# Supplement to Radon Radio Theatre Program

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with

**Ms. Chrystine Kelley**
Colorado Department of Public health and Environment
**Dr. Leo Moorman**
Radon Home Measurement & Mitigation
Fort Collins, Colorado
**Hosted by: Douglas L. Kladder**
Director, CERTI

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*The Center for Environmental Research and Technology provides educational programs for environmental health professional, with a special emphasis in supporting the radon professional.*

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# Units Used to Express Radiation Dose

From: National Academy of Sciences:
Health Risks from Exposure to Low Levels of Ionizing Radiation:
BEIR VII Phase 2 (2006)

Radiation exposures are measured in terms of the quantity *absorbed dose*, which equals the ratio of energy imparted to the mass of the exposed body or organ. The unit of absorbed dose is joules per kilogram (J/kg). For convenience this unit has been given the special name gray (Gy).

Ionizing radiation can consist of electromagnetic radiation, such as X-rays or gamma rays (γ-rays), or of subatomic particles, such as protons, neutrons, and α-particles. X- and γ-rays are said to be sparsely ionizing, because they produce fast electrons, which cause only a few dozen ionizations when they traverse a cell. Because the rate of energy transfer is called *linear energy transfer* (*LET*), they are also termed *low-LET* radiation; low-LET radiations are the subject of this report. In contrast, the heavier particles are termed *high-LET* radiations because they transfer more energy per unit length as they traverse the cell.

Since the high-LET radiations are capable of causing more damage per unit absorbed dose, a weighted quantity, *equivalent dose*, or its average over all organs, *effective dose*, is used for radiation protection purposes. For low-LET radiation, *equivalent dose* equals *absorbed dose*. For high-LET radiation—such as neutrons, α-particles, or heavier ion particles—*equivalent dose* or *effective dose* equals the *absorbed dose* multiplied by a factor, the *quality factor* or the *radiation weighting factor* (see Glossary), to account for their increased effectiveness. Since the weighting factor for radiation quality is dimensionless, the unit of *equivalent dose* is also joules per kilogram. However, to avoid confusion between the two dose quantities, the special name sievert (Sv) has been introduced for use with *equivalent dose* and *effective dose*.

Although the BEIR VII report is about low-LET radiation, the committee has had to consider information derived from complex exposures—especially from atomic bomb radiation—that include a high-LET contribution in addition to low-LET radiation. A *weighted dose*, with a weight factor that differs from the quality factor and the radiation weighting factor, is employed in these computations. The unit sievert is likewise used with this quantity.

Whenever the nature of the quantity is apparent from the context, the term *dose* is used equally in this report for *absorbed dose*, *equivalent dose*, *effective dose*, and *weighted dose*. With regard to risk assessment, reference is usually to the *equivalent dose* to specified organs or to the *effective dose*. The unit sievert is then used, although absorbed dose and equivalent dose are equal for low-LET radiation. In experimental radiation biology and radiotherapy, exact specification of absorbed dose is required and the dose values are frequently larger than in radiation protection considerations. With reference to those fields, therefore, use is made of absorbed dose and the unit is gray.

The Public Summary refers to radiation protection, and the dose therefore is given as sieverts throughout that chapter (for a more complete description of the various dose quantities and units used in this report, see the Glossary and the table below).

TABLE 1 Units of Dose

| Unit[a] | Symbol | Conversion Factors |
|---|---|---|
| Becquerel (SI) | Bq | 1 disintegration/s = $2.7 \times 10^{-11}$ Ci |
| Curie | Ci | $3.7 \times 10^{10}$ disintegrations/s = $3.7 \times 10^{10}$ Bq |
| Gray (SI) | Gy | 1 J/kg = 100 rads |
| Rad | rad | 0.01 Gy = 100 erg/g |
| Sievert (SI) | Sv | 1 J/kg = 100 rem |
| Rem | rem | 0.01 Sv |

NOTE: Equivalent dose equals absorbed dose times *Q* (quality factor). Gray is the special name of the unit (J/kg) to be used with absorbed dose; sievert is the special name of the unit (J/kg) to be used with equivalent dose.

# Conversion Factors and Abbreviations

## Conversion factors and abbreviations for various physical quantities Use for gammas only.

| Unit | Abbreviation | Equivalent value for other physical quantities applies to gammas only |
|---|---|---|
| Roentgen | R | 0.88 rad in air.<br>and in soft tissue:<br>0.95 rem<br>0.0095 Sv<br>9.5 mSv |
| Roentgen absorbed dose | rad | 1 rem<br>0.01 Sv |
| Roentgen equivalent man | rem | 0.01 Sv<br>(is not the same as a Roentgen, see above) |
| milli Sievert | mSv | 100 mrem<br>0.105 R (in soft tissue) |
| Becquerel | Bq | 1 disintegration per second, or<br>$2.7\ 10^{-11}$ Ci |
| Curie | Ci | $3.7\ 10^{10}$ disintegrations per second or<br>$3.7\ 10^{10}$ Bq |
| milli Roentgen per hour | mR/h | Equivalent to 1000 μR/h, and equivalent to 0.95 mrad/h, and equivalent to 0.95 mrem/h, and equivalent to 0.0095 mSv/h |
| micro Roentgen per hour | μR/h | 0.001 mR/h, and<br>equivalent to 0.95 μrad/h, and<br>equivalent to 0.95 μrem/h, and<br>equivalent to 9.5 nSv/h |

# Gamma Dosage Example Use in Program

To perform simple calculation to determine annual dose based upon a measurement at a specific location (note exposure increases with proximity to the source).

1.) Make measurement at location of interest, performing several measurements if source has large area.

*For example 30 micro R/Hour*

2.) Make a measurement of background radiation in a portion of the building well away from the suspected source.

*For example 13 micro R/Hour*

3.) Subtract the background measurement from the source measurement to determine the net exposure rate from the suspected source.

*Using the example: 30-13 =17 microR/Hour*

4.) Determine amount of time a person would be at that assumed location during a year.

*Example assume 4 hours per day at that location, 365 days per year*
*Or*
*4 hours/day x 365 days/year = 1,460 hours per year*

5.) Determine dose per year from the net additional radiation from the suspected source for a person spending an assumed amount of time at the location measured:

*Example: 17 microR/Hour x 1,465 hours/year = 24,820 microR/year*

6.) Convert to milliR/year by dividing by 1000

*Example: 24,820 microR/year/(1000 microR/milliR) =24.82 millR/year*

7.) Convert to absorbed dose rate in mrem/yr by multiplying with 0.95 mrem/mR.

*Example: 24.82 mR/year x 0.95 mrem/mR = 23.58 mrem/year*

8.) Compare result to maximum exposure guidance above background for the general public (assumed to be a recommended maximum annual recommended limit of 100 mRem/Year.

9.) You can also convert your result to SI Units as follows:

*Example 23.58 mrem/year / (100 mrem/mSv) = 0.2358 mSv/year*

# Additional Clarification of Measurement Units and Radioactive Dose

Compiled by Dr. Leo Moorman
Radon Home Measurement & Mitigation
1919 Corriedale Court, Fort Collins, CO 80526 Telephone: (970) 416-0196
Email: lmoorman1@aol.com, Home Page: http://www.radon-mitigation.org

When measuring radioactive decay and the radiation it generates, it is important to distinguish four physical quantities. This is especially the case if radioactivity from a source is to be calculated from a measurement of only a fraction of the radiation it emits.

Each physical quantity described below measures a different aspect of radiation and radioactivity and each quantity has its own unit. Several quantities have an old unit (often still used in the USA) and a newer unit that reflects more general internationally used units (SI-unit). Some quantities can be converted to each other using numerical factors, but the numerical factors may be different for different types of radiation and cannot be used blind folded.

**Each measure of a physical quantity can also be divided by time to find a so called "rate" or "average rate".** This will make the unit appear with the add-on "per second" or "per minute" or "per hour" or even "per year". Sometimes such conversions involve an exposure time that is assumed to be only a fraction of the total time, thus details in various assumptions are important to be conveyed.

We give each physical quantity with its unit and a few examples below.
(m= milli=$10^{-3}$, μ=micro=$10^{-6}$, n=nano=$10^{-9}$, p=pico=$10^{-12}$)

## 1) EXPOSURE (X)

**For gamma and X-rays: amount of ionization they produce in air**
A measure of ionizing radiation based on its ionization capability in air.
**Unit: Roentgen (R) = 2.58 $10^{-4}$ Coulomb (electrical charge) per kilogram (C/kg)**

*Example:*
Average Exposure Rate of background at sea level is 6 micro-Roentgen per hour (μR/hr).

## 2) ABSORBED DOSE: (D)

Measure of the **amount of Energy released in a target material**.
**SI-unit: Gray (Gy)**
**1 Gy = 1J/kg = 100 rad**
**older unit: radiation absorbed dose (rad)**

*Examples:*
An exposure of 1 Roentgen gives an Absorbed Dose in air of $8.8\ 10^{-3}$ Gy =0.88 rad
An exposure of 1 Roentgen gives an Absorbed Dose in soft tissue of $9.5\ 10^{-3}$ Gy =0.95 rad.

Thus an exposure rate of 10 μR/hr equals an Absorbed Dose rate of 95 nGy/hr in soft tissue.

## 3) DOSE EQUIVALENT (H)

Measure of the potential for how much **biological damage** the radiation can do.

The biological Quality factor (Q) links D and H. **as in H=QD**

**SI-units: When "Absorbed Dose" is expressed in Gy, the "Dose Equivalent" is expressed in Sievert (Sv)**

**With the Absorbed Dose in "rad", the older unit of dose equivalent is "rem" abbrev. for "roentgen equivalent man". This Q=1 holds for X-rays, gamma rays and electrons. Often for protons Q=2 is used.**

For Ionizing Radiation alphas and neutrons, Q-factors larger than 1 are appropriate depending on the linear energy transfer(LET) of the radiation, thus a direct conversion factor for these is not possible unless many details about the radiation is known, but often Q=10 and up to 20 is used to indicate the damage is greater by these.

*Examples:*
3 mSv = 300 mrem, is the Dose Equivalent from natural background radiation for a person in the USA at sea level.

The dose equivalent to a person that is given a typical dental X-ray is 20 micro-Sievert (μSv) per photo.

## 4) (RADIO-)ACTIVITY OF A SOURCE:

Characterizes the **strength of the radioactivity** of a source material.

Measures the radioactive decays per unit of time in which a nucleus of a chemical element changes to a nucleus of a different chemical element.

**SI unit: Becquerel (Bq)**
**1 Bq = 1 nuclear desintegration per second.**
**Older unit: Curie (Ci)= 3.7 $10^{10}$ Bq**
*Examples:*
Characterizing the radioactivity of indoor air can be done in Bq/$m^3$ or in the USA is often done picoCurie per liter: pCi/L
Conversion: 1 pCi/L= 37 Bq/$m^3$
1 adult human with body weight of 70 kg (154 pounds), at a radioactive density of 100 Bq/kg, is a radioactive source of 7000 Bq.

A typical smoke detector in a home using Americium, is a radioactive source of 30,000 Bq.

A private water well could contain 10,000 pCi/L of radioactivity per liter water.

## 5.) From radiation measurement to source strength.

When the sample is inside the measurement volume, such as is the case with a Continuous Radon Monitor (CRM) device or electret ionization chamber (EIC), all (or a known fraction of) radiation inside the volume may be measured but the device may still respond differently to various types of radiation. This and the sensitivity of the detector are parts of the calibration factor of the instrument.

When the radioactive source to be measured is outside the measurement volume (as in a survey Geiger counter that is confined to gamma radiation, with a shield covering the probe), only a fraction of the radiation of the source is measured and apart from obvious geometric factors between detector volume and source, shielding against additional radiation (betas, alphas) the inhomogeneity and extend of the source may have significant effects on the radiation strength measured.

Thus a gamma measurement with a Geiger counter is not a good method to measure radon release from a granite slab, but it can establish if there may be a concern that indicates further investigation of the granite slab, provided the counter used is calibrated to relevant gammas for this research.

On the other hand, such a measurement (with proper calibration) can allow for a calculation of local gamma radiation in terms of an average rate for the Dose Equivalent received by a person at locations in the kitchen where the measurements are done in the unit of Sievert (or mrem) per year based on the conversions given above..

# Additional Links to web viewable programs and other references

**New York Times Article, July 24, 2008**
http://www.nytimes.com/2008/07/24/garden/24granite.html?_r=1&oref=slogin

**CBS Morning Show, July 25, 2008**
http://www.cbsnews.com/stories/2008/07/25/earlyshow/health/main4292754.shtml

**KHOU Webcast May 8, 2008 follow-up**
http://www.khou.com/video/index.html?nvid=243177

**EPA's Position on Granite Counter Tops:**
http://www.epa.gov/radon/
Go to link and select box on the right and about halfway down that says:

| What about radon in granite counter tops? Learn more |
|---|

Web viewable copy of National Academy of Sciences:
Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2 (2006)
http://www.nap.edu/openbook.php?isbn=030909156X

**Personal Radiation Calculator –**
Calculate how much radiation you may get based upon where you live and other exposures.
http://www.epa.gov/rpdweb00/understand/calculate.html

**American Association of radon Scientists and Technologists Position on Granite Counter Tops**
http://www.aarst.org/images/AARST_Granite_Position_Statement_8-04-2008.pdf

**BuildClean**
An Organization Investigating Health Concerns Associated with Granite Counter Tops
Home: http://www.buildclean.org/?id=1
Audio interview with Stan Liebert: http://www.buildclean.org/default/Podcast/flash.html