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Radiation exposure

Radiation exposure is a measure of the ionization of air due to ionizing radiation from photons; that is, gamma rays and X-rays.[1] It is defined as the electric charge freed by such radiation in a specified volume of air divided by the mass of that air.

Radiation exposure	
Common symbols	*X*
SI unit	C/kg
Other units	röntgen
In SI base units	A·s/kg

The SI unit of exposure is the coulomb per kilogram (C/kg), which has largely replaced the roentgen (R).[2] One roentgen equals 0.000 258 C/kg; an exposure of one coulomb per kilogram is equivalent to 3876 roentgens.

As a measure of radiation damage **exposure** has been superseded by the concept of absorbed dose which takes into account the absorption characteristic of the target material.

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Exposure conversion to absorbed dose

Dose is the measure of energy per unit mass deposited by ionizing radiation. For a given radiation field, the absorbed dose will depend on the type of matter which absorbs the radiation. For instance, for an exposure of 1 roentgen by gamma rays with an energy of 1 MeV, the dose in air will be 0.877 rad, the dose in water will be 0.975 rad, the dose in silicon will be 0.877 rad, and the dose in averaged human tissue will be 1 rad. A table giving the exposure to dose conversion for these four materials for a variety of gamma ray energies can be found in the reference.[3]

Exposure rate constant

The gamma ray field can be characterized by the exposure rate (in units of, for instance, roentgen per hour). For a point source, the exposure rate will be linearly proportional to the source's radioactivity and inversely proportional to the square of the distance,[4]

$$F = \Gamma \times \alpha / r^2$$

where F is the exposure rate, r is the distance, α is the source activity, and Γ is the exposure rate constant, which is dependent on the particular radionuclide used as the gamma ray source.

Below is a table of exposure rate constants for various radionuclides. They give the exposure rate in roentgens per hour for a given activity in millicuries at a distance in centimeters.[5]

Exposure rate constants for various radionuclides
R•cm^2 / hr•mCi

Radionuclide	Exposure rate constant
cobalt-60	12.838
molybdenum-99	1.03
technetium-99m (6 hour)	0.720
palladium-103 (unfiltered)	1.48[6]
silver-110m (250 day)	14.9
caesium-137	3.400
iodine-125 (unfiltered)	1.46[6]
iridium-192 (unfiltered)	4.69[6]
radium-226	8.25

Radiation measurement quantities

The following table shows radiation quantities in SI and non-SI units:

Ionizing radiation related quantities

Quantity	Unit	Symbol	Derivation	Year	SI equivalence
Activity (*A*)	becquerel	Bq	s^{-1}	1974	SI unit
	curie	Ci	3.7×10^{10} s^{-1}	1953	3.7×10^{10} Bq
	rutherford	Rd	10^6 s^{-1}	1946	1,000,000 Bq
Exposure (*X*)	coulomb per kilogram	C/kg	C·kg^{-1} of air	1974	SI unit
	röntgen	R	esu / 0.001293 g of air	1928	2.58×10^{-4} C/kg
Absorbed dose (*D*)	gray	Gy	J·kg^{-1}	1974	SI unit
	erg per gram	erg/g	erg·g^{-1}	1950	1.0×10^{-4} Gy
	rad	rad	100 erg·g^{-1}	1953	0.010 Gy
Equivalent dose (*H*)	sievert	Sv	J·kg^{-1} × W_R	1977	SI unit
	röntgen equivalent man	rem	100 erg·g^{-1} x W_R	1971	0.010 Sv
Effective dose (*E*)	sievert	Sv	J·kg^{-1} × W_R × W_T	1977	SI unit
	röntgen equivalent man	rem	100 erg·g^{-1} × W_R × W_T	1971	0.010 Sv

Although the United States Nuclear Regulatory Commission permits the use of the units curie, rad, and rem alongside SI units,[7] the European Union European units of measurement directives required that their use for "public health ... purposes" be phased out by 31 December 1985.[8]

References

- N. J. Carron, *An Introduction to the Passage of Energetic Particles through Matter*, 2007, Taylor and Francis Group
- Glenn F. Knoll, *Radiation Detection and Measurement*, fourth edition, 2010, John Wiley and Sons, Inc.
- Andrew Holmes-Siedle and Len Adams, *Handbook of Radiation Effects*, second edition, 2002, Oxford University Press

Notes

1. *Knoll*, p. 56
2. *Holmes-Siedle and Adams*, p. 4
3. Carron, p. 141
4. Knoll, p. 57
5. Stanford University Environmental Health and Safety, radionuclide safety data sheets (http://web.stanford.edu/dept/EHS/prod/researchlab/radlaser/RSDS.html)
6. Khan, Faiz (2015). *The Physics of Radiation Therapy*. Philadelphia, PA: Lippincott Williams & Wilkins. p. 358.
7. *10 CFR 20.1004* (https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1004.html). US Nuclear Regulatory Commission. 2009.
8. The Council of the European Communities (1979-12-21). "Council Directive 80/181/EEC of 20 December 1979 on the approximation of the laws of the Member States relating to Unit of measurement and on the repeal of Directive 71/354/EEC" (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31980L0181:EN:NOT). Retrieved 19 May 2012.