



# Radiation Dose

One of the most confusing things about understanding radiation effects is visualizing “how much” radiation is involved. It is very difficult to keep the units which measure radiation straight. A number describing the amount of radiation means nothing without evaluating the units, but this is not easy.

For example...

# ...try to match the letter with the amount of radiation involved in each example

- Amount of potassium 40 in the body
- Dose to Atomic bomb survivors
- You can safely hold this amount of alpha radiation
- One coast to coast flight
- A diagnostic X-ray

A. Billions of becquerels

B. About 250 picocuries

C. 2-10,000 millirem

D. 0-5 Gy

E. 2 millirads

(Answers: B, D, A, E, C... confusing isn't it?)

# Commonly Used Radiation Units

Each of these units has a different technical meaning. All are used by experts to talk about radiation. With so many terms, you can see why it is important to know what the unit means when you are evaluating radiation information.

RAD

REM

Gray

Sievert

Curie

Becquerel

Absorbed dose (Gray or rad)  
Average dose  
Organ dose  
Dose commitment  
Collective dose  
Effective dose (Sievert or rem)  
Committed effective dose  
Equivalent dose  
Collective equivalent dose  
Committed equivalent dose  
Uniform equivalent dose  
Dose equivalent  
Collective dose equivalent  
Ambient dose equivalent  
Directional dose equivalent  
Individual dose equivalent  
Individual dose equivalent, penetrating  
Individual dose equivalent, superficial  
Dose and dose-rate effectiveness factor  
Man-gray  
Man-sievert  
Tissue weighting factor  
Relative biological effectiveness (RBE)  
Quality factor (Q)  
Fatality probability coefficient  
Nominal fatality probability coefficient  
Radiation weighting factor ( $w_R$ )  
Linear energy transfer (LET)  
Radioactivity (Becquerel or curie)

# Understanding Radiation Units

## Activity

The number of times each second a radioactive material decays and releases radiation.

## Dose (Absorbed)

The amount of radiation energy absorbed into a given mass of tissue.

## Dose (Equivalent)

Measures the energy per unit mass times adjustments for the type of radiation involved (quality factor) and the biological response in the tissue (a weighting factor).  
Equivalent dose converts dose into a measure of risk.

# Understanding Radiation Units

## Activity

- Disintegration/sec=1 **Becquerel (Bq)**
- 37 billion Bq = 1 curie

## Dose (Absorbed)

- 1 joule/kg=1 **Gray(Gy)**
- 1Gray=100 rad =100,000 mrad

## Dose (Equivalent)

- Gray x quality factors= **Sievert (Sv)**
- 1 Sievert =100 rem =100,000 mrem

Standard Units

S.I. Units

## ACTIVITY

# How much is a picocurie (pCi)?

- Many times the media reports excess radiation in picocuries. It takes 1,000,000,000,000 pCi to make 1 Curie. A becquerel is 1 disintegration/second. It takes 27 pCi to make one Bq, so a pCi represents less radioactivity than a Bq and results in very, very little dose.

## ACTIVITY

# How much is a Becquerel(Bq)?

- The natural  $^{40}\text{K}$  activity in the body of an adult human of normal weight is 4000-6000 Bq.
- There is an average of about 50 Bq per cubic meter of air inside a home from radon.
- Even though a  $^{60}\text{Co}$  source of strong gamma radiation containing billions of Bq can kill you if you are standing 5 meters from it, it is harmless at a distance of 100 meters.
- A Bq has 27 times more disintegrations than a pCi, but is still a very small amount of radiation.

## ABSORBED DOSE

# How much radiation is an X-ray?

- An average chest X-ray may give a dose of 10 millirads. This is the same as 0.01 rads or 0.0001 Gray.
- A millirad is comparatively small. Average normal background level of radiation is 370 mrad/year.
- One Gray is a relatively large amount of radiation. If 3-4 Gray are delivered over a short time to the whole body, they can be deadly.

## EQUIVALENT DOSE

# What is equivalent dose?

Different types of radiation behave in different ways. In order to compare the amount of risk or biological change that occurs, quality factors are introduced.

**For example:**

- The damage produced by 1 Gy of **x-radiation** is equal to that produced by 1 Gy of gamma radiation. Thus, gamma radiation has a quality factor of 1 or  $1 \text{ Gy gamma rays} \times 1 = 1 \text{ Sv}$ .
- The damage produced by 20 Gy of **x-radiation** is equal to that from 1 Gy of **alpha radiation**. Alpha radiation has a quality factor of 20 or  $1 \text{ Gy of alpha radiation} \times 20 = 20 \text{ Sv}$ .
- Quality factors for other types of radiation are between 1 & 20.

## EQUIVALENT DOSE

# Radiation Weighting Factors

| Type and Energy Range  | Weighting Factor |
|--|------------------|
| X and $\gamma$ rays, electrons, positrons and muons              | 1                |
| Neutrons <10 keV   | 5                |
| Neutrons 10 keV to 100 keV                                       | 10               |
| Neutrons >10 keV to 2 MeV  | 20               |
| Neutrons > 2 MeV to 20 MeV                                       | 10               |
| Neutrons >20 MeV   | 5                |
| Protons, other than recoil protons and energy >2 MeV             | 2                |
| Alpha particles, fission fragments, nonrelativistic heavy nuclei | 20               |

## EQUIVALENT DOSE

# Tissue Weighting Factors

| <b>0.01</b>         | <b>0.05</b>      | <b>0.12</b>        | <b>0.20</b>   |
|---------------------|------------------|--------------------|---------------|
| <b>Bone surface</b> | <b>Bladder</b>   | <b>Bone Marrow</b> | <b>Gonads</b> |
| <b>Skin</b>         | <b>Breast</b>    | <b>Colon</b>       |               |
|                     | <b>Liver</b>     | <b>Lung</b>        |               |
|                     | <b>Esophagus</b> | <b>Stomach</b>     |               |
|                     | Thyroid          |                    |               |
|                     | Remainder        |                    |               |

## EQUIVALENT DOSE

# How much is a Sievert (Sv)?

Radiation induced cancers have been seen in the atomic bomb survivors exposed to as low as 0.2 Sieverts.

A Sievert is a relatively large amount of radiation.

The annual background radiation exposure for a typical American is 0.0037 Sv, 3.7 mSv or 370 millirem.

$$1 \text{ Sv} = 1000 \text{ mSv} = 100,000 \text{ mrem}$$

## EQUIVALENT DOSE

# How much is a millirem (mrem)?

- The annual background radiation exposure for a typical American 370 mrems.
- The average dose from watching color TV is 2 mrem each year.
- The granite from Grand Central Station exposes its employees to 120 mrem of radiation each year
- People in Denver receive 50 mrem more each year than those in LA because of the altitude.
- The nuclear industry contributes to less than 1 mrem/year to an individual's background radiation.
- A millirem is a small unit of measure.

# A millirem measures the amount of radiation energy absorbed into the tissue.

1000 millirems = 1 rem = 0.01 Gy

1 Gy = 1 Joule / kg times a quality factor to adjust for the type of radiation (alpha, beta, or gamma)

**But how much energy is that?**

1 Joule = 0.24 calorie

1 calorie = amount of energy to heat up 1 milliliter of water 1 degree C.

**Therefore 4.16 Gy would produce the same amount of energy it would take to heat up 1 milliliter of water 1 degree C.**

# Dose-rate

The effectiveness of the dose is dependent on the dose-rate

| Dose                      | Dose -Rate                              |                              |
|---------------------------|---|------------------------------|
| 1 bottle of Aspirin       | Over 50 seconds??<br>Or over 50 years?? | Death<br>Minimal health risk |
| or                        |   |                              |
| 250,000 mrem of Radiation | Over 50 seconds??<br>Or over 50 years?? | Death<br>Minimal health risk |