Embargo 12 mei 2014

APPENDIX to
Coordinated examination: radiation protection
Expertise Level 3

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examination date: 13 May 2013
duration of examination: 13.30 - 16.30 h

Instructions:

- ❑ **If you use data other than that provided in this appendix, please state the source!**
- ❑ **This appendix consists of 15 numbered pages. Please check this!**

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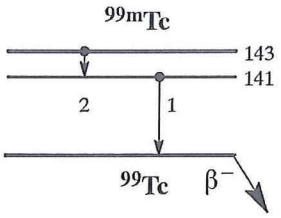
^{99m}Tc Z = 43

Half-life and decay

$T_{1/2}$ = 6,006 h = 2,17×10^4 s λ = 3,21×10^{-5} s^{-1}

Decay scheme



Main emitted radiation

Straling	y (Bq·s)$^{-1}$	E (keV)
γ_1	0,889	141
ce M γ_2	0,914	2
ce N γ_2	0,076	2
K_α	0,062	18
LMX	0,102	2

Source constants

Air kerma rate	k = 0,018 μGy/h per MBq/m^2
Ambient dose equivalent rate	h = 0,023 μSv/h per MBq/m^2

Miscellaneous

Specific activity	A_{sp} = 1,95×10^{17} Bq/g
Exemption levels	C_v = 10^2 Bq/g en A_v = 10^7 Bq
Skin contamination	H_{huid} = 5×10^{-11} Sv/s per Bq/cm^2
Wound contamination / injection	$e(50)$ = 1,1×10^{-11} Sv/Bq
Transport	A_1 = 10 TBq
	A_2 = 4 TBq

Production and applications

Het radionuclide ^{99m}Tc is de dochter van ^{99}Mo. Het wordt geproduceerd in een Mo/Tc-generator en op zeer grote schaal in de nucleaire geneeskunde gebruikt voor diagnostische doeleinden: voor afbeeldingen en functiestudies.

N = 56

^{99m}Tc

Metabolic model

For health physics purposes, it is assumed that technetium spreads from the blood as follows: 4% to the thyroid, 3% to liver and the remainder to the rest of the body, with a biological half-life for the blood is set at 0.02 days, The biological half-lives for the organs/tissues are:

Fractie	$T_{1/2}$
0,75	1,6 d
0,20	3,7 d
0,05	22 d

N.B. Dit model geldt niet voor patiënten, zie pagina 14.

Ingestion and lung clearance

Ingestie		
Alle verbindingen	$f_1 = 0,8$	
Inhalatie		
Halogenide, nitraat, hydroxide, oxide	$f_1 = 0,8$	Klasse M
Overige verbindingen	$f_1 = 0,8$	Klasse F

Dose conversion coefficient and radiotoxicity equivalent for workers (w) and members of the public (b)

	Ingestie $f_1 = 0,8$	Inhalatie F	Inhalatie M	
$e(50)(w)$	$2,2\times10^{-11}$	$2,0\times10^{-11}$	$2,9\times10^{-11}$	Sv/Bq
$A_{Re}(w)$	$4,5\times10^{10}$	$5,0\times10^{10}$	$3,4\times10^{10}$	Bq
$e(50)(b)$	$2,2\times10^{-11}$	$1,2\times10^{-11}$	$1,9\times10^{-11}$	Sv/Bq
$A_{Re}(b)$	$4,5\times10^{10}$	$8,3\times10^{10}$	$5,3\times10^{10}$	Bq

Data for total body counting (after single intake)

Time (d)	Total body activity (Bq per Bq intake)		
0,25	$4,8\times10^{-1}$	$3,6\times10^{-1}$	$3,7\times10^{-1}$
1	$4,4\times10^{-2}$	$3,2\times10^{-2}$	$3,7\times10^{-2}$
2	$1,8\times10^{-3}$	$1,3\times10^{-3}$	$1,4\times10^{-3}$
3	$7,9\times10^{-5}$	$5,7\times10^{-5}$	$6,1\times10^{-5}$
5	$1,7\times10^{-7}$	$1,2\times10^{-7}$	$1,5\times10^{-7}$
7	$4,1\times10^{-10}$	$2,7\times10^{-10}$	$4,2\times10^{-10}$

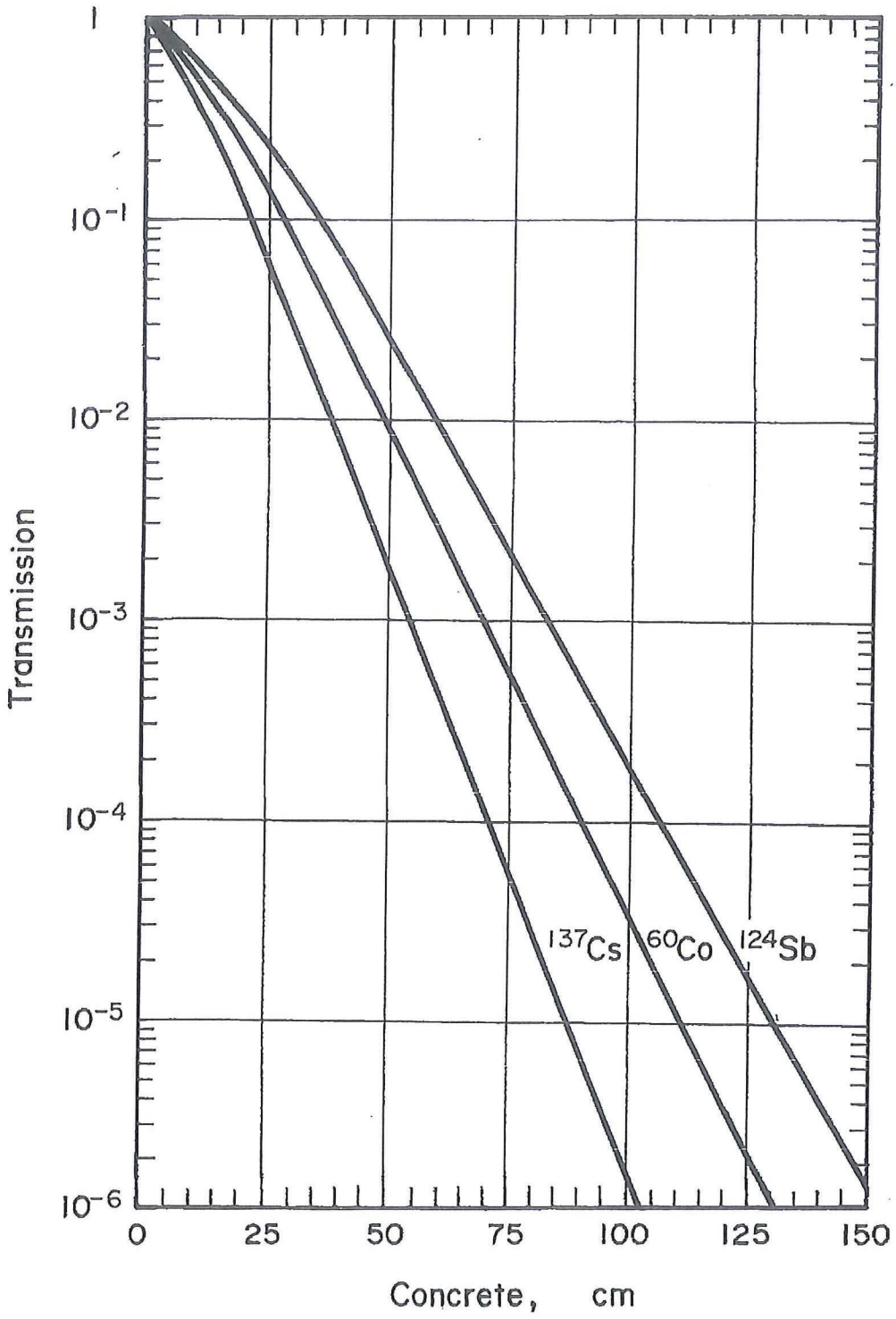


Fig. 18. Broad-beam transmission of gamma rays from various radionuclides through concrete, density 2 350 kg m^{-3}.

Broad beam transmission of gamma rays from various radionuclides through concrete. (based upon ICRP Publication 33, 1982, p. 47)

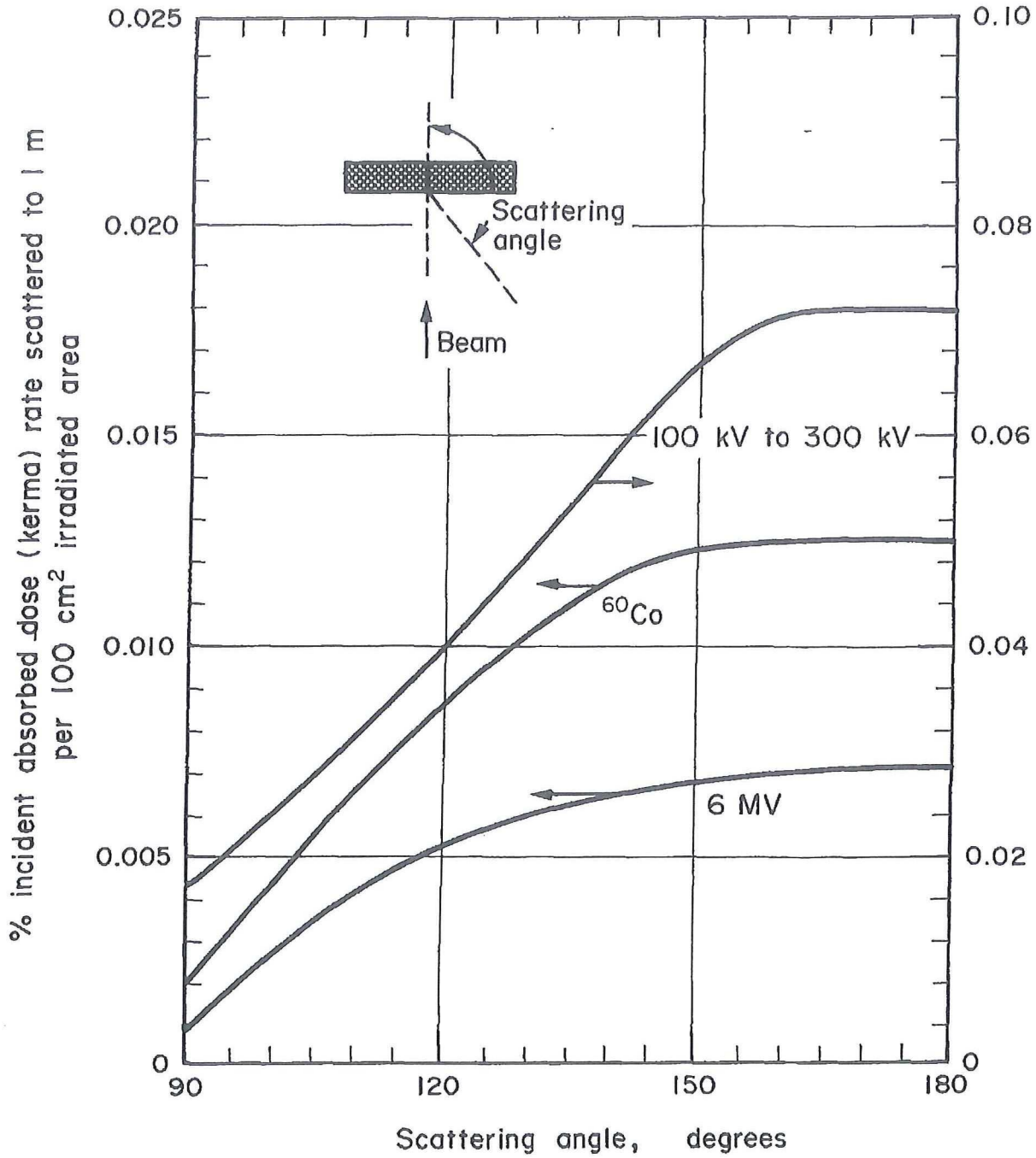


Fig. 22. Scattering patterns of diverging x-ray and gamma-ray beams normally incident on a concrete shield. Per cent scatter is related to primary beam measurements in free air at the point of incidence.

Scattering percentages in concrete of various photon energies (based upon ICRP Publication 33, 1982, p. 56)

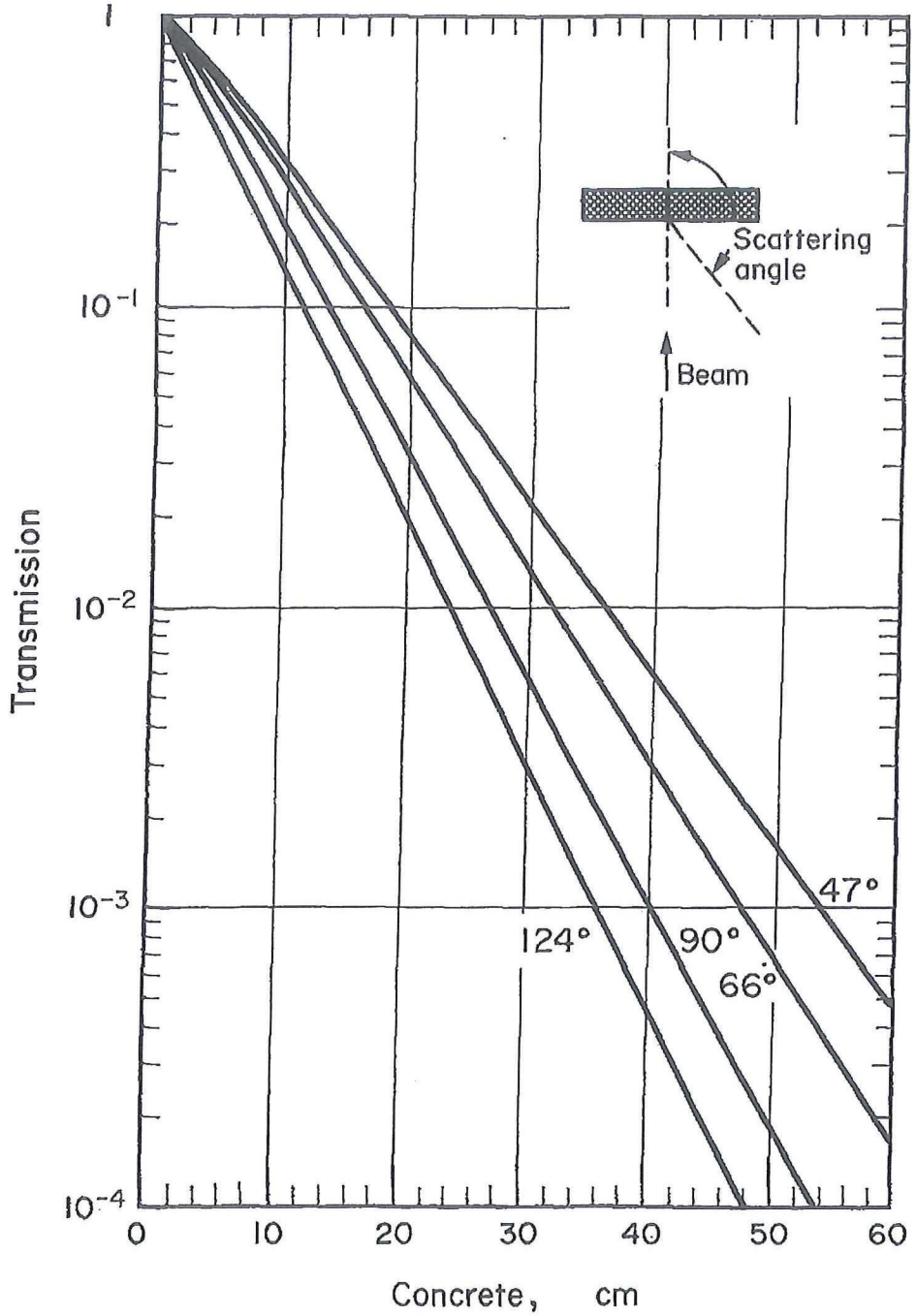


Fig. 25. Broad-beam transmission of ^{60}Co gamma rays scattered at various angles from a patient-simulating phantom through concrete, density 2 350 kg m^{-3}.

Broad beam transmission of ^{60}Co gamma radiation scattered at various angles from a patient-simulating phantom through concrete (based upon ICRP Publication 33, 1982, p. 60)

83-BISMUTH-207

Halflife = 31.55 Years
Decay Mode(s): $\varepsilon+\beta^+$

Feb-2011

RADIATIONS	y(i) $(Bq\text{-}s)^{-1}$	E(i) (MeV)	y(i)×E(i)
β^+ 1	3.80E–04	3.830E–01*	1.46E–04
γ 2	9.77E–01	5.697E–01	5.57E–01
ce-K, γ 2	1.54E–02	4.817E–01	7.40E–03
ce-L, γ 2	4.42E–03	5.538E–01[a]	2.45E–03
ce-M, γ 2	1.11E–03	5.658E–01[a]	6.31E–04
ce-M+, γ 2	1.46E–03	5.673E–01[a]	8.26E–04
γ 4	7.45E–01	1.064E+00	7.92E–01
ce-K, γ 4	7.08E–02	9.757E–01	6.91E–02
ce-L, γ 4	1.84E–02	1.048E+00[a]	1.93E–02
ce-M, γ 4	4.40E–03	1.060E+00[a]	4.66E–03
ce-N+, γ 4	1.45E–03	1.063E+00[a]	1.54E–03
γ 5	1.31E–03	1.442E+00	1.89E–03
γ 6	6.87E–02	1.770E+00	1.22E–01
ce-K, γ 6	2.38E–04	1.682E+00	4.00E–04
$K\alpha_1$ X-ray	3.65E–01	7.497E–02	2.74E–02
$K\alpha_2$ X-ray	2.17E–01	7.280E–02	1.58E–02
$K\beta$ X-ray	1.63E–01	8.490E–02*	1.38E–02
L X-ray	3.32E–01	1.060E–02*	3.52E–03
Auger-K	2.83E–02	5.670E–02*	1.60E–03
Auger-L	5.44E–01	7.970E–03*	4.34E–03

Listed X, γ and $\gamma\pm$ Radiations	1.53E+00
Omitted X, γ and $\gamma\pm$ Radiations**	1.54E–03
Listed β, ce and Auger Radiations	1.12E–01
Omitted β, ce and Auger Radiations **	1.06E–04
Listed Radiations	1.65E+00
Omitted Radiations**	1.65E–03

* Average Energy (MeV).
a Maximum Energy (MeV) for subshell.
** Each omitted transition contributes <0.100 % to $\sum$ E(i)×y(i) in its category.

Lead-207 Daughter is stable.

MIRD data for ^{207}Bi (http://www.nndc.bnl.gov/mird/)

In principle, sealed sources should be tested annually for leaks. In the case of sources with activity both less than 1 MBq and less than 0.02 Re_{ing}, however, no checks are required.

Table: Action to be taken upon discovery of external contamination from a sealed source.

wiped activity	*action*
$> 2 \cdot 10^{-3}$ Re_{ing}	Call in expert (level 3) and notify inspectorates immediately.
$> 2 \cdot 10^{-4}$ Re_{ing}	Call in expert (level 3).
> contamination norm or $> 2 \cdot 10^{-5}$ Re_{ing}	Recheck source.

A source is deemed to be leaking when the amount of activity wiped exceeds:

- α emitters 18.5 Bq
- other nuclides 185 Bq

If the holder is wiped, rather than the source itself, the above values must be reduced by a factor of 10. The action to be taken depends upon the amount of activity measured, as shown in the table above.

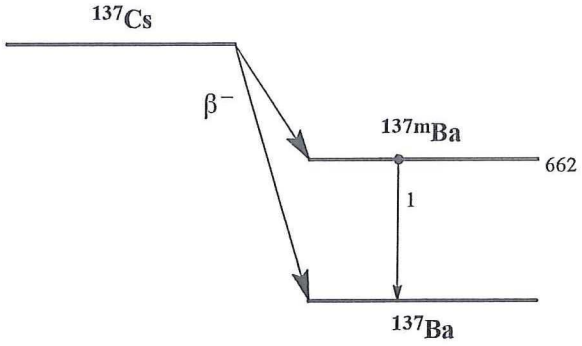
Table and excerpt from the draft Directive on Sealed Radioactive Sources

^{137}Cs Z = 55

Half-life and decay

$T_{1/2} = 30{,}25$ j $= 9{,}55\times10^{8}$ s $\qquad \lambda = 7{,}26\times10^{-10}$ s^{-1}

Decay scheme



Main emitted radiation

Van ^{137m}Ba ($T_{1/2} = 2{,}55$ m; y = 0,946):

Straling	y (Bq·s)$^{-1}$	E (keV)	Straling	y (Bq·s)$^{-1}$	E (keV)
β^-	0,946	173 | 512	γ_1	0,898	662
β^-	0,054	425 | 1173	ce K γ_1	0,083	624

Source constants 137mBa in equilibrium with 137Cs

Air kerma rate	k = 0,077 µGy/h per MBq/m^2
Ambient dose equivalent rate	h = 0,093 µSv/h per MBq/m^2

Miscellaneous

Specific activity	A_{sp} = $3{,}19\times10^{12}$ Bq/g
Exemption levels	C_v = 10^1 Bq/g en $A_v = 10^4$ Bq
Skin contamination	H_{huid} = 5×10^{-10} Sv/s per Bq/cm^2 (incl. ^{137m}Ba)
Wound contamination / injection	$e(50)$ = $1{,}4\times10^{-8}$ Sv/Bq (incl. ^{137m}Ba)
Transport	A_1 = 2 TBq
	A_2 = 0,6 TBq

Production and applications

Het radionuclide ^{137}Cs is een belangrijk splijtingsproduct. Het wordt onder meer gebruikt als gamma-referentiebron en als bron bij brachytherapie.

N = 82 ^{137}Cs

Metabolic model

For health physics purposes, it is assumed that caesium spreads from the homogenously over all tissues and organs, The biological half-lives for the organs are:

Fractie	$T_{1/2}$
0,1	2 d
0,9	110 d

Ingestion and lung clearance

Ingestie		
Alle verbindingen	$f_1 = 1$	
Inhalatie		
Alle verbindingen	$f_1 = 1$	Klasse F

Dose conversion coefficient and radiotoxicity equivalent for workers (w) and members of the public (b)

	Ingestie	Inhalatie	
	$f_1 = 1$	F	
$e(50)(w)$	$1{,}3\times10^{-8}$	$6{,}7\times10^{-9}$	Sv/Bq
$A_{Re}(w)$	$7{,}7\times10^{7}$	$1{,}5\times10^{8}$	Bq
$e(50)(b)$	$1{,}3\times10^{-8}$	$4{,}8\times10^{-9}$	Sv/Bq
$A_{Re}(b)$	$7{,}7\times10^{7}$	$2{,}1\times10^{8}$	Bq

Data for total body counting (after single intake)

Time (d)	Total body activity (Bq per Bq intake)	
0,25	$1{,}0\times10^{0}$	$7{,}4\times10^{-1}$
1	$9{,}9\times10^{-1}$	$6{,}0\times10^{-1}$
2	$9{,}6\times10^{-1}$	$5{,}1\times10^{-1}$
3	$9{,}4\times10^{-1}$	$4{,}7\times10^{-1}$
5	$9{,}0\times10^{-1}$	$4{,}4\times10^{-1}$
7	$8{,}8\times10^{-1}$	$4{,}2\times10^{-1}$