}I), cesium (^{134}Cs, ^{136}Cs, ^{137}Cs), tellurium (^{132}Te), and inert gases (e.g. xenon ^{133}Xe).

- Time of intake: exposure to radioactive plume,. highest concentration of the activity in the air. Conservative approach.

- Residents and evacuees in contaminated areas: first concern is internal exposure to radioiodine and thyroid cancer risk (especially for children)

➢ Emergency INTAKE SCENARIO

✓ early phase: acute intake through inhalation (cont.)

- Major contribution of intake: ^{131}**I**, $T_{1/2}$= 8.02 d,. Once incorporated into the human body, radioiodine accumulates in the thyroid.
  Activity measurements of ^{131}I in the thyroid should be performed soon

- Other short-lived radionuclides: ^{132}Te/^{132}I, ^{133}I,…

- ^{134}Cs, ^{137}Cs are easily detected in total body by γ spectrometry (WBC) (longer half life)

✓ **Intermediate phase:** continuous or incidental **ingestion** may contribute to the intake through food chain (difficult to evaluate). Prompt restriction on distribution and consumption of contaminated food and drink is required.

Internal dosimetry in emergency situations

- **In-vivo monitoring** of incorporated radionculides (internal gamma emitters)

  - **On site measurements** (high level of background).
    Field Triage for internal gamma emitters
    - ✓ Mobile units of body counters (national and international support)
    - ✓ Portable detectors NaI(Tl), HPGe, LaBr3 (gamma spectrometry)
    - ✓ Other equipment

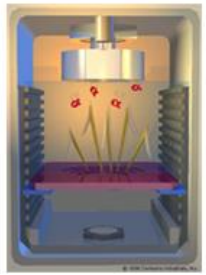
    Objectives: 1) to identify persons with highest internal exposures who require more reliable dose estimation and medical follow-up
    2) reassurance individuals with no significant exposure

  - **Whole Body Counting facilities (WBC)**
    Outside emergency area, lower level of background.
    in vivo monitoring individuals with highest internal exposure detected in the Triage.
    - ✓ Appropriate calibration phantoms for adults and children
    - ✓ Age-dependent efficiency calibration.
    - ✓ Counting geometries adapted for children

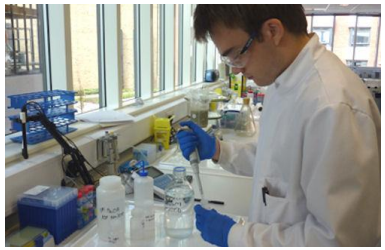
Internal dosimetry in emergency situations

- Individual monitoring . **In-vitro bioassay measurements**:
  - On site analysis: few mobile units available
  - Bioassay laboratories outside emergency area
    - ✓Samples of a big group of exposed people
    - ✓Sample turnaround in routine must be shortened for





- **Intercomparisons on Emergency Bioassay** organized by
  EURADOS WG7,
  REMPAN-WHO (Radiation Emergency Medical Preparedness and Assistance Network),
  GHSI (Global Health Security Initiative Lab. Network)
  PROCORAD Association of radiotoxicology
  .



Objective: to develop methods with sensitivity enough to meet the requirements for **emergency bioassay**.

Internal dosimetry in emergency situations

➢ DOSE ASSESSMENT AND DOSE RECONSTRUCTION

Lessons learned from Fukushima Daiichi NPP accident (11/3/2011). Release of 142.9 pBq of ^{131}I and 12.4 pBq ^{137}Cs to the environment

Measurements at early stage after the accident (Tokonami et al 2012)

1.- **Screening campaign**: ^{131}I activity in the thyroid of 1,149 children <15y old in Iwaki, Kawamata and Iitate on **24-30 March**

- NaI(Tl) scintillation survey meter on the neck
- 1% of children exceeded 0.04 μSv h^{-1}.
- **Max dose rate**: 0.07 μSv h^{-1}, equivalent to a thyroid dose of **35 mSv**

➢ DOSE ASSESSMENT AND DOSE RECONSTRUCTION

Measurements at early stage after the accident (Tokonami et al 2012) cont.

2.- **Thyroid monitoring** of 62 residents and evacuees **12-16 April**, 60 persons from Namie town

- ^{131}I activity measurements in the thyroid with NaI(Tl) scintillation spectrometer at the neck of examinees

- ^{131}I in the thyroid detected in 46 out of the 62 measured persons
- Maximum ^{131}I activity in thyroid of an adult: 1.5 kBq.

- Acute inhalation 15 March (largest release event)

- **Median thyroid equivalent dose: 4.2 mSv (children), 3.5 mSv (adults)** << mean thyroid dose in Chernobyl accident (490 mSv in evacuees).

- **Maximum thyroid doses: 23 mSv for children and 33 mSv for adults**

➢ DOSE ASSESSMENT AND DOSE RECONSTRUCTION

- **Individual Monitoring of population at NIRS WBC (Eunjoo Kim et al 2016)**

  - 74 persons from Fukushima area, monitored **in June–July 2011**
  - 28.8% of adults, 4.5% children with **detectable ^{137}Cs and ^{134}Cs**
  - **No results of ^{131}I > DL**
  - Cs in Urine data: poor correlation with WBC results (Cs in total body)
  - **Activity of ^{137}Cs and ^{134}Cs in the body (WBC): using proper age-dependent calibration efficiency** (BOMAB phantoms family for calibration 5y, 10y and15y old children, adult female and male)

➢ *DOSE ASSESSMENT AND DOSE RECONSTRUCTION*

Individual Monitoring of population at NIRS WBC (Eunjoo Kim et al 2016)

- **Intake scenario and dose assessment:**
  - Acute inhalation 12/03/2011(1st explosion event at NPP)
  - Particle size AMAD= 1 μm (public exposure)
  - Age-dependent retention fractions & dose coefficients (ICRP 119)
  - MONDAL MONDES Software (Ishigure 2004)
  - **$E(50)_{max}$=0.63 mSv (63y old man); $E(50)_{max}$=0.20 mSv (5y old child)**
  - Contribution from ingestion: negligible
- **Reconstruction of early doses from the measurements of Cs:**

  From Tokonami **2012: Intake ratios $^{131}I/^{134}Cs$= 3 – 5 (3.8)**
  Median thyroid equivalent dose: 3.5 mSv,
  Maximum thyroid equivalent dose 84 mSv

Namie Town (E. Kim 2016) Adults :Median thyroid dose 3.5 mSv,; Max 32 mSv

Namie Town adults (Tokonami 2012): Median 3.5 mSv,; Max 33 mSv

Internal dosimetry in emergency situations:

recent developments

Internal dosimetry in emergency situations

- **TMT Handbook** (Rojas-Palma, 2009) provides information and recommendations for **triage, monitoring and treatment** of people exposed to ionising radiation following a malevolent act.

http://www.tmthandbook.org/

Internal dosimetry in emergency situations

- **CATHYMARA Project (EC FP7/ EURATOM OPERRA 2016-2017)**
  "Child and Adult Thyroid Monitoring After Reactor Accident"
  Chair: David Broggio (IRSN, France)

Objective: **optimal monitoring strategies and dose assessment of post accidental ^{131}I in the thyroid of exposed individuals, particularly for children.**

WP2 – Survey on current regulations and recommendations.
WP3 – Intercomparison of WBC Mobile Units and portable detectors (γspectr)
WP4 – Intercomparison for Trained responders (non spectrometric devices)
WP5 – Monte Carlo calculations
WP6– Criteria for dose assessments
WP7– Recommendations and Dissemination of knowledge.

Main outcome: **technical guidelines for large scale post-accidental thyroid monitoring and dose assessments (May 2017)**

Internal dosimetry in emergency situations

- **SHAMISEN Project (EC FP7/ EURATOM OPERRA 2016-2017)**
  Nuclear Emergency Situations. Improvement of Medical And Health Surveillance
  Chair: Elisabeth Cardis (ISGlobal, Spain)

  - ✓ Lessons learned from experiences of exposed population due to radiation accidents (e.g. Fukushima, Chernobyl)
  - ✓ Objective: to develop recommendations for health surveillance of people involved in radiation accidents,
  - ✓ Dose reconstruction in an intermediate to long-term time frame
  - ✓ Involvement of stakeholders and decision makers as well as scientific, medical and non-expert communities
  - ✓ Post accidental epidemiology

Internal dosimetry in emergency situations

- **SHAMISEN Project – Internal Dosimetry (C. Challeton -de Vathaire, D. Franck)**

  Recommendations on individual dose assessment (workers and population)

  - Based on environmental and individual monitoring data taking into account histories of locations, food habits, indoor/outdoor stay,...of exposed individuals

  - Doses during a) emergency phase (the passage of the plume),
    b) the transition phase to a post-accidental situation (counter measures not implemented yet)
    c) the long-term post-accidental phase (residual contamination in the locations affected by the accident)

http://www.isglobal.org/-/shamisen

Internal dosimetry in emergency situations

Project approved : 1st EJP-CONCERT Call . (1.1.2017 – 31.12.2019),

Chair: Wolfgang Raskob (KIT, Germany)

Kick-off meeting: KIT Campus North, Karlsruhe, Germany

CONFIDENCE PROJECT
Coping with uncertainty for improved modelling and decision making in nuclear emergencies

- ✓ **WP1** model improvement & proposing solutions for the operational application

- ✓ **WP2 reduction of uncertainties in dose assessment to improve the picture of the radiological situation and come to a risk estimation** – C.Woda (HMGU)
  - Task 1 is related to environmental monitoring
  - Task 2 is related to individual dose measurements (retrospective dosimetry, internal dosimetry, biological dosimetry)
  - Task 3 is related to risk assessment.

- ✓ **WP3** improvement of radioecological models
- ✓ **WP4** on countermeasures in the transition phase introducing also countermeasures for the late phase
- ✓ **WP5** on social ethical and communication aspects of decision-making
- ✓ **WP6** on decision making
- ✓ **WP7** on education and training

Internal dosimetry in emergency situations

- **Current (and future) developments to improve internal dosimetry in case of radiation emergency exposures (EURADOS SRA)**

  - ✓ Improvement of the calibration of in vivo techniques for children monitoring (including calibration phantoms scaled by age),
  - ✓ more rapid in vitro bioassay methods
  - ✓ better interpretation of monitoring data in case of decorporation therapy
  - ✓ appropriate and validated software for the calculation of committed effective doses to the public (using age dependent dose coefficients) and for the assessment of absorbed doses
  - ✓ application of biodosimetry methods to accidental internal exposures
  - ✓ A better evaluation of the contributions to dose from short-lived radionuclides
  - ✓ the rapid transfer of dosimetric data to decision-makers
  - ✓ effective communication with stakeholders and exposed persons.

THANKS FOR YOUR ATTENTION