

CEMP TRAINING SESSION 15-17 JULY 2013

RADIATION UNITS OF MEASUREMENT

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2013 Training Session

Activity Units

Disintegrations Per Unit Time

- Traditional (US) unit is Curie
 - 1 Ci = 3.7×10^{10} dps (dis/sec)
 - 1 Ci = 2.22×10^{12} dpm (dis/min)
 - 1 Ci = 1×10^{12} pCi
 - 1 Ci = 37 GBq (G= 10^9)
 - International unit is Becquerel
 - 1 Bq = 1 dps = 2.70×10^{-11} Ci
 - 1 GBq = 0.0270 Ci

Occupational Dose Equivalent Limits

- **General Public**
100 mrem/yr
- **Any Occupational Worker (unmonitored)**
100 mrem/yr
- **Radiation Worker (monitored)**
5,000 mrem/yr = 5 rem/yr

DOE & USNRC Occupational Dose Limits

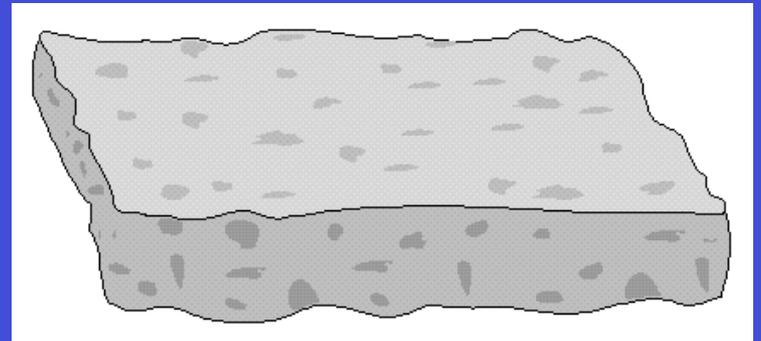
Whole Body	5	rem per yr
Lens of Eyes	15	rem per yr
Extremities	50	rem per yr
Skin	50	rem per yr
Organ or Tissue	50	rem per yr
Unborn Child	0.5	rem pregnancy
US Background	0.62	rem per yr ~ 2 mrem per day

Emergency Dose Limits

- Protecting property if 5 rem not practical
 - **10 rem**
- Lifesaving or protection of small population if dose limit not practical:
 - **25 rem**
- Lifesaving or protection of large population (volunteer basis for person aware of risk)
 - **> 25 rem**

Absorbed Dose

- Energy deposited by any form of ionizing radiation in a unit mass of material
- Roentgen Absorbed Dose (rad)
- Gray (Gy)
- $1 \text{ Gy} = 100 \text{ rad}$



US Radiation Symbol - Radioactivity



IAEA Radiation Symbol - Radioactivity



Ionizing Radiation Dose Ranges (Rem)



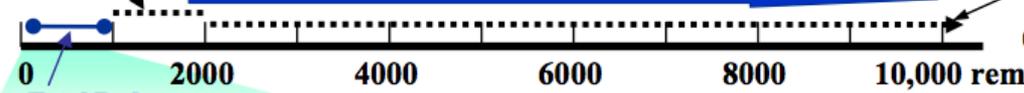
Office of Science
U.S. DEPARTMENT OF ENERGY

Whole body, acute: G-I destruction; lung damage; cognitive dysfunction (death certain in 5 to 12 days)*

Cancer Radiotherapy: total dose to tumor

Whole body, acute: cerebral/vascular breakdown (death in 1-5 days)*

Life Span Study (A-bomb survivors)



Whole body, acute: circulating blood cell death; moderate G-I damage (death probable in 2-3 weeks)*

Whole body, acute: marked G-I and bone marrow damage (death probable in 1-2 weeks)*

Estimated dose for 3-yr Mars mission

Human LD₅₀ range, acute exposure with **no** medical intervention (50% death in 3-6 weeks)*

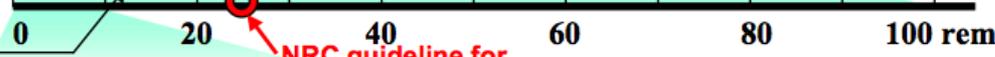
Human LD₅₀ range, acute exposure with **medical intervention**

*Note: Whole body acute prognoses assume **no** medical intervention.)

Cancer Epidemiology

Evidence for small increases in human cancer above 10 rem acute exposure, 20 rem chronic exposure

Typical mission doses on Int. Space Station (ISS)



NRC guideline for lifesaving ~ 25 rem

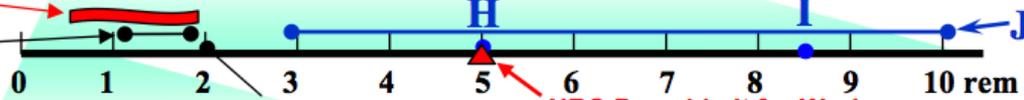
Medical Diagnostics, rem

A- Chest x-ray (1 film)	0.01
B- Dental oral exam	0.16
C- Mammogram	0.25
D- Lumbosacral spine	0.32
E- PET	0.37
F- Bone (Tc-99m)	0.44
G- Cardiac (Tc-99m)	0.75
H- Cranial CT (MSAD) (multiple scan average dose)	5
I- Barium contrast G-I fluoroscopy (2 min scan)	8.5
J- Spiral CT	3 - 10

"Radiological Emergency" guidelines for public relocation

DOE Low Dose Program

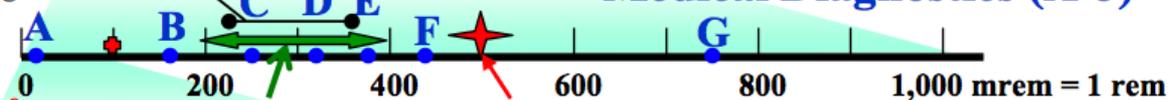
"Full-body CT screening" (one scan)



NRC Dose Limit for Workers = 5 rem/yr = 50 mSv/yr

Typical annual doses for commercial airline flight crews
DOE administrative control = 2 rem/yr = 20 mSv/yr

Medical Diagnostics (A-J)



Cleanup criteria for site decommissioning/license termination 25 mrem/yr

Natural background, average ≈ 300 mrem/yr (includes radon)

Temporary "Special Case" annual Public Limit (NRC, DOE)

Regulations & Guidelines (~ four orders of magnitude)

Round-trip NY to London

NCRP "Negligible Dose"

ANSI standard N43.17 Personnel scanner, max = 25 mrem/yr

NRC Dose Limit for Public 100 mrem/yr = 1 mSv/yr (DOE, ICRP, NCRP)

LD₅₀ = Lethal Dose to 50% (the acute whole body dose that results in lethality to 50% of the exposed individuals)

Absorbed dose: 100 rad = 1 Gray
Dose equivalent: 100 rem = 1 Sievert
100 mrem = 1 mSv

(Chart compiled by NF Metting, Office of Science DOE/BER; 24Jan2005, "Orders of Magnitude") (1 rem = 1 rad for x- and gamma-rays)

Note: This chart was constructed with the intention of providing a simple, user-friendly, "order-of-magnitude" reference for radiation quantities of interest to scientists, managers, and the general public. In that spirit, most quantities were expressed in the more commonly used radiation protection unit, the rem (or Sievert, 2nd page), and medical doses are not in "effective" dose. It is acknowledged that the decision to use one set of units does not address everyone's needs. Disclaimer: Neither the United States Government nor any agency thereof, nor any of its employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information disclosed.

TABLE : DOSE-LIMITING RECOMMENDATIONS OF STANDARDS-SETTING BODIES; DOSES IN REMS*

Type of exposure-group	EPA (1987)	NCRP (1971)	ICRP (1977)	ICRP (1990)
Occupational Exposure				
Whole body prospective	5/yr	5/yr	5/yr	2/yr averaged over 5 yrs
retrospective	—	10–15 any year	—	Max. 2/yr
to N years of age	100 total career	5($N-18$)	—	
Skin		15/yr	(see text)	50
Hands	50/yr	75/yr; 25/qtr	(see text)	50
Forearms	—	30/yr; 10/qtr	(see text)	
Gonads	5/yr	5/yr	(see text)	
Lens of eye	15/yr	5/yr	(see text)	15
Thyroid	—	15/yr	(see text)	
Any other organ	50/yr	15/yr; 5/qtr	(see text)	
Pregnant women	0.5 gestation	0.5 gestation	‡	
General population				
Individual	0.1/yr	0.5/yr	0.5/yr	0.1/yr
Average	—	5/30 yrs	—	

*Based on EPA notice in Federal Register, 46 FR 7836, 1981; NCRP report 39, 1971; ICRP report 26, 1977; ICRP report 60, 1990.

†Several alternative standards proposed.

‡Less than 0.3 times normal occupational dose from discovery of pregnancy through gestation.

Personal Dosimeter Alarming Gamma Dose & Dose Rate 100 nSv/hr-10 Sv/hr

Ludlum Model 25 Series small-sized personal dosimeter automatically alarms if dose rate or accumulated dose (0-19.9Sv) setpoint exceeded

Audible signal & bright, blinking red light.
Displays time remaining before dose limit exceeded at current dose rate

Worn on belt, lanyard, or armband

With R or Sv units and USA certification
Model Display Range Intrinsic Safety Part

Typical Ranges
0.01 mR/hr - 1,000 R/hr
100 nSv/hr - 10 Sv/hr



Gamma Field Measurements (0-50 $\mu\text{Sv/hr}$ or 0-5000 $\mu\text{R/hr}$)

**Ludlum Model 19 gamma μR meter
Internal 2.5cm-Dx2.5cm (1x1 in) NaI
Range of 0-50 $\mu\text{Sv/hr}$ (0-5000 $\mu\text{R/hr}$)**

**Aluminum cast instrument housing
with separate battery compartment**

Front panel controls include

- rotary switch for 5-decade range**
- instrument shut-off,**
- audio on/off switch**
- fast/slow response switch**
- push buttons activates meter lamp**
- count reset**
- highvoltage display**
- battery test**

**Alarm light on front panel with audio
signal**



Alpha/Beta Contamination Surveying

Model 2360 survey meter & Model 43-93, 100 cm² alpha/beta detector

Measure alpha and beta as separate
counts and data log results

2360 meter analog/digital unit with
ratemeter, scaler, data logging

Detector ZnS(Ag) - 0.254 mm (0.01 in)
thick plastic scintillator

Background typically < 3 cpm alpha
< 300 cpm beta

Efficiencies (4π)

20% - ²³⁹Pu

15% - ⁹⁹Tc

20% - ⁹⁰Sr/Y



Alpha Sample Counter

**Model 2000 Scaler Counter with
Model 43-10 Detector Alpha
counting system**

**Scaler reading on digital, 6-digit LED readout
Count 0.1 - 999 mins (or secs)**

**RS-232 port connects to PC for recording,
control or printer**

**Model 43-10 sample head holds 5.1 cm (2 in)
diameter samples**

**ZnS(Ag) detector background < 3 cpm
4 π efficiency 37% for Pu-239**



Alpha/Beta/Gamma Measurement (0-500 kcpm) Model 3 analog ratemeter with Model 44-9 GM pancake detector

Front panel controls has rotary switch

- four-decade range
- instrument shut-off
- battery test
- audio on/off switch
- fast/slow response switch
- count reset button

GM pancake halogen quenched with
5 sqcm window & protective screen

Typical efficiencies

- 5% - ^{14}C (beta)
- 22% - $^{90}\text{Sr}/^{90}\text{Y}$ (beta – gamma)
- 19% - ^{99}Tc (beta – gamma)
- < 1% - $^{99\text{m}}\text{Tc}$ (beta – gamma)
- 32% - ^{32}P (beta)
- 15% - ^{239}Pu (alpha)



Hand & Feet Contamination Monitoring

Model 4906AB industrial duty alpha beta monitoring system for hands & feet

Color, touch-screen LCD system

Displays status & points of potential contamination.

6 gas-flow proportional detectors activated by optical switches

Alarms annunciate locally
Built-in ethernet interface to connect to network



Neutron Measurements (0-100 mSv/hr)

**Model 12- 4 Neutron Dose Rate
Instrument**

**Range 0-100 mSv/hr (0-10 rem/hr)
for neutrons - thermal to 12 MeV**

**Detector 22.9 cm (9.0 in) ^3He tube
gamma background reject
<10 cpm to 100 mSv/hr (10 R/hr)**

**Four-decade analog meter with
separate battery compartment**

Front panel controls

- four decade range
- instrument shut-off and battery test
- audio on/off switch fast/slow count
- switch count reset
- high-voltage test push-button

