The Status and Challenges of External Personal Dosimetry

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Introduction

- 20 years ago
  - Pencil dosemeters
  - Film dosemeters
  - Thermoluminescent dosemeters

Personal dosimetry: measuring operational quantity $H_p(10)$

- Protection quantities
  - Effective dose E
  - Equivalent dose in organs H_T
- Occupational limits are expressed in these quantities
  - No deterministic effects (tissue effects)
  - Limit stochastic effects
- Effective dose E is non-measurable
  - Operational quantities: personal dose equivalent
    - $H_p(d)$ with d: 10, 3, 0,07 mm
- Objective of personal dosimetry:
  - Control legal limits and facilitate ALARA
    - Measuring $H_p(d)$ for all practical situations, independent of energy, direction, type,… with an overall prescribed accuracy
    - Also being practical (weight, ergonomic, costs,…)

Types of dosemeters

- Whole body dosemeter
  - Beta/gamma
  - Neutron
- Extremity dosemeter
  - Ring
  - Wrist
  - Finger stall
- Eye lens dosemeter

- Active – Passive dosemeters
  - Different types of detection mechanism

- Not objective of the presentation to present pro’s and con’s of different techniques

Different passive dosimetry systems used world wide

- Film dosemeter
  - On decline….

Different passive dosimetry systems used world wide

- Thermoluminescent detectors
  - Different materials: LiF:Mg,Ti – LiF:Mg,Cu,P – $Li_2B_4O_7$:Cu - …
  - Different manufacturers: Harshaw, Rados, Panasonic, …

Different passive dosimetry systems used world wide

- Optically Stimulated Luminescence detectors
  - Different materials: Al_2O_3:C, BeO
  - Different manufacturers: Landauer, Dosimetrics

Different passive dosimetry systems used world wide

- Radio Photoluminescence Detectors
  - Glass dosemeters
  - Chiyuda Technology

Size of services is increasing

- In the past: in many countries no national approval of dosimetry services
- Now this is changed: approval procedures are in place in many countries
  - Also recommended in RP160 publication (“Technical Recommendation for individual monitoring”)
  - In BSS: dosimetry service must be approved
- Often: ISO 17025 accreditation is required
- E.g. Belgium:
  - ISO 17025
  - IEC 62387
  - Participate in intercomparisons

Size of services is increasing

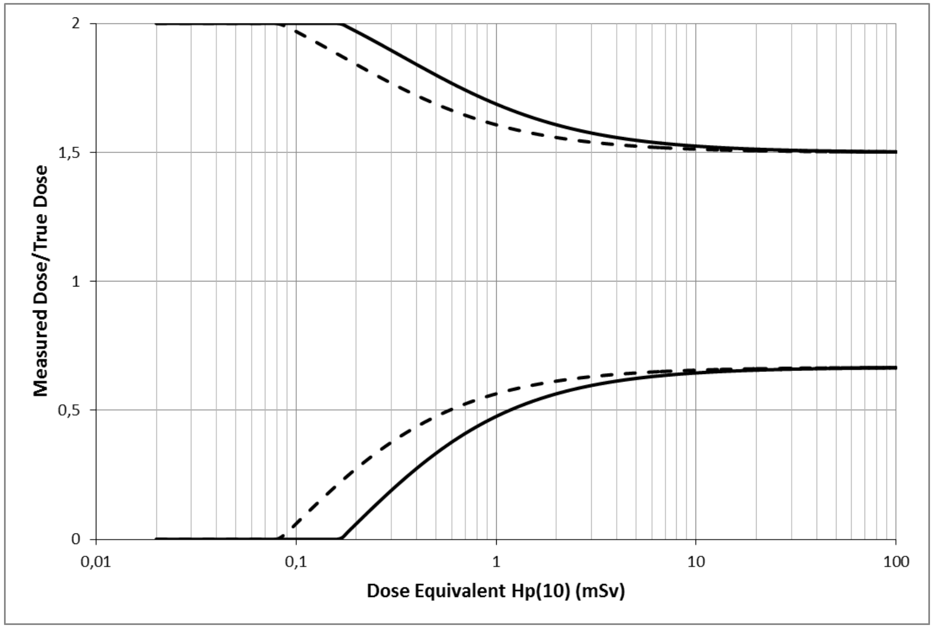
- Such extra requirements can be difficult for smaller services
  - Knowledge can be missing (no scientific collaborator, no scientific background, no literature, no conference participation,…)
  - Also extra costs…
  - E.g. Belgium
    - Cost for Approval
    - Cost for Accredititation
    - Cost for intercomparisons
  - Extra cost of around 6000 Euro per year
    - For large service this is easier to bear…
- Extra competition
  - Large international players seek extension of market share
  - Some countries don't even have any service anymore

Size of services is increasing

- Result
  - Smaller services disappear
    - E.g. Belgium: from 12 to 9 …
  - Or smaller services work in kind of subcontracting of big services
    - With technical support
    - Sometimes like post office, sometimes with reader
- Not necessarily bad evolution, such scale increase
  - More cost effective
  - More knowledge
  - Better tested systems
- This trend will probably continue

Overall accuracy: ICRP75

- Accuracy required:
  - factor 1.5 in either direction for doses near the limit
  - Factor 2.0 for lower doses
  - Trumpet curve
- For neutrons a worse accuracy is expected



Large uncertainties allowed in personal dosimetry

- Factor of 2 is actually not very strict…
- Compare to e.g. gamma spectrometry
- Leads to doubts on performance of dosimetry service by customers
- Most services don't report the uncertainty on the reports
  - What would customer reaction be if on the report:

    "In 1 month 200 µSv ± 200 µSv is measured…."
  - They would mistrust dosemeter service
  - They would pay less attention to the correct use of their dosemeter

Large uncertainties allowed in personal dosimetry

- Why are such large uncertainties allowed?
  - Other uncertainties involved to get to risk assessment…

- $H_p(10)$ is only estimation of E: large uncertainty
  - System of operational quantities is estimation for limiting quantities
  - In case of non-homogeneous irradiations ($H_p(10)$ can underestimate)
  - $H_p(10)$ is not a perfect quantity: see an example of corpulent persons
- From E to risk: large uncertainty (Hiroshima/Nagasaki data)
  - And not personalized!
- So why should dosimetry service do an effort to get a 5% better results with their dosemeter?
  - trust in results would improve
  - Every uncertainty gained is positive

Uncertainty sources

- Sources of uncertainties:
- No dosemeter is perfect for $H_p(10)$
  - Energy and angle of incident radiation
  - Fading, environmental characteristics, individual sensitivity, non-linearity…
- IEC 62387 lays down requirements for type testing: e.g.
  - Coefficient of variation: 5-15%
  - Non-linearity: ~10%
  - Energy/angle: -30% to +70% for E>65 keV
- Also calibration: around 6% uncertainty added
- Largest contribution from energy and angle
  - In workplace, mostly E and angle is not known
- Any improvements in personal dosemeters should merely focus on energy and angle

How well do dosemeters measure $H_p(10)$?

- EURADOS intercomparisons give a good image of performance of (mainly European) services
- IC2012
  - 87 participating services
  - 68% TLD, 14% film, 13% OSL, 6% other (APD, DIS, RPL)
- 1400 irradiated dosemeters
  - 6% of data points outside trumpet curve
  - 79% of services have no outliers
  - 90% of services have maximum 2 outliers (ISO 14146 criterium)
  - Overall mean response= 0.98 compared to reference

- In general: personal dosimetry services have no problems in satisfying trumpet curve

How well do dosemeters measure $H_p(10)$?

- Conclusion: good!
- BUT: in intercomparisons only standard fields are used
  - no mixed fields
  - no other influence factors (like environmental influences)
  - no high energy and high angles
  - Standard fixation on phantom
- No workplace fields….

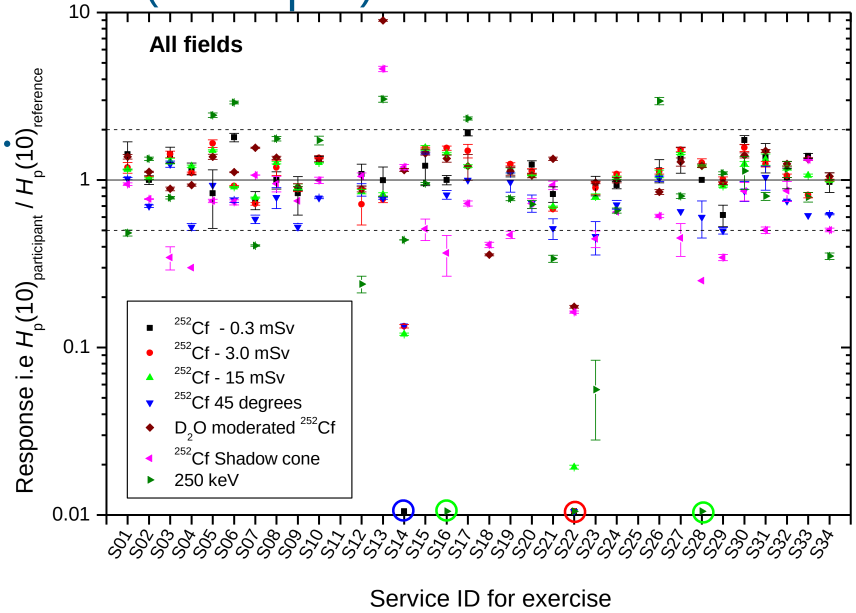
Extremity and neutron: worse results

- EURADOS IC 2009: extremity dosemeters
  - 59 participating services
  - Outliers for gamma irradiations: 10%
  - Outliers for beta irradiations: 35%
- The lower the energy, the worse the result
- For Kr-85: 65% of the results were outside the trumpet curve

- Clearly improvements are needed for low energy and high angles

Extremity and neutron: worse

- EURADOS ICn 2012: neutron dosemeters
  - 34 participating services
  - Two steps were needed
    - Many systems needed information on neutron spectrum
    - First step with very little info
    - Second step with more detailed info
  - Around half of the service could estimate (in step 2) the real dose within a factor of 2
- Clearly improvements are needed …



Extremity and neutron: worse

- Conclusion: certainly a lot of improvements needed for neutrons
  - Energy of the field is still a big influence factor
  - Gamma influence can be strong
  - Low doses are difficult
  - Influence backscatter

Non radiological uncertainties

- Next to radiological uncertainties…
- Loosing dosemeter: all data lost…
- Not wearing correctly
  - Dependent on homogeneity of the field
- Far from body
  - Especially for neutron dosemeters
- Ergonomy is important
- ! Eye lens dosemeter
  - Nobody wants to wear the present eye lens dosemeter
- Also similar problems with ring dosemeters
  - How to measure the maximum dose?

Feedback on doses helps

- More feedback (on-line)
  - Better use and care on dosemeters by workers
- Active personal dosemeters (APD) give more feedback to worker
  - Often used as ALARA or alarm dosemeter
  - Mostly in combination with passive dosemeter as Dose-of-Record
- Present APDs: technologically suited as only dosemeter
  - Reliability is ok
    - Less loss of results if dosemeter fails or gets lost
    - EURADOS study: less results get lost than with passive dosemeters
  - Radiological characteristics are ok
    - Comparable and even better than passive dosemeters
- BUT: approval, QC and calibration important
  - Not stand alone use.... Still need of approved dosimetry service
  - Regular calibrations is needed
  - May be less suited for some fields, like pulsed fields

Feedback on doses helps

- Recent developments: e.g. DIS (Direct Ion Storage) based
  - Dosemeter between passive and active
    - No alarm, no immediate read-out
    - But can be consulted if needed via intermediate device
  - Communication with iPAD, iPhone, pc….
  - No return to dosimetry service for read-out anymore
  - Long stand alone battery life
- BUT: approval, QC and calibration important
  - Not stand alone use…. Still need of approved dosimetry service
  - Regular calibrations is needed

- Will be important in the future…

Reporting level

- APD have a higher sensitivity
  - Show up to 0,1 µSv
  - Passive systems have reporting levels of 50-100 µSv (per month)
- Is not the same as a detection level of 0,1 µSv

- Background subtraction is very important: need to know only the occupational exposure
- ICRP: minimal reporting level:"... should be derived from the duration of the monitoring period and an annual effective dose of no lower than 1 mSv or an annual equivalent dose of about 10% of the relevant dose limit."
- For monthly exchange: 83 µSv
- For daily exchange (APD): 5 µSv (200 working days)

Some examples of background subtraction

- Example: background between 1,5 and 3,0 µSv/day
- For monthly exchange:
  - between 90 and 180 µSv need to be subtracted from dosemeter result
  - If national average used: 130 µSv
  - All doses lower than 50 µSv can be variation of background…
  - Lowest limit of detection (LLD): not better than around 70 µSv/month
  - Specific background per customer: LLD of 30-40 µSv can be achieved
- No need for passive dosemeter to 1 µSv accurate…

Some examples of background subtraction

- Example: background between 1,5 and 3,0 µSv/day
- For daily use (APD):
  - Dependent on how many hours the APD is switched on
  - E.g. 10 hours per day (only during entering zone)
  - between 0,6 and 1,2 µSv needs to be subtracted from dosemeter result
  - If national average used: 0,9 µSv
  - All doses lower than 0,3 µSv can be variation of background…
  - Lowest limit of detection (LLD): not better than around 0,4 µSv/month
  - Specific background per customer: LLD of 0,2 µSv can be achieved
  - Well below ICRP requirements
- But no need for passive dosemeter to 0,01 µSv accurate…

- In the 1975-77: tv series on how it would be in 1999: “Space 1999”

- Conclusion: it is difficult to predict the future….

How will dosimetry look in 20 years?

- Many will still use passive dosemeters, similar as present dosemeters
  - Present dosemeters fulfil requirements, are cost effective
  - What improvements are needed?
    - Maybe decrease requirements for accuracy? To enhance the trust in the dosemeters
    - More active feedback, no more returning of dosemeters, ...
    - Still improvements needed for neutrons, extremity, double dosimetry, eye lens,..., also in ergonomic aspects
    - Due to variation of background: no need for more sensitive detectors
  - $H_p(10)$ is best quantity for dosemeters?
    - Maybe directly DNA lesions? Individual risk assessment?
  - More to computational methods?
    - Maybe no physical dosemeter anymore needed?

<u>So even if all dosemeters fulfil the requirements still exciting developments ahead....</u>

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