A Method for Determining Organ Dose from External Exposure Monitoring Data

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INTRODUCTION

- Organ dose is needed for a compensation decision under the United States Energy Employees Occupational Illness Compensation Program Act (EEOICPA) of 2000.
- To determine organ dose from monitoring data, Dose Conversion Factors (DCFs) are needed.
- Dose Conversion Factors are dependent on:
  - Organ of Interest (Cancer Location)
  - Radiation Monitoring Method
  - Photon Energy
  - Exposure Geometry

METHOD

Monitoring Device Conversion

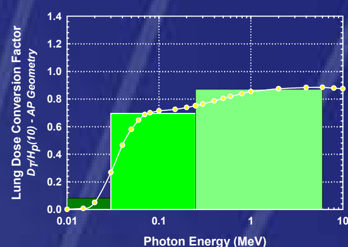
- *Problem:*
  1. ICRP Publication 74 Organ Dose Conversion Coefficients use a non measurable quantity of free-air KERMA.
  2. Measured Radiation Exposure or Dose quantities include:
     - Exposure (Roentgen (R))
     - Ambient Dose Equivalent ($H^*(10)$)
     - Personal Dose Equivalent ($H_p(10)$)
- *Solution:* Organ dose is determined by first converting measured dose to free-air KERMA and then applying DCFs in ICRP 74.

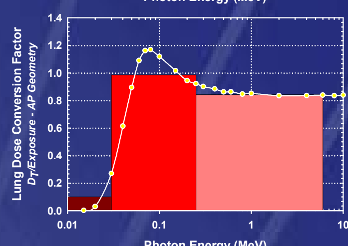
$$DCF(D_{M,Hp(10)\rightarrow D_T}) = \frac{1}{\frac{H_p(10)}{K_a}} \times \frac{D_T}{K_a}$$

Energy Interval Estimation

- *Problem:*
  1. Photon exposures typically cover a wide range of energies.
  2. Organ dose conversion coefficients are tabulated for discrete energies.
  3. Probability of Causation calculations used in the NIOSH Interactive RadioEpidemiological Program (NIOSH-IREP) use three photon energy intervals based on Radiation Effectiveness Factors (REFs).
     - Photons < 30 keV
     - Photons 30-250 keV
     - Photons > 250 keV
- *Solution: Calculate average dose conversion factor by integrating over energy interval and dividing by the energy range.*

$$DCF(D_M, E_{\gamma,0.030-0.250MeV}) = \frac{\int_{0.030}^{0.250} f(E)dE}{Range} = 0.695\ \frac{\text{Lung Dose - Gy}}{\text{H}_\text{p}(10)\text{Gy}}$$





Exposure Geometry

- *Problem:*
  1. Organ dose is dependent on exposure geometry.
  2. Typical work environment can result in multiple exposure geometries. Organ dose conversion coefficients are tabulated for discrete energies.
  3. Of the six exposure geometries presented in ICRP Publication 74, only four are of primary interest in occupational dose.
- *Solution: An average dose conversion factor can be developed using a time weighted average approach.*

$$DCF(D_M, E_\gamma)_W = w_{AP}DCF(D_M, E_\gamma)_{AP} + w_{PA}DCF(D_M, E_\gamma)_{PA} + w_{ROT}DCF(D_M, E_\gamma)_{ROT} + w_{ISO}DCF(D_M, E_\gamma)_{ISO}$$

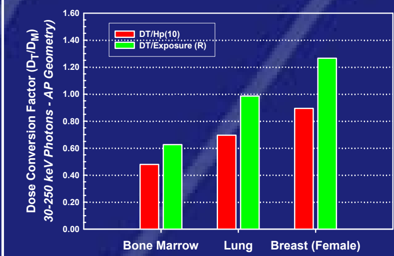
Facility	Job	Geometry	TWA
Uranium Facility	General Laborer	ISO	75%
		AP	25%
	Machinist	AP	75%
		ISO	25%
Reactor	Fuel Handler	AP	50%
		ROT	50%
	Reactor Operator	ROT	75%
		ISO	25%
Chemical Separations	Glovebox Chemist	AP	90%
		ROT	10%
	Security Guard	ROT	50%
		ISO	50%

- **Example of Work Specific Dose Conversion Factor** *(same cancer and energy interval)*
  - Lung Cancer Dose Conversion Factor
    Organ Dose/Exposure (D_T/D_M)
    30-250 keV photons (E_γ)

1. Glovebox Chemist
   $DCF(D_M,E_\gamma)_W$ = 0.965 Gy/100R
2. Security Guard
   $DCF(D_M,E_\gamma)_W$ = 0.702 Gy/100R

RESULTS

- Large variances in Dose Conversion Factors can result due to monitoring methodology.



- Computational methodology should be from most specific information to least.
- Generally, monitoring methodology and energy spectrum are known more precisely than exposure geometry.
- Same methodology can be applied to neutron monitoring.

CONCLUSIONS

- Published information can be used to convert monitored film badge and dosimeter results into organ doses relatively easily.
- Using this methodology the magnitude of the differences between monitored external dose and organ dose can be evaluated and accounted for in external dose reconstruction.

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