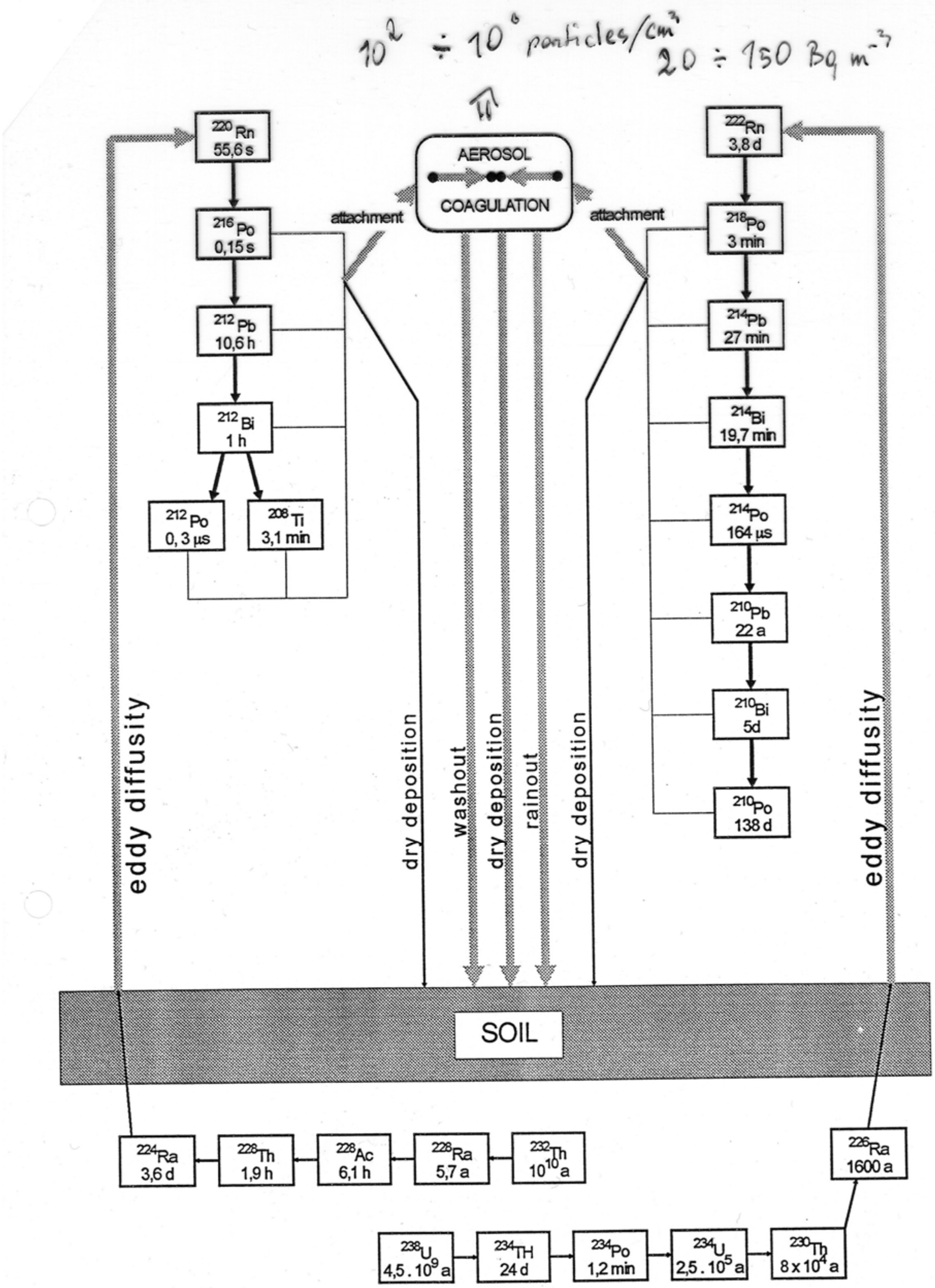
Radon in the environment

- Production in the soil, Emanation from the soil

- Sources and entry routes into dwellings

- Aerosol size distribution

- Diurnal variation


10^2 ÷ 10^6 particles/cm³
20 ÷ 150 Bq m⁻³
AEROSOL
COAGULATION
attachment
attachment
220Rn 55,6 s
216Po 0,15 s
212Pb 10,6 h
212Bi 1 h
212Po 0, 3 µs
208Ti 3,1 min
222Rn 3,8 d
218Po 3 min
214Pb 27 min
214Bi 19,7 min
214Po 164 µs
210Pb 22 a
210Bi 5d
210Po 138 d
eddy diffusity
dry deposition
washout
dry deposition
rainout
dry deposition
eddy diffusity
SOIL
224Ra 3,6 d
228Th 1,9 h
228Ac 6,1 h
228Ra 5,7 a
232Th 10^10 a
226Ra 1600 a
238U 4,5 . 10^9 a
234TH 24 d
234Po 1,2 min
234U 2,5 . 10^5 a
230Th 8 x 10^4 a

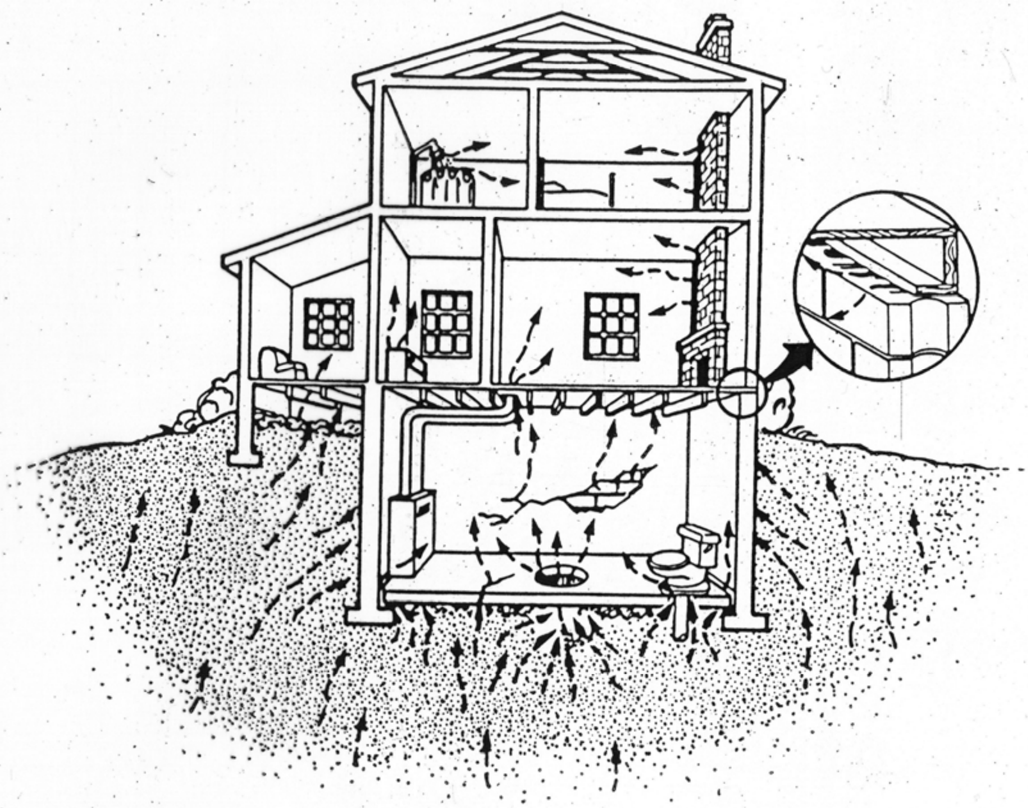


FIG. 5.4. Sources and entry routes of indoor radon.

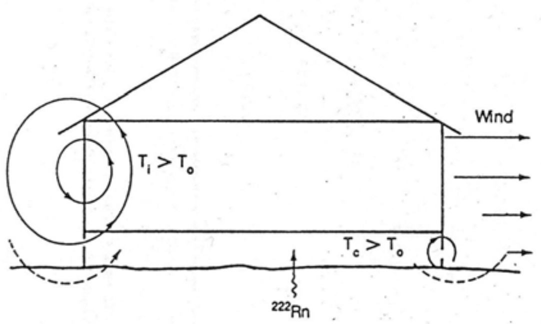


Figure XI. **Schematic diagram of mechanisms related to radon transport from soil, through a vented crawl space and into a house.**
[N10]

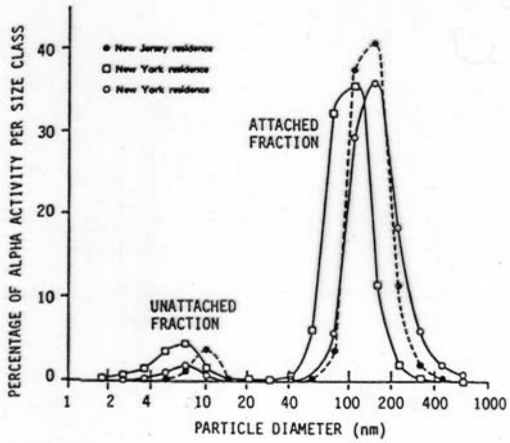


Figure XVIII. Histograms of size distribution of radon decay products.
[G11]

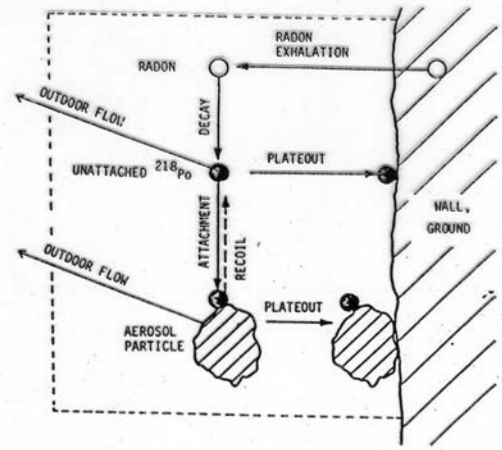


Figure XIX. The basic processes influencing the activity balance of radon decay products.
[P5]

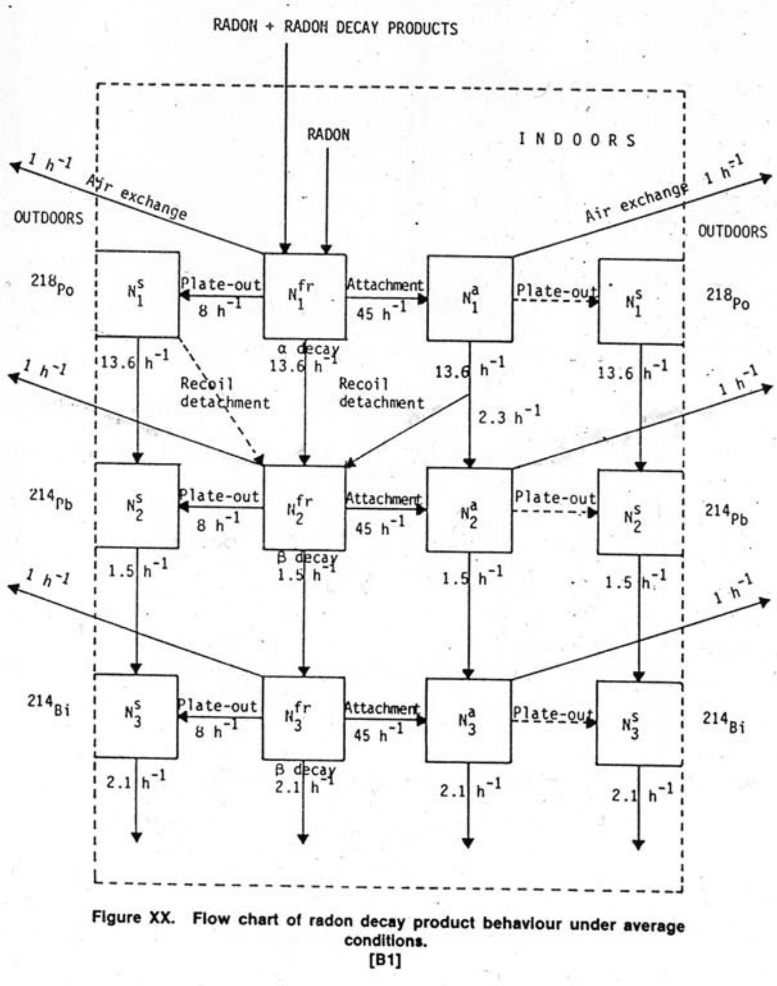


Figure XX. Flow chart of radon decay product behaviour under average conditions.
[B1]

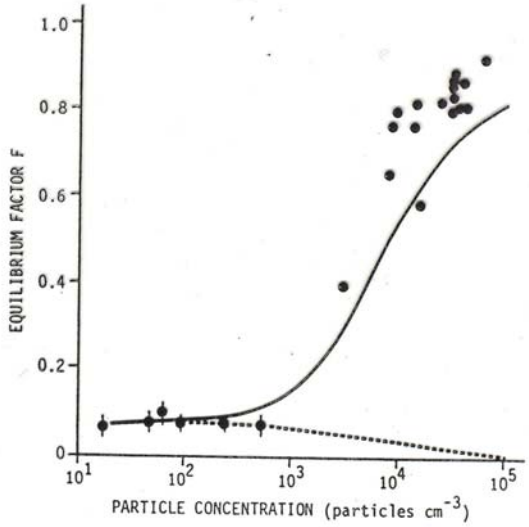


Figure XXIII. Equilibrium factor F versus particle concentration. Measured data and representative uncertainties are indicated by the solid circles and error bars. The solid line is based on calculated values for total radon decay products, while the dashed line indicates calculated values for unattached radon decay products.
[S43]

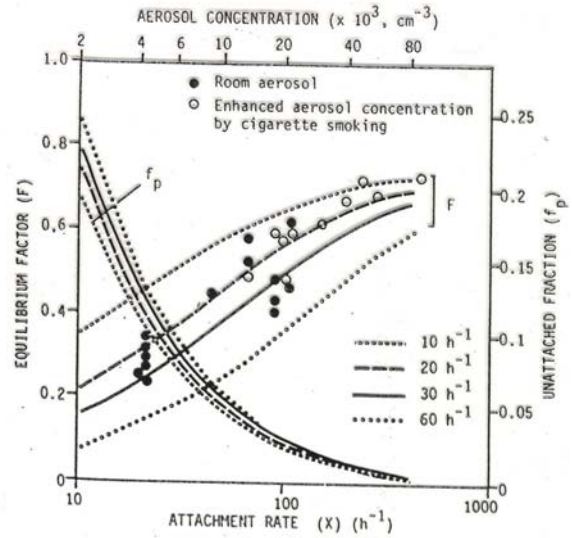


Figure XXII. Equilibrium factor and unattached fraction for radon decay products as a function of aerosol concentration.
[P5]

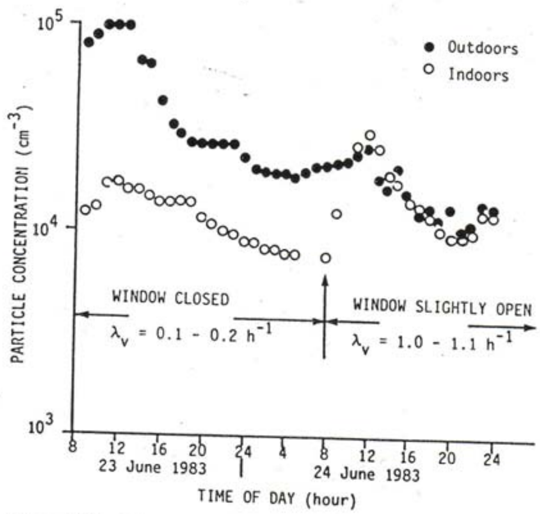


Figure XXI. Diurnal variation of aerosol concentrations outdoors and indoors of a building for different ventilation rates.
[P5]

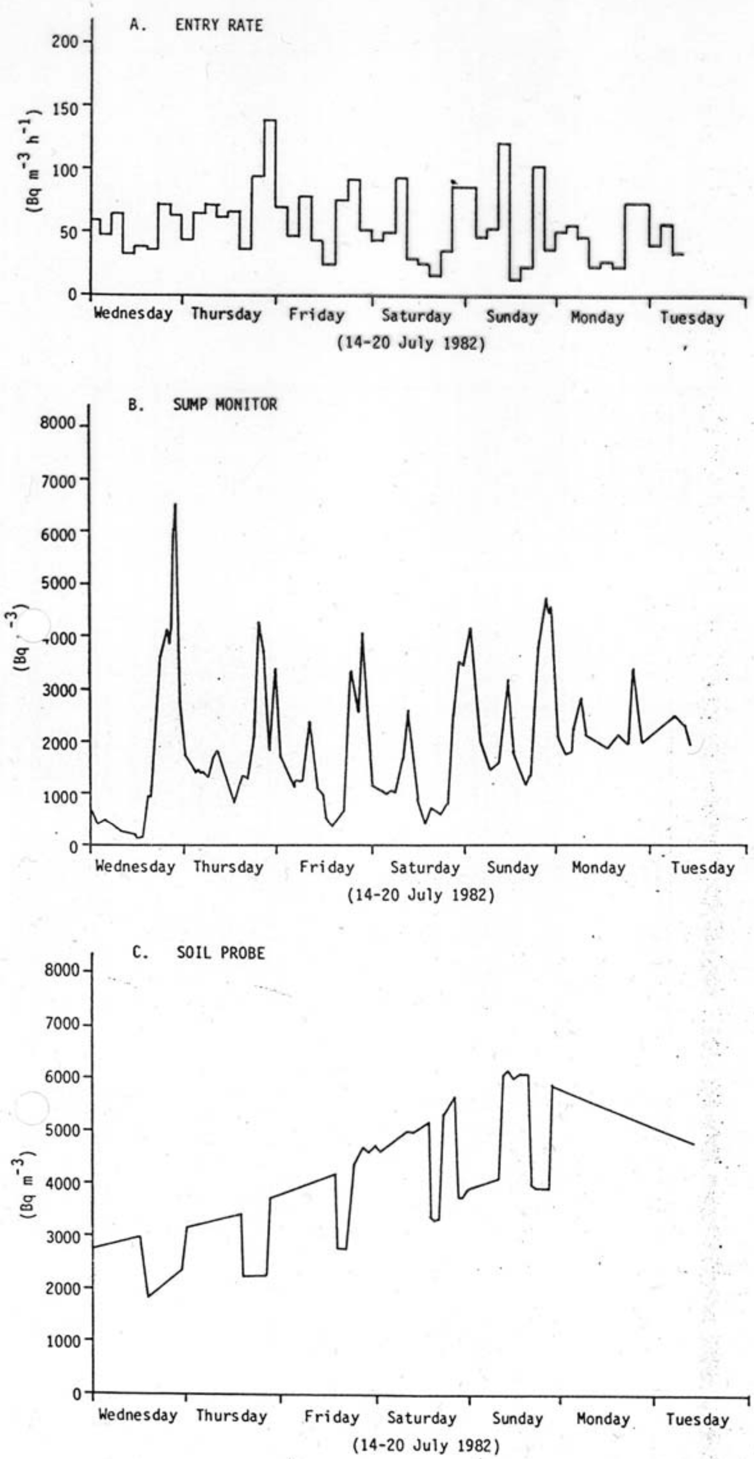


Figure XII. Variation with time in a single-family house with a basement of (a) radon entry rate; (b) the radon concentration in the basement sump; and (c) in the soil adjacent to the house.
[N4]

CONVERSION FACTORS FOR RADON UNITS

INTRODUCTION

The following conversion factors are useful for converting between units commonly used for the measurement of radon and radon decay products.
For some conversion factors the following assumptions have been made and are indicated in parentheses beside the units

(a) the equilibrium ratio between radon progeny and the parent radon is 0.5
(b) the dwelling occupancy factor is 100%.
(c) the dose conversion coefficient is $1x10^{-5}$ m Sv per $Bq.h.m^{-3}$ EER (equilibrium equivalent radon concentration-ICRP-50 sec.3.3)
(d) 1WLM is 1 WL for 170 h
1 WLM = 6.3×10^5 $Bq.h.m^{-3}$ EER
1 $Bq.h.m^{-3}$ EER =1.60×10^{-6} WLM
(ICRP-50, section A.5)

ACTIVITY

1 becquerel (Bq) = disintegration per second (s^{-1})

1 curie (Ci)	= 3.7×10^{10} Bq	
1 picocurie (pCi)	= 0.037	Bq
1 becquerel (Be)	= 0.27	pCi

RADON CONCENTRATION

becquerel per cubic metre

$1Bq.m^3$	= 2.7×10^{-2}	$pCi.L^{-1}$	
	= 1.35×10^{-4}	WL	(a)
	= 0.5	$Bq.m^{-3}$EER	(a)

picocurie per litre

1 pCi.L-1	= 37	$Bq.m^{-3}$	
	= 5×10^{-3}	WL	(a)
	= 18.5	$Bq.m^{-3}$EER	(a)

RADON PROGENY CONCENTRATION

Working Level

1WL	= 7.4×10^3	$Bq.m^{-3}$	(a)
	= 3.7×10^3	$Bq.m^{-3}$EER	
	= 2.0×10^2	pCi.L	(a)
0.02 WL	= 1.48×10^2	$Bq.m^{-3}$EER	(a)
	= 4	$pCi.L^{-1}$	(a)

becquerel per cubic metre, EER

$1Bq.m^{-3}$EER	= 2	$Bq.m^{-3}$
	= 5.4×10^{-2}	$pCi.L^{-1}$
	= 2.7×10^{-4}	WL

POTENTIAL ALPHA ENERGY CONCENTRATION

1 Working Level(WL)	= 1.3×10^5	$MeV.L^{-1}$
	= 2.08×10^{-5}	$J.m^{-3}$

1WL corresponds to radon progeny concentration in equilibrium with 100 $pCi.L^{-1}$radon (3700 $Bq.m^{-3}$)

RADON, RADON PROGENY EXPOSURE

Average of 1 becquerel per cubic metre Rn for a year

1 $Bq.m^{-3}$ y	= 4.38×10^{-2}	mSv	(a,b,c,d)
	= 7.0×10^{-3}	WLM	(a,b,d)
	= 8.76×10^3	$Bq.h.m^{-3}$	

Average of picocurie per litre radon for a year

1 $pC.L^{-1}$y	= 1.62	mSv	(a,b,c,d)
	= 0.26	WLM	(a,b,d)
	= $3 24 \times 10^5$	$Bq.h.m^{-3}$	

Average of one Working Level for a year

1 WLy	= 51.53	WLM	
	= 6.48×10^7	$Bq.h.m^3$	(a,b,d)
	= 3.24×10^7	$Bq.h.m^{-3}$EER	(a,b,d)
	= 1.75×10^6	$pCi.h.L^{-1}$	(a.b.d)
	= 324	mSv	(a,b,c,d)

Average of 1 becquerel per cubic metre, equilibrium equivalent Rn concentration for a year

1 Bq m^3y EER	= 8.76×10^{-2}	mSv	(a,b,c,d)
	= 1.4×10^{-2}	WLM	(a,b,d)
	= 1.75×10^4	$Bq.h.m^{-3}$	(a,b,d)
	= 8.76×10^3	$Bq.h.m^{-3}$ EER	(a,b,d)

Größe	SI-Einheit	Größendefinition	alte Einheit	Einheitenzeichen	Umrechnung
Aktivität	Becquerel Einheitenzeichen: Bq $1\ Bq = 1\ s^{-1}$	Anzahl radioaktiver Kernumwandlungen pro Zeiteinheit	Curie	Ci	$1\ Ci = 3{,}7 \cdot 10^{10}\ Bq$
Energiedosis	Gray Einheitenzeichen: Gy 1 Gy = 1 J/kg	Gesamte absorbierte Strahlungsenergie in der Masseneinheit	Rad	rd	$1\ rd = 10^{-2}\ Gy$
Äquivalentdosis	Sievert Einheitenzeichen: Sv 1 Sv = 1 J/kg	Energiedosis multipliziert mit dem dimensionslosen Bewertungsfaktor der vorliegenden Strahlenart	Rem	rem	$1\ rem = 10^{-2}\ Sv$
Ionendosis	Coulomb pro Kilogramm Einheitenzeichen: C/kg	Elektrische Ladung der in einer luftgefüllten Ionisationskammer erzeugten Ionen, dividiert durch die Masse der darin enthaltenen Luft	Röntgen	R	$1\ R = 2{,}58 \cdot 10^{-4}\ C/kg$
Energiedosisleistung	Gray pro Sekunde (bzw. Gray pro Stunde) Einheitenzeichen: Gy/s (bzw. Gy/h)	Energiedosis pro Zeiteinheit	Rad pro Sekunde (bzw. Rad pro Stunde)	rd/s rd/h	$1\ rd/s = 10^{-2}\ Gy/s$ $1\ rd/h = 10^{-2}\ Gy/h$
Äquivalentdosisleistung	Sievert pro Sekunde (bzw. Sievert pro Stunde) Einheitenzeichen: Sv/s (bzw. Sv/h)	Äquivalentdosis pro Zeiteinheit	Rem pro Sekunde (bzw. Rem pro Stunde	rem/s rem/h	$1\ rem/s = 10^{-2}\ Sv/s$ $1\ rem/h = 10^{-2}\ Sv/h$
Ionendosisleistung	Ampere pro Kilogramm Einheitenzeichen: A/kg	Ionendosis pro Zeiteinheit	Röntgen pro Sekunde (bzw. Röntgen pro Stunde)	R/s R/h	$1\ R/s = 0{,}93\ A/kg$ $1\ R/h = 2{,}58 \cdot 10^{-4}\ A/kg$

Radionuklid	Γ_{20} (mGy·m²/h·GBq)	Γ_H (mSv·m²/h·GBq)
^{22}Na	0.281	0.3206
^{57}Co	0.0133	0.0152
^{60}Co	0.307	0.3503
^{99}Mo	0.0341	0.0389
^{99}Tc-m	0.0141	0.0161
^{131}J	0.0518	0.0591
^{133}Xe	0.0121	0.0138
^{137}Cs*	0.0768	0.0876
^{192}Ir	0.109	0.1244
^{198}Au	0.0548	0.0625
^{226}Ra**	0.197	0.225
^{241}Am	0.00576	0.00657

Faktor 1,14

Tab. 8.3: Dosisleistungskonstanten für Photonenstrahlung aus [Reich]. Γ_H ist mit dem im Text erwähnten Umrechnungsfaktor aus den Kermakonstanten Γ_{20} berechnet. *: im Gleichgewicht mit Folgeprodukten, **: gefiltert mit 0.5 mm Pt und im Gleichgewicht mit Folgeprodukten. Die numerischen Werte für ^{137}Cs und ^{60}Co unterscheiden sich geringfügig von den Ergebnissen in den Beispielen 2 und 3, da dort etwas abweichende Werte für die Energieumwandlungskoeffizienten verwendet wurden.