Radiological Exposure Devices

Erich Hrnecek

EC Joint Research Centre (JRC)
ITU - Institute for Transuranium Elements
Nuclear Safeguards & Security
Karlsruhe, Germany

http://itu.jrc.ec.europa.eu
http://www.jrc.ec.europa.eu

Overview

- Introduction
- Exposure - Effects
- Accidents
- REDs
- Exercises

Potential Scenarios

- Radioactive Exposure Device (RED)
- Radiological Dispersal Device (RDD)
- Improvised Nuclear Device (IND)

RED

Radioactive source out of legal control

Potential to expose people to lethal doses of radiation

Irradiation, no incorporation if sealed source

Dose assessment, medical monitoring

Psychological & Economical impact

RDD

Detonation of explosive device + radioactive material

Injury

External contamination

Incorporation

Psychological & Economical impact

IND

National emergency situation

Large number of victims

Effects: blast, heat, radiation

Irradiation, incorporation

External exposure: irradiation

Internal exposure: incorporation

Stochastic effects:

Propability of occurence increases with dose, no treshold dose
e.g. cancer incidence

Deterministic effects:

Severity of effect increases with dose, treshold dose
e.g. organ dysfunction, lens opacification, blood changes

Deterministic effects

Dose (whole body irradiation)	Effects
< 0.25 Sv	No clinically recognizable damage
0.25 Sv	Decrease in white blood cells
0.5 Sv	Increasing destruction of the leukocyte-forming organs (causing decreasing resistance to infection)
1 Sv	Marked changes in the blood picture (decrease in the leukocytes and neutrophils)
2 Sv	Nausea and other symptoms
5 Sv	Damage to the gastrointestinal tract causing bleeding and ≈ 50% death
10 Sv	Destruction of the neurological system and ≈ 100% death within 24 h

Ref.: K. H. Lieser, Nuclear and Radiochemistry: Fundamentals and Applicationss. VCH/Wiley 1997.

Symptoms

Nausea

Vomitting

Headache

Diarrhoea

Weakness

Changes in blood (reduction in Lymphocytes)

1987, Goiânia, Brasil

^{137}Cs teletherapy unit source removed by scrap collectors, source capsule opened

54 persons hospitalized, 4 died

112.000 persons monitored

Large psychological and economical impact

Source: IAEA, STI/PUB/815, Vienna, 1988

1994, Tammiku, Estonia

3 persons entered radioactive waste repository

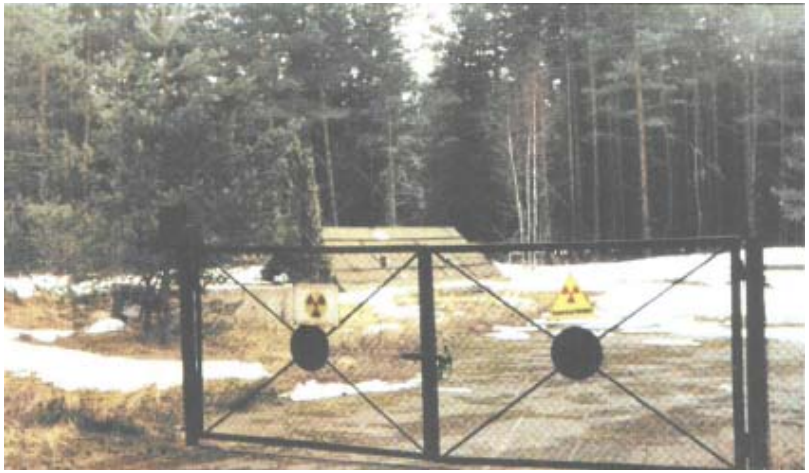
Removed ^{137}Cs radiation source

Source stored at home

5 persons with deterministic effects

1 Person died

Source: IAEA, STI/PUB/1053, Vienna, 1998



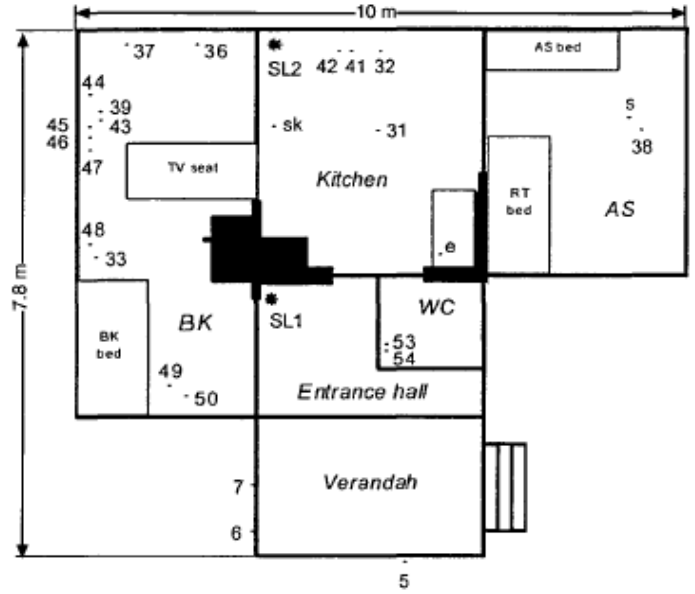


FIG. 3. The plan of the house in Kiisa. Possible source locations (SL1 and SL2) are indicated by the large asterisks. The sample codes are given in Table III.

2000, Samut Prakarn, Thailand

^{60}Co teletherapy unit out of regulatory control

Teletherapy head stolen from unsecured storage area

Disassembled at junkyard

10 persons with deterministic effects

3 Person died

Source: IAEA, STI/PUB/1124, Vienna, 2002

2002, China

^{192}Ir put in office of business rival
74 persons with irradiation symptoms

1995, Zheleznodorozhny, Russia

Criminal act ^{137}Cs source in door of truck,
5 months exposure, 1 dead

1993, Moscow, Russia

Radioactive source in chair of company director, 1 death

1991, Bratsk, Russia

2 similiar cases, 1 injury

1979, La Hague, France

Radioactive graphite fuel element plugs under driver‘s seat in car, person tried to kill his employer

1972, Texas, USA

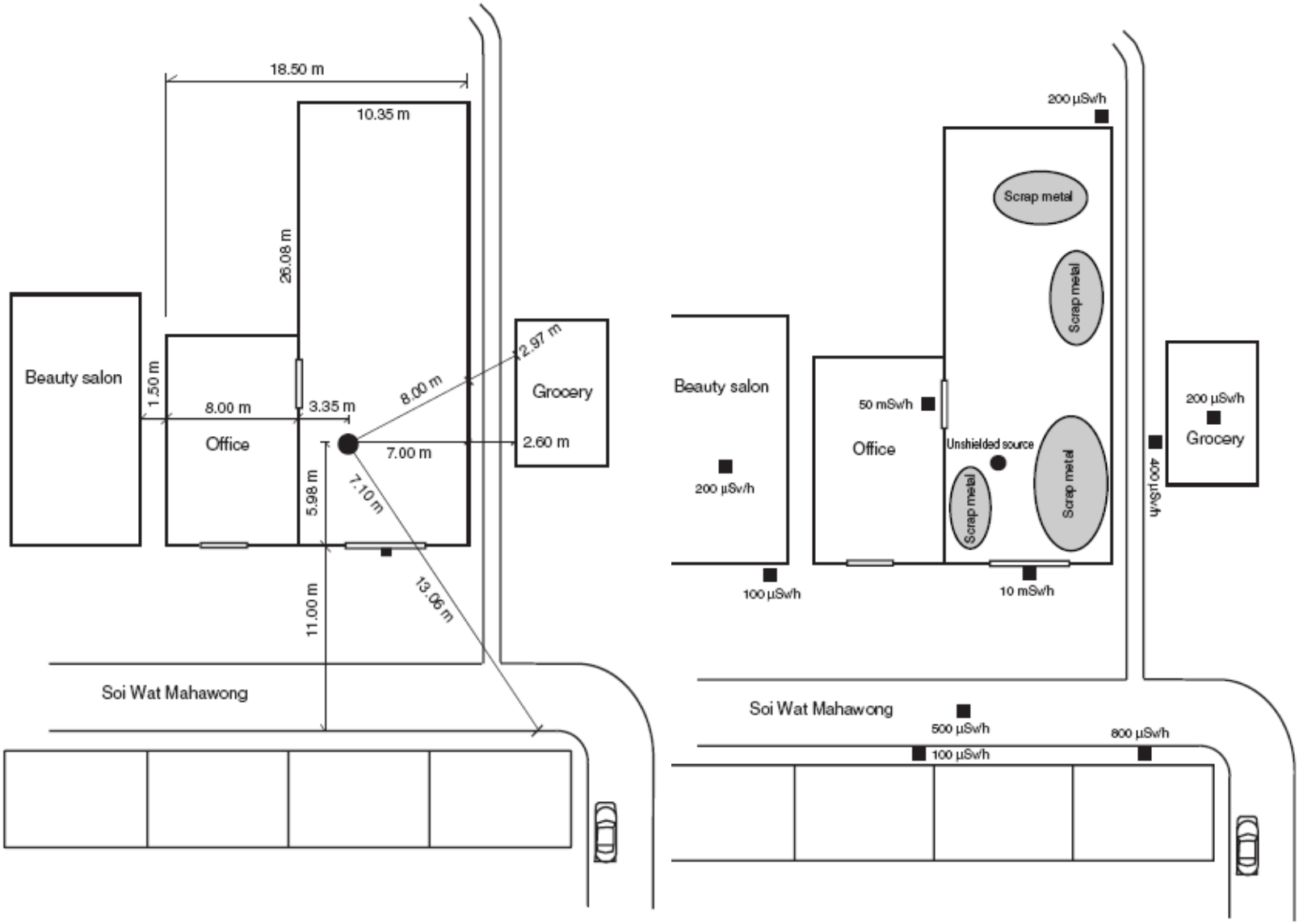
Man used ^{137}Cs sources to intentionally irradiate his 11 year old son after divorce

Source: http://www.johnstonsarchive.net/nuclear/radevents/index.html

2000, Samut Prakarn

Source activity?

Scenario


18.50 m
10.35 m
26.08 m
Beauty salon
1.50 m
8.00 m
3.35 m
Office
8.00 m
2.97 m
Grocery
2.60 m
7.00 m
5.98 m
7.10 m
11.00 m
13.06 m
Soi Wat Mahawong
200 µSv/h
Scrap metal
Scrap metal
Beauty salon
50 mSv/h
Office
Unshielded source
Scrap metal
Scrap metal
200 µSv/h
Grocery
200 µSv/h
200 µSv/h
100 µSv/h
10 mSv/h
Soi Wat Mahawong
500 µSv/h
100 µSv/h
800 µSv/h

Measured: ^{60}Co, 20 mSv/h, ~6 m distance

Source activity?

- Dosimetry & Shielding
- Source activity without shielding
- Source activity with 10 cm Fe shielding (scrap metal)

Element: Mass:

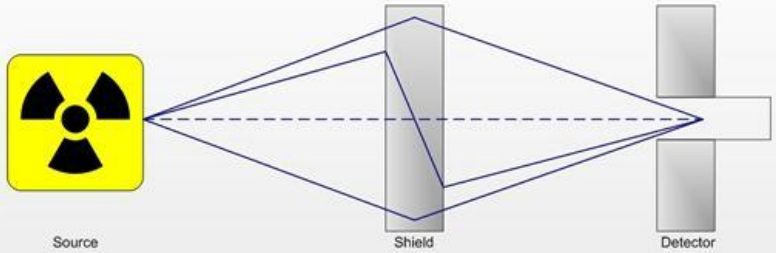
Co 60 Nuclide Mixtures Selector

Dosimetry and Shielding | Dose rate/Thickness graph | Options

Source strength Activity(Bq) 1E+12

Shielding material Air 600 cm

Dose rate (µSv/h)



Start Reset

Half-Value Shield Thickness(cm)	2.77E+04
Tenth-Value Shield Thickness(cm)	6.50E+04
Equivalent Dose Rate Constant Γ (mSv·m²/GBq/h)	3.37E-01
Gamma Dose Rate (µSv/h)	9.31E+03
Effective Build-up factor	1.04E+00
Effective Number of Mean Free Paths (µ·d)	3.96E-02

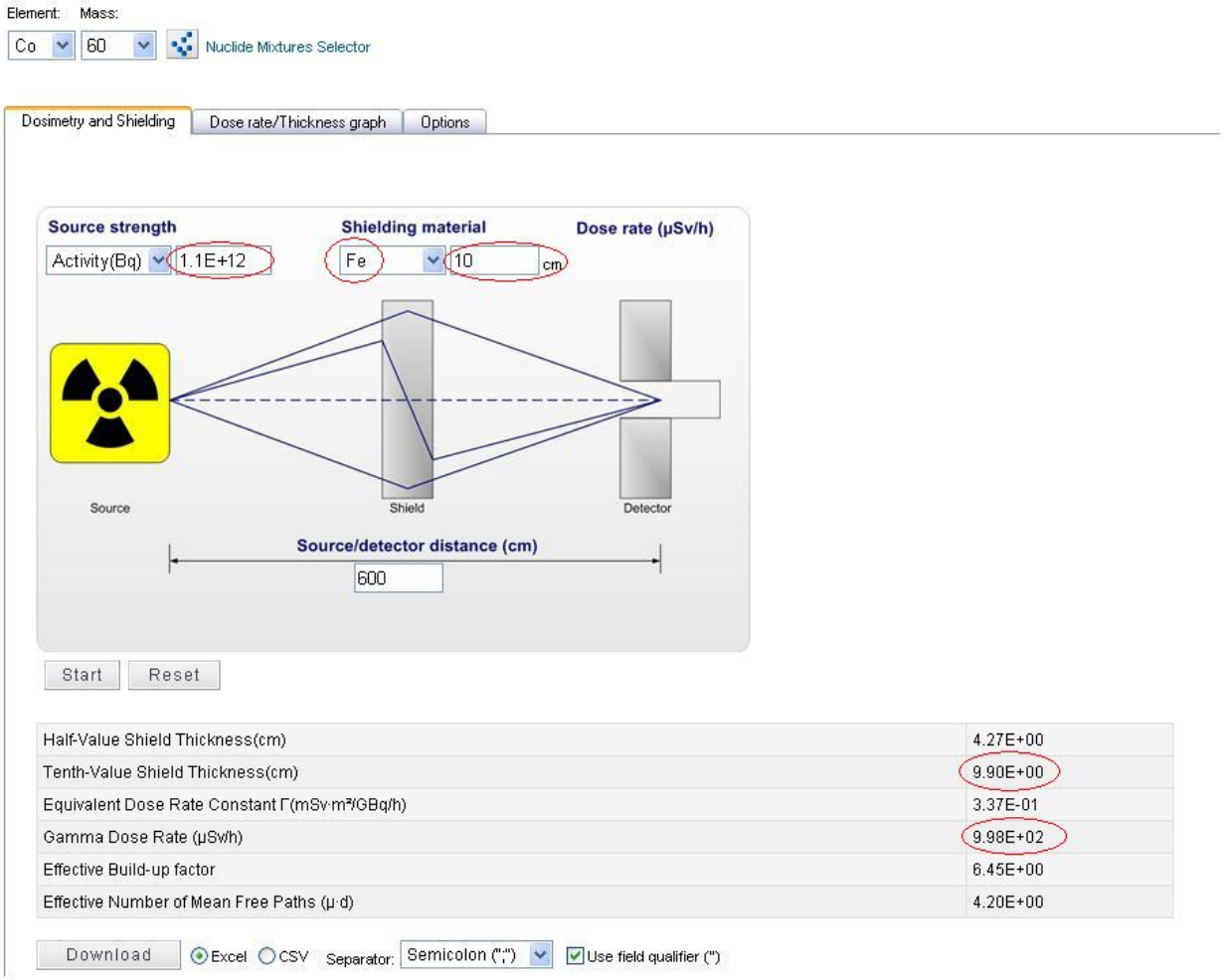
Download Excel CSV Separator: Semicolon (";") Use field qualifier (")

Equivalent Dose Rate Constant Γ

$\Gamma(mSv \cdot m^2/GBq/h) = 0.337\ mSv\ m^2 / GBq\ h$

$GBq = mSv\ m^2 / \Gamma = 10*36/0.337 = 1068\ GBq = 1.1\ TBq$

With 10 cm Fe shielding



Result:

Dose rate decreased by a factor of ~ 10 with 10 cm Fe

Conclusion:

as amount of shielding material is not well known
only estimate possible

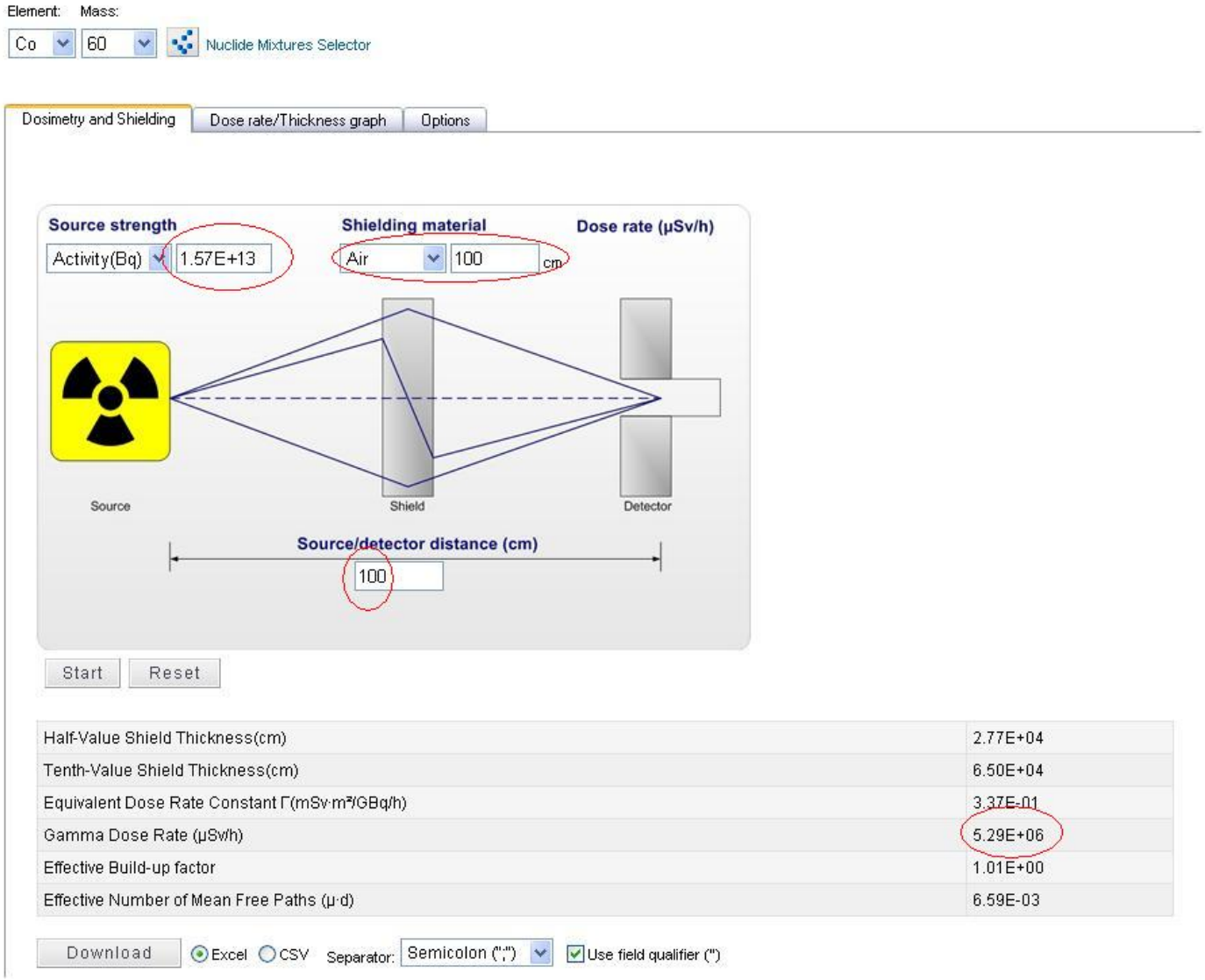
1.1 TBq without shielding

~ 10 TBq with 10 cm Fe

Remark: source had 15.7 TBq

Next problem: recovery

Dose rate in 1 m distance for 15.7 TBq ^{60}Co?


Element: Mass:
Co 60 Nuclide Mixtures Selector
Dosimetry and Shielding
Dose rate/Thickness graph
Options
Source strength
Activity(Bq) 1.57E+13
Shielding material
Air 100 cm
Dose rate (µSv/h)
Source
Shield
Detector
Source/detector distance (cm)
100
Start
Reset
Half-Value Shield Thickness(cm) 2.77E+04
Tenth-Value Shield Thickness(cm) 6.50E+04
Equivalent Dose Rate Constant Γ(mSv·m²/GBq/h) 3.37E-01
Gamma Dose Rate (µSv/h) 5.29E+06
Effective Build-up factor 1.01E+00
Effective Number of Mean Free Paths (µ·d) 6.59E-03
Download
Excel
CSV
Separator: Semicolon (";")
Use field qualifier (")

5.3 Sv/h

Recovery 2:

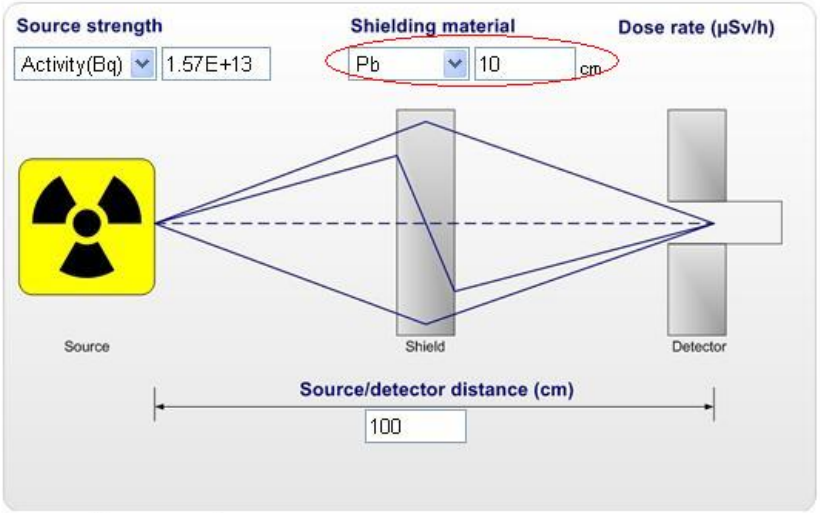
10 cm Pb shielding

What time allowed for 10 mSv?

Element: Mass:

Co 60 Nuclide Mixtures Selector

Dosimetry and Shielding | Dose rate/Thickness graph | Options



Start Reset

Half-Value Shield Thickness(cm)	2.02E+00
Tenth-Value Shield Thickness(cm)	5.03E+00
Equivalent Dose Rate Constant Γ(mSv·m²/GBq/h)	3.37E-01
Gamma Dose Rate (µSv/h)	2.93E+04
Effective Build-up factor	4.30E+00
Effective Number of Mean Free Paths (µ·d)	6.66E+00

Download Excel CSV Separator: Semicolon (";") Use field qualifier (")

29,3 mSv/h
~ 20 min

For comparison:

15.7 TBq 137Cs, 1m distance

15.7 TBq 137Cs, 10 cm Pb, 1m distance

Dose rate?


Z
N
Select
51 Antimony 137
Element:
Mass:
Cs
137
Zoom
View:
5
Select colour theme:
Karlsruhe
alpha
beta⁻
ec/beta⁺
IT
n
SF
p
ec
57
56
55
54
53
La135 19.5 h
La136 114 ms 9.87 m
La137 6.0E4 y
La138 0.09 1.0E11 y
La139 stable 99.91
La140 1.68 d
La141 3.92 h
La142 1.52 h
Ba134 stable 2.417
Ba135 1.2 d stable 6.592
Ba136 3.1E2 ms stable 7.854
Ba137 2.55 m stable 11.232
Ba138 stable 71.698
Ba139 1.38 h
Ba140 12.77 d
Ba141 18.27 m
Cs133 stable 100
Cs134 2.91 h 2.07 y
Cs135 53 m 2.3E6 y
Cs136 19 s 13.03 d
Cs137 30.06 y
Cs138 2.91 m 33.41 m
Cs139 9.27 m
Cs140 1.06 m
Xe132 8.39 ms stable 26.89
Xe133 2.19 d 5.24 d
Xe134 10.44 290 ms 1.1E16 y
Xe135 15.29 m 9.14 h
Xe136 8.87 2.1E20 y
Xe137 3.82 m
Xe138 14.08 m
Xe139 39.68 s
I131 8.02 d
I132 1.38 h 2.3 h
I133 9 s 20.8 h
I134 3.6 m 52.5 m
I135 6.57 h
I136 46.9 s 1.39 m
I137 24.51 s
I138 6.46 s

Decay Engine | Options

Quantity: Becquerel 1.57E+13 Accuracy Factor: 1E-02

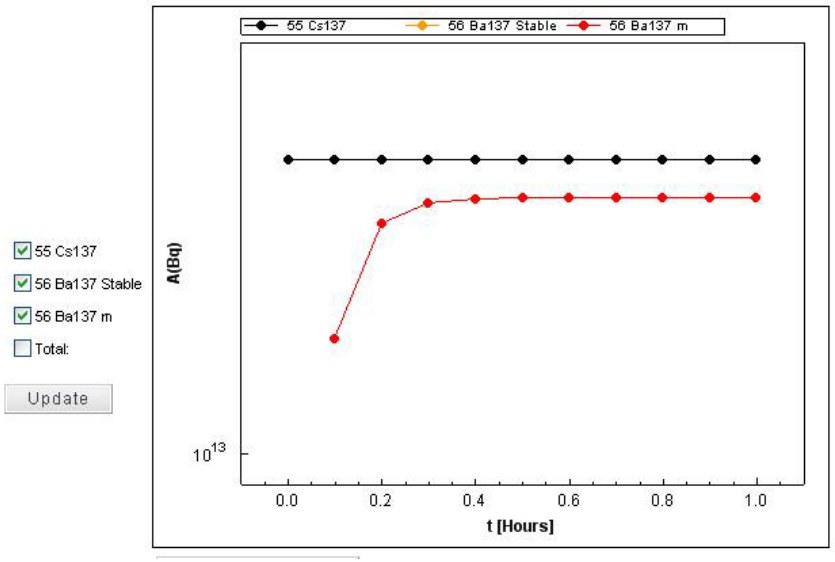
Time: Hours 1 Number of timesteps: 10 Number of chains: 2

Start | Start in background | Reset | Show details | Create Nuclide Mixture

Parent+Daughters	Half-life	N(atoms)	M(g)	A(Bq)	G(keV/s)	Sf Rate (/s)
55 Cs137	30.06 y	2.15E+22	4.88E+00	1.57E+13	2.58E+10	0
56 Ba137 Stable	stable	5.32E+16	1.21E-05	0	0	0
56 Ba137 m	2.55 m	3.27E+15	7.44E-07	1.48E+13	8.83E+15	0
Total:		2.15E+22	4.88E+00	3.05E+13	8.83E+15	0

Download | Excel | CSV | Separator: Semicolon (";") | Use field qualifier (")

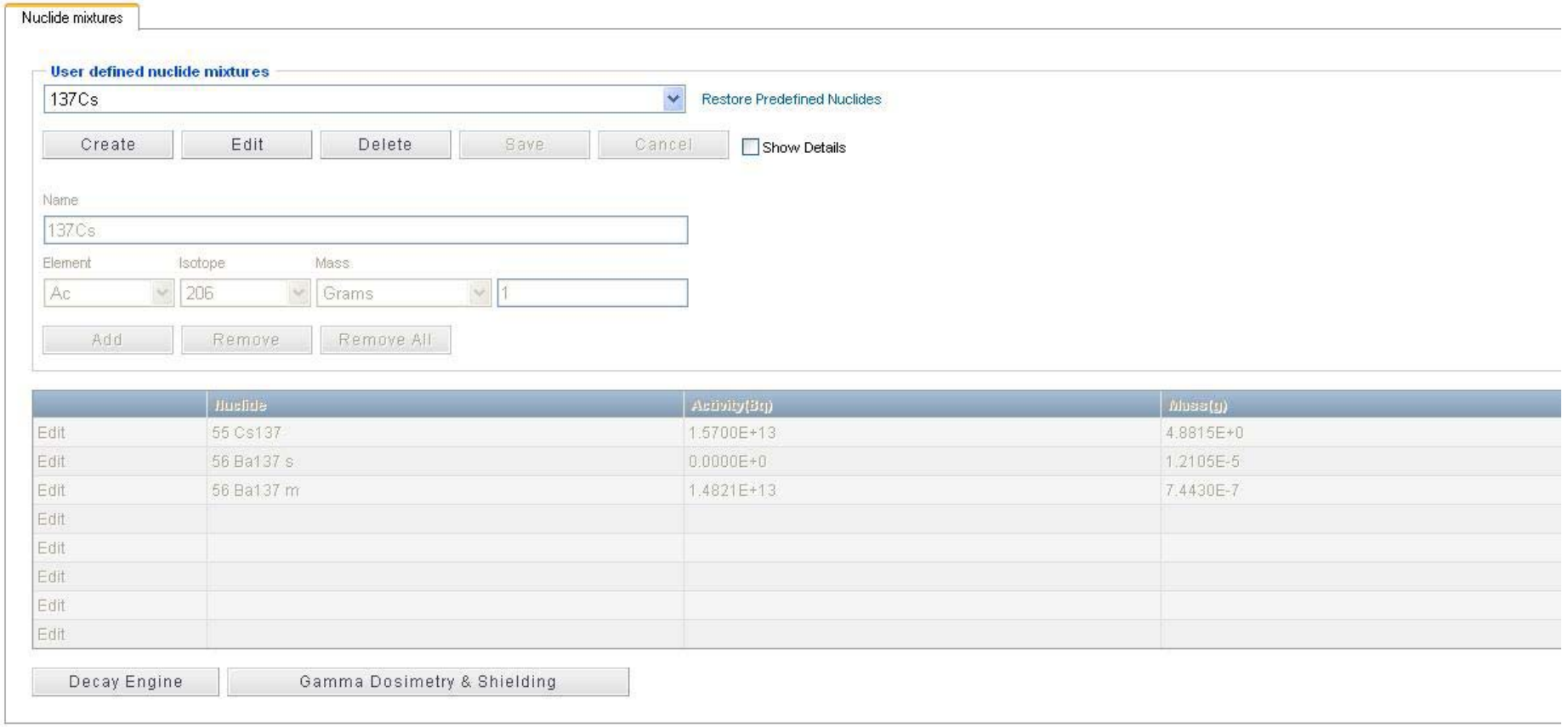
Type of graph: Activities



55 Cs137
56 Ba137 Stable
56 Ba137 m
Total:

Update

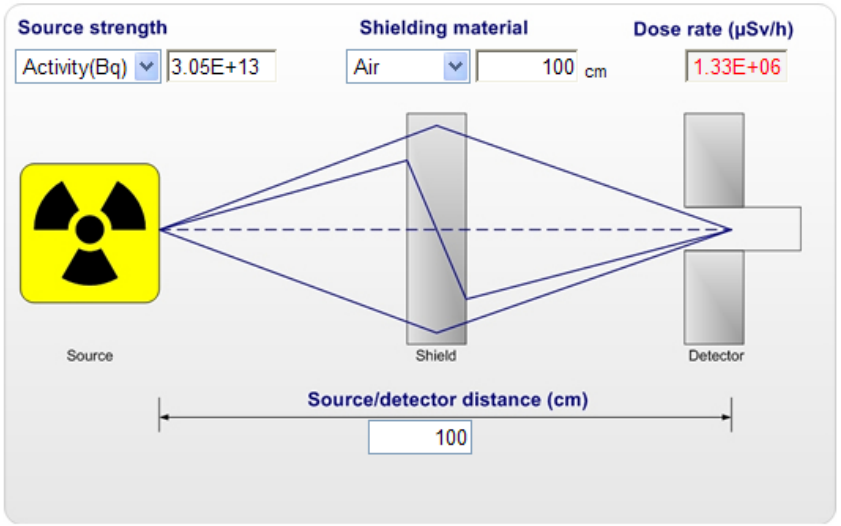
Nuclide mixtures



Nuclide Mixtures:

137Cs

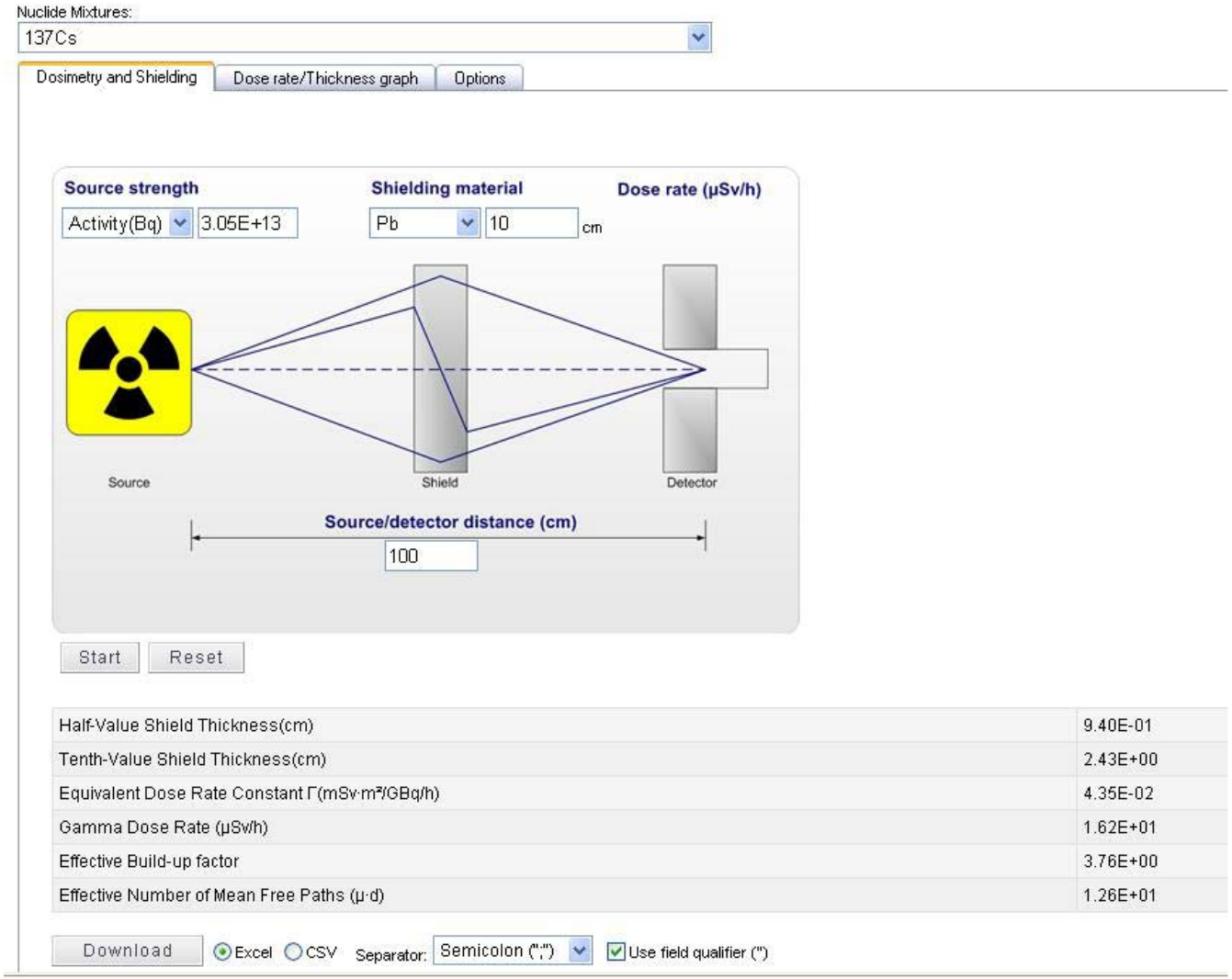
Dosimetry and Shielding | Dose rate/Thickness graph | Options



Start Reset

Half-Value Shield Thickness(cm)	2.59E+04
Tenth-Value Shield Thickness(cm)	5.50E+04
Equivalent Dose Rate Constant Γ(mSv·m²/GBq/h)	4.35E-02
Gamma Dose Rate (µSv/h)	**1.33E+06**
Effective Build-up factor	1.01E+00
Effective Number of Mean Free Paths (µ·d)	9.38E-03

Download ◉ Excel ○ CSV Separator: Semicolon (";") ☑ Use field qualifier (")


Nuclide Mixtures:
137Cs
Dosimetry and Shielding
Dose rate/Thickness graph
Options
Source strength
Shielding material
Dose rate (µSv/h)
Activity(Bq)
3.05E+13
Pb
10
cm
Source
Shield
Detector
Source/detector distance (cm)
100
Start
Reset
Half-Value Shield Thickness(cm) 9.40E-01
Tenth-Value Shield Thickness(cm) 2.43E+00
Equivalent Dose Rate Constant Γ(mSv·m²/GBq/h) 4.35E-02
Gamma Dose Rate (µSv/h) 1.62E+01
Effective Build-up factor 3.76E+00
Effective Number of Mean Free Paths (µ·d) 1.26E+01
Download
Excel
CSV
Separator:
Semicolon (";")
Use field qualifier (")