ICRP 26/30 Dosimetry System

Learning Objectives

- Identify the parameters of the ICRP 26/30 system and their current use in regulations
- Identify reference sources of internal dose parameters in current regulations
- Demonstrate simple dose calculations and evaluate compliance with current regulations

ICRP 30 Concepts

- In general, internally deposited radionuclides are not uniformly distributed
- Intake vs. Uptake vs. Deposition
- Source organ vs. Target organ
- Organ Dose Equivalent (ODE)
- Effective Dose Equivalent (EDE)
- Annual, Committed and Total Dose Equivalents

ICRP30 Limits

- *Both* the stochastic and non-stochastic limits must be met, i.e.,
- Total CODE < 0. 5 Sv (50 rem) per year

AND

Total CEDE < 0.05 Sv (5 rem) per year

- If w_T for the target organ is < 0.1, the non-stochastic limit will usually apply and take precedence

Example Problems

- A worker receives in a single year an external DDE of 30 mSv and CODE to the lung (w_T = 0.12) of 200 mSv. Have any ICRP30 limits been exceeded?
- A worker received in a single year an external DDE of 30 mSv and CODE to the thyroid (w_T = 0.03) of 600 mSv. Have any ICRP30 limits been exceeded?

Solutions

- Example 1:
  - Total ODE = 30 + 200 = 230 mSv
  - 230 < 500, ok
  - Total EDE = 30 + (200 x 0.12) = 54 mSv
  - 54 > 50, violation
- Example 2:
  - Total ODE = 30 + 600 = 630 mSv
  - 630 > 500, violation
  - Total EDE = 30 + (600 x 0.03) = 48 mSv
  - 48 < 50, ok

Dose Conversion Factors (a.k.a. Dose Coefficients)

- Relate dose in Sv to intake in Bq (multiply by 3.7 to get rem/pCi)
- The dose parameter may be CODE for a specific target organ
- The dose parameter may be CEDE, i.e., the weighted sum of CODE’s
- Computed for each radionuclide, and for different chemical forms of the radionuclide
- Published in Federal Guidance Report #11 (EPA)

Table 2.1, Cont'd.

Nuclide	Class/f_1	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid	Remainder	Effective
		Committed Dose Equivalent per Unit Intake (Sv/Bq)							
Sr-87m	D $3\ 10^{-1}$	$4.54\ 10^{-12}$	$2.74\ 10^{-12}$	$4.47\ 10^{-11}$	$3.29\ 10^{-12}$	$2.33\ 10^{-12}$	$2.11\ 10^{-12}$	$1.38\ 10^{-11}$	**$1.16\ 10^{-11}$**
	Y $1\ 10^{-2}$	$2.48\ 10^{-12}$	$1.43\ 10^{-12}$	$5.81\ 10^{-11}$	$1.66\ 10^{-12}$	$1.04\ 10^{-12}$	$8.54\ 10^{-13}$	$1.03\ 10^{-11}$	**$1.12\ 10^{-11}$**
Sr-89	D $3\ 10^{-1}$	$4.16\ 10^{-10}$	$4.16\ 10^{-10}$	$2.16\ 10^{-9}$	$5.63\ 10^{-9}$	$8.37\ 10^{-9}$	$4.16\ 10^{-10}$	$1.32\ 10^{-9}$	**$1.76\ 10^{-9}$**
	Y $1\ 10^{-2}$	$7.95\ 10^{-12}$	$7.96\ 10^{-12}$	$8.35\ 10^{-8}$	$1.07\ 10^{-10}$	$1.59\ 10^{-10}$	$7.96\ 10^{-12}$	$3.97\ 10^{-9}$	**$1.12\ 10^{-8}$**
Sr-90	D $3\ 10^{-1}$	$2.64\ 10^{-9}$	$2.64\ 10^{-9}$	$3.73\ 10^{-9}$	$3.36\ 10^{-7}$	**$7.27\ 10^{-7}$**	$2.64\ 10^{-9}$	$3.36\ 10^{-9}$	$6.47\ 10^{-8}$
	Y $1\ 10^{-2}$	$2.69\ 10^{-10}$	$2.69\ 10^{-10}$	$2.86\ 10^{-6}$	$3.28\ 10^{-8}$	$7.09\ 10^{-8}$	$2.69\ 10^{-10}$	$5.73\ 10^{-9}$	**$3.51\ 10^{-7}$**
Sr-91	D $3\ 10^{-1}$	$6.41\ 10^{-11}$	$4.45\ 10^{-11}$	$9.21\ 10^{-10}$	$1.23\ 10^{-10}$	$1.14\ 10^{-10}$	$4.08\ 10^{-11}$	$3.33\ 10^{-10}$	**$2.52\ 10^{-10}$**
	Y $1\ 10^{-2}$	$5.65\ 10^{-11}$	$1.74\ 10^{-11}$	$2.13\ 10^{-9}$	$2.23\ 10^{-11}$	$1.27\ 10^{-11}$	$9.64\ 10^{-12}$	$5.78\ 10^{-10}$	**$4.49\ 10^{-10}$**
Sr-92	D $3\ 10^{-1}$	$3.03\ 10^{-11}$	$2.44\ 10^{-11}$	$7.12\ 10^{-10}$	$3.68\ 10^{-11}$	$2.56\ 10^{-11}$	$2.19\ 10^{-11}$	$2.25\ 10^{-10}$	**$1.70\ 10^{-10}$**
	Y $1\ 10^{-2}$	$1.02\ 10^{-11}$	$6.49\ 10^{-12}$	$1.05\ 10^{-9}$	$6.98\ 10^{-12}$	$4.36\ 10^{-12}$	$3.92\ 10^{-12}$	$2.90\ 10^{-10}$	**$2.18\ 10^{-10}$**

Annual Limit on Intake (ALI)

- Defined as the dose limit divided by the dose conversion factor
- Dose limit may be either stochastic (SALI) or non-stochastic (NALI)
- Different ALI’s for inhalation and ingestion
- Only one significant figure
  - Example: Cs-137
  - 0.05 Sv/8.6×10^{-9} Sv/Bq = 6×10^{8} Bq

Some ALI's of Interest in Microcuries

Radionuclide	ALI (inhalation)	ALI (ingestion)
H-3	80,000	80,000
P-32	400	600
Co-60	30	200
Sr-90	4	400
Cs-137	200	100
Ra-226	0.6	2
U-238	0.8	200
Pu-239	0.006	0.8

Derived Air Concentration (DAC)

- The DAC is the ALI divided by the volume of air breathed in a year by a worker
- Breathing rate = 20 liters per minute
- 20L x 60 x 40 x 50 = 2400 m^3
- DAC's are in Bq/m^3 or $\mu Ci/cm^3$
- There are separate DAC's for submersion (noble gases)

DAC-hours

- If we assume constant, standard breathing rate, we can compute intake from DAC-hour values
- DAC is based on 2000 working hours per year, so 2000 DAC-hours = 1 ALI
- Can then compute dose from DAC-hours, as fraction of ALI
- Can correct for respiratory protection,if used
- But remember that ALI is based on more restrictive of stochastic or non-stochastic limit when computing dose (CEDE or CODE)

Some DAC's of Interest

Radionuclide	DAC, MBq/m^3	DAC, $\mu Ci/cm^3$
H-3	0.8	2×10^{-5}
P-32(D)	0.01	4×10^{-7}
P-32(W)	0.006	2×10^{-7}
Co-60	5×10^{-4}	1×10^{-8}
Sr-90	6×10^{-5}	2×10^{-9}
Pu-239	1×10^{-7}	3×10^{-12}
Submersion		
H-3	2×10^{4}	0.5
Ar-41	0.1	3×10^{-6}
Xe-133m	5	1×10^{-4}

	Inhalation			Ingestion	
		ALI	DAC		ALI
Nuclide	Class/f_1	MBq	MBq/m^3	f_1	MBq
Cobalt					
Co-55	W 0.05	100	0.04	0.05	40
17.54 h	Y 0.05	100	0.04	0.3	60
Co-56	W 0.05	10	0.005	0.05	20
78.76 d	Y 0.05	7	0.003	0.3	20
Co-57	W 0.05	100	0.04	0.05	300
270.9 d	Y 0.05	20	0.01	0.3	200
Co-58	W 0.05	40	0.02	0.05	60
70.80 d	Y 0.05	30	0.01	0.3	50
Co-58m	W 0.05	3000	1	0.05	2000
9.15 h	Y 0.05	2000	1	0.3	2000
Co-60	W 0.05	6	0.003	0.05	20
5.271 y	Y 0.05	1	$5\ 10^{-4}$	0.3	7
Co-60m	W 0.05	$1\ 10^{5}$	60	0.05	$4\ 10^{4}$
10.47 m	Y 0.05	$1\ 10^{5}$	40	0.3	$4\ 10^{4}$
Co-61	W 0.05	2000	1	0.05	700
1.65 h	Y 0.05	2000	0.9	0.3	800
Co-62m	W 0.05	6000	3	0.05	1000
13.91 m	Y 0.05	6000	2	0.3	1000

Nuclide	Class/f_1	Inhalation ALI μCi	Inhalation DAC $\mu Ci/cm^3$	Ingestion f_1	Ingestion ALI μCi
Cobalt					
Co-55	W 0.05	3000	$1\ 10^{-6}$	0.05	1000
17.54 h	Y 0.05	3000	$1\ 10^{-6}$	0.3	2000
Co-56	W 0.05	300	$1\ 10^{-7}$	0.05	500
78.76 d	Y 0.05	200	$8\ 10^{-8}$	0.3	400
Co-57	W 0.05	3000	$1\ 10^{-6}$	0.05	8000
270.9 d	Y 0.05	700	$3\ 10^{-7}$	0.3	4000
Co-58	W 0.05	1000	$5\ 10^{-7}$	0.05	2000
70.80 d	Y 0.05	700	$3\ 10^{-7}$	0.3	1000
Co-58m	W 0.05	$9\ 10^{4}$	$4\ 10^{-5}$	0.05	$6\ 10^{4}$
9.15 h	Y 0.05	$6\ 10^{4}$	$3\ 10^{-5}$	0.3	$7\ 10^{4}$
Co-60	W 0.05	200	$7\ 10^{-8}$	0.05	500
5.271 y	Y 0.05	30	$1\ 10^{-8}$	0.3	200
Co-60m	W 0.05	$4\ 10^{6}$	0.002	0.05	$1\ 10^{6}$
10.47 m	Y 0.05	$3\ 10^{6}$	0.001	0.3	$1\ 10^{6}$
Co-61	W 0.05	$6\ 10^{4}$	$3\ 10^{-5}$	0.05	$2\ 10^{4}$
1.65 h	Y 0.05	$6\ 10^{4}$	$2\ 10^{-5}$	0.3	$2\ 10^{4}$
Co-62m	W 0.05	$2\ 10^{5}$	$7\ 10^{-5}$	0.05	$4\ 10^{4}$
13.91 m	Y 0.05	$2\ 10^{5}$	$6\ 10^{-5}$	0.3	$4\ 10^{4}$

MPC for Water

- The occupational MPC for water equals the ALI divided by the annual water intake
- 1.1 L/day x 5 x 50 = 275 L
- MPC = ALI/0.275 m^3
- Any MPC may be derived from ALI and the appropriate dose limit
  - eg, SDWA limit = 4 mrem/yr
  - MPC = $8x10^{-4}$ ALI/0.730 m^3 (If ALI based on stochastic limit)

Things to Remember
about ALI's and DAC's

- Different ALI's for inhalation and ingestion
- ALI is based on more restrictive of stochastic or non-stochastic limit
- ALI and DAC depend on chemical form of radionuclide (solubility class)
- Do not confuse volume of air breathed (2400 m^3) with hours worked (2000); 1 ALI = 2000 DAC-hours
- DAC based on submersion for noble gases

Example Problems

- The ALI for Co-60 is 30 μCi. Assume the lung is the only organ receiving significant dose. What is the CEDE from an intake of 15 μCi?
- An accelerator worker is involved in an incident such that he receives the following exposures: 20 mSv external DDE; 200 mSv to lens of eye; 900 DAC-hours to tritium; 300 DAC-hours to Cs-137.
  - Have any regulatory limits been exceeded?

Solutions

- 15/30 = 0.5 ALI
  - w(lung) = 0.12, so based on stochastic limit
  - 0.5 x 50 mSv = 25 mSv CEDE
- DDE = 20 mSv
  - Both H-3 and Cs-137 irradiate whole body uniformly, so ALI based on stochastic limit 900 + 300 = 1200 DAC-hours
  - 1200/2000 x 50 mSv = 30 mSv CEDE
  - Total EDE = 20 + 30 = 50, ok

BUT: limit for lens of eye = 150 mSv, so a limit was exceeded

Another Solution

- Use sum rule:
  - Intake (1)/ALI(1) + intake (2)/ALI(2) + ... + DDE/L < or = 1.0

  Alternately:
  - DAC-h(1)/2000 + DAC-h(2)/2000 + ... + DDE/L < or = 1.0
  - 900/2000 + 300/2000 + 2/5 = 0.4 + 0.15 + 0.40 = 1.0 ok, BUT still exceeds separate lens of eye limit