Case 3
Acute inhalation of ^{60}Co

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The event

- Preparation facility for ^{60}Co sources
- Irradiated capsule (containing 900 TBq of ^{60}Co) was opened in a hot cell. After 10 minutes dose rate alarms sounded.
- Operators closed the source and put on respirators and protective clothing.

Additional information

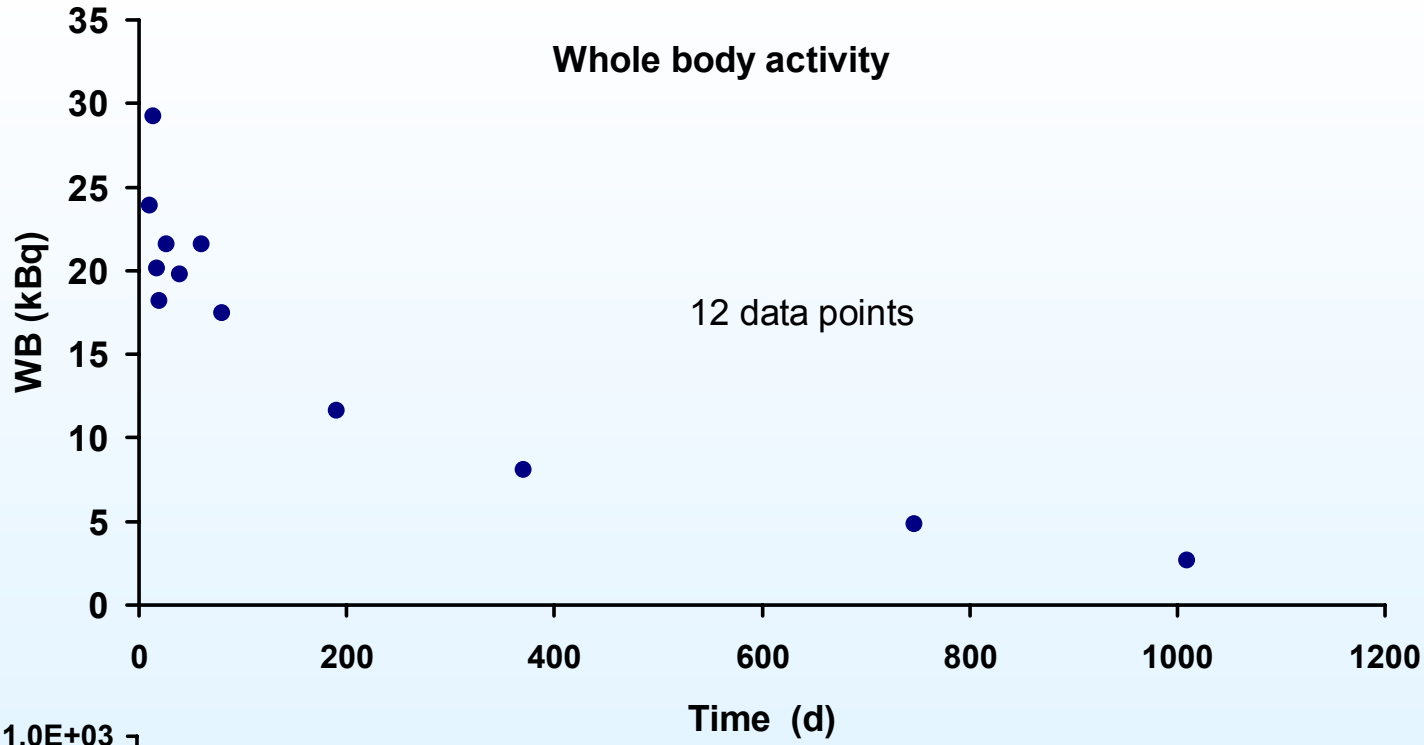
- Cobalt metal and/or oxide (temperature during irradiation about 300 - 400°C)

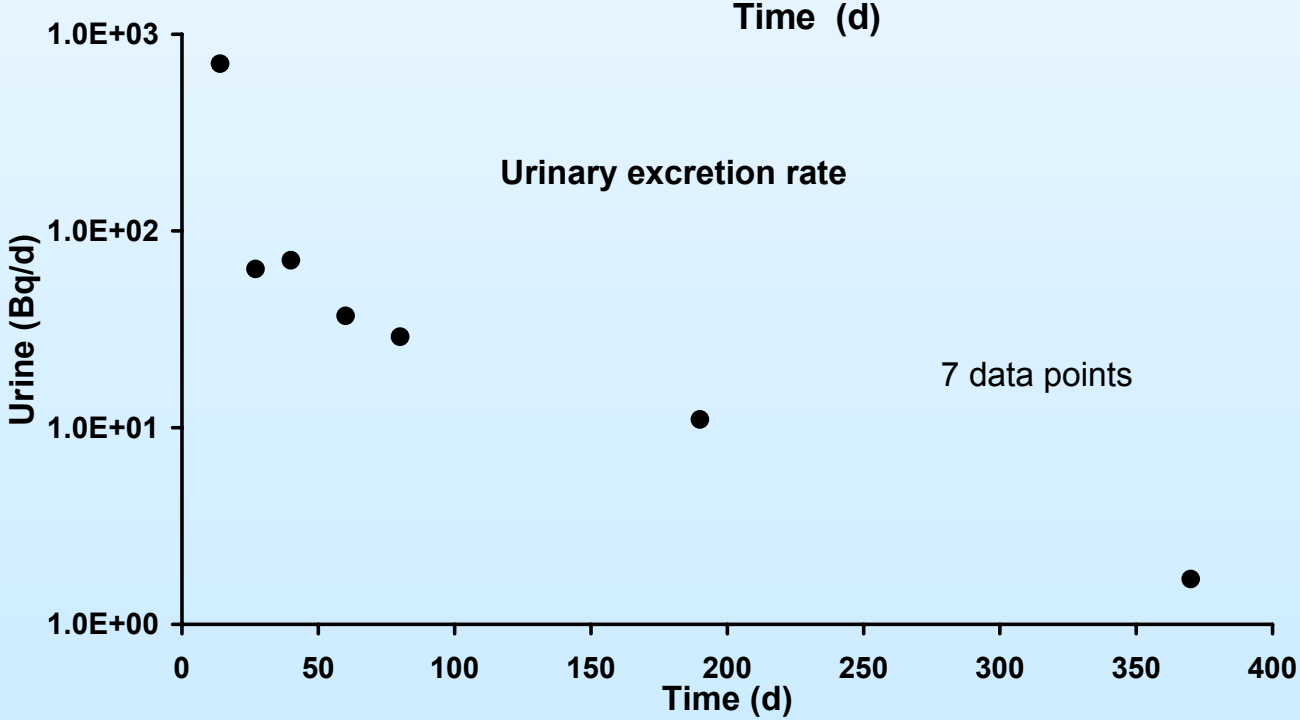
- Whole body measurements

  Assume measurements are lognormally distributed

  SF = 1.07 for Type A errors.
  SF = 1.18 for Type B errors.

- Urine measurements
  (Total SF = 1.8)


Whole body activity
WB (kBq)
35
30
25
20
15
10
5
0
12 data points
0
200
400
600
800
1000
1200
Time (d)


Urinary excretion rate
Urine (Bq/d)
1.0E+03
1.0E+02
1.0E+01
1.0E+00
7 data points
0
50
100
150
200
250
300
350
400
Time (d)

Hand calculation

$$\text{Intake, } I = \frac{M}{f(t)}$$

where f(t) is the predicted value for unit intake

- Whole body measurement at 10 days is $2.39\ 10^{4}$ Bq
- $f(t = 10d) = 6.5\ 10^{-2}$
  (ICRP 78, Inhalation, Type S, 5μm AMAD)

$$\textbf{Intake} \approx \frac{\mathbf{2.39\ 10^{4}}}{\mathbf{6.5\ 10^{-2}}} = \mathbf{3.7\ 10^{5}\ Bq = 370\ kBq}$$

Hand calculation

Intake ≈ 370 kBq

assuming inhalation, Type S and a 5μm AMAD

ICRP 68 dose coefficient for ^{60}Co is 1.7 10^{-8} Sv/Bq (inhalation, Type S; 5μm AMAD)

Effective dose of ≈ 6 mSv

'IDEAS' Evaluation

- Whole body data above critical monitoring value
- Special monitoring case
- Special evaluation for inhalation is needed (Flow chart 5)

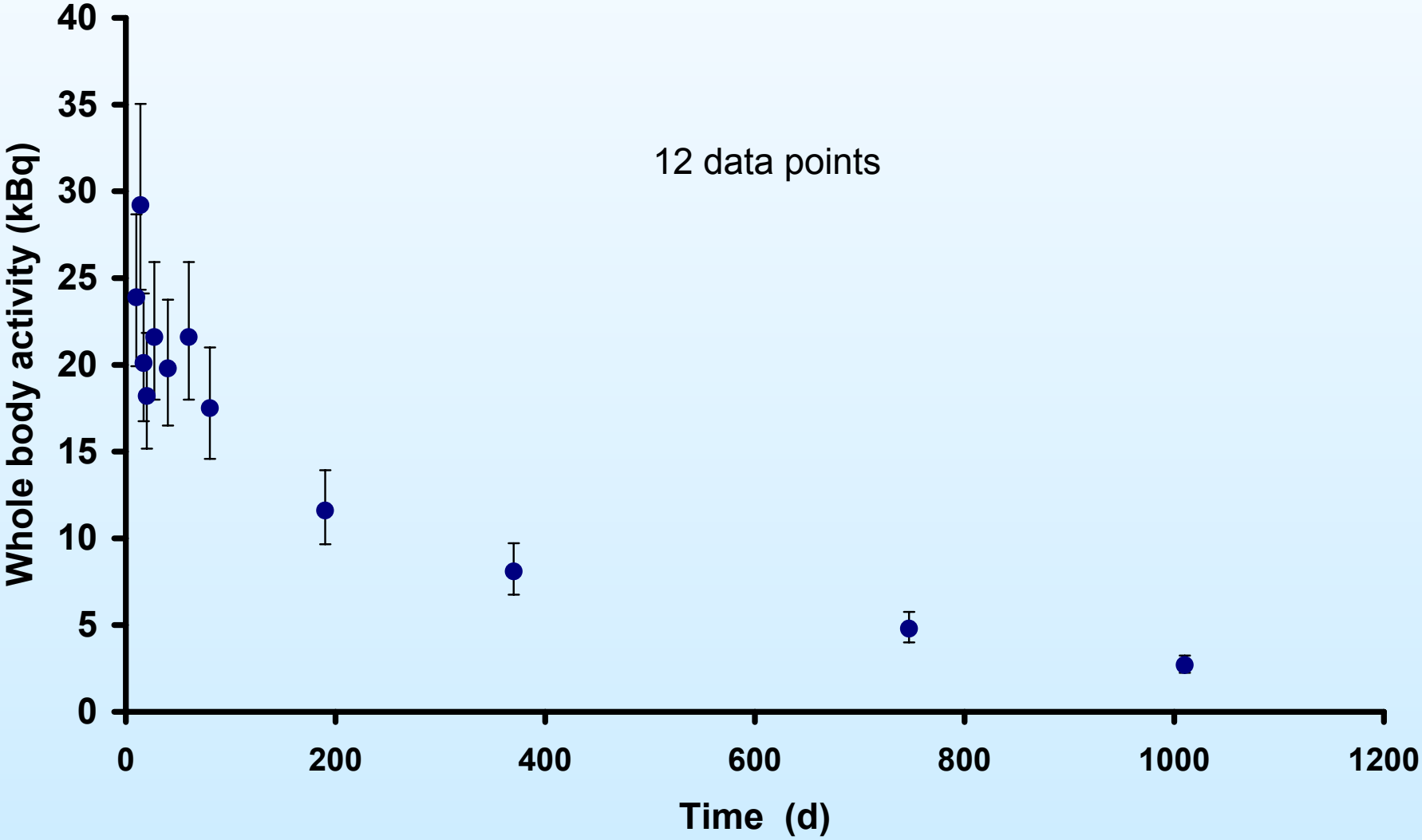
Step 5.1: Identification of data and assignment of realistic uncertainties

- Whole body measurements (12 data points)
  - **Lognormal distribution**
  - SF = 1.07 for Type A errors (counting errors).
  - SF = 1.18 for Type B errors (other errors such as calibration errors).

$$\text{Total SF} = \exp\left[\sqrt{\sum_i \ln^2(\text{SF}_i)}\right]$$

$$= 1.2$$

Whole body activity of ^{60}Co



Step 5.1: Identification of data and assignment of realistic uncertainties

- Urine measurements (7 data points)

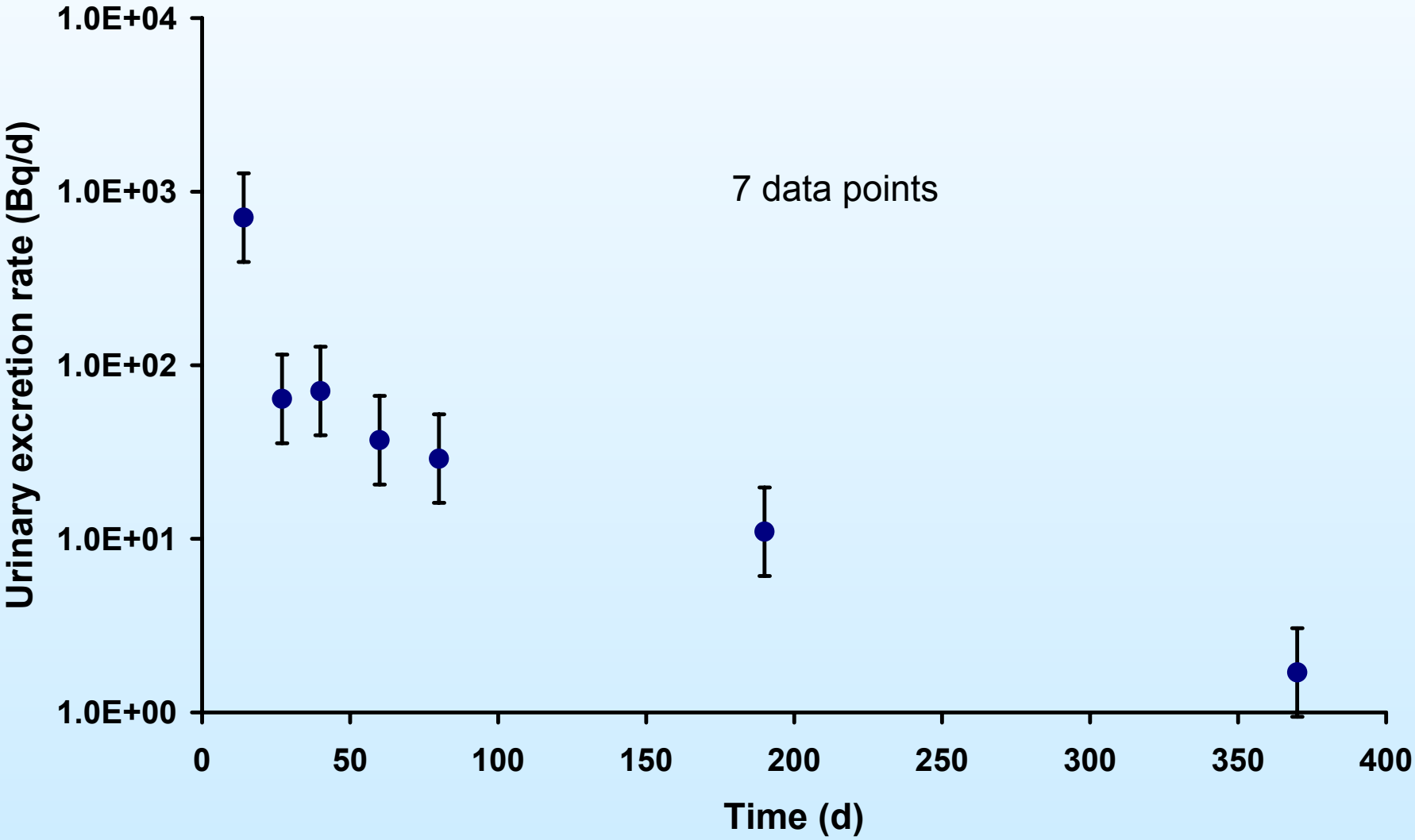
- Lognormal distribution with a total SF = 1.8

  Type A errors (i.e counting statistics errors)

  Type B errors due to:

  - calibration errors
  - biological variation
  - sampling procedures

Urinary excretion rate of ^{60}Co



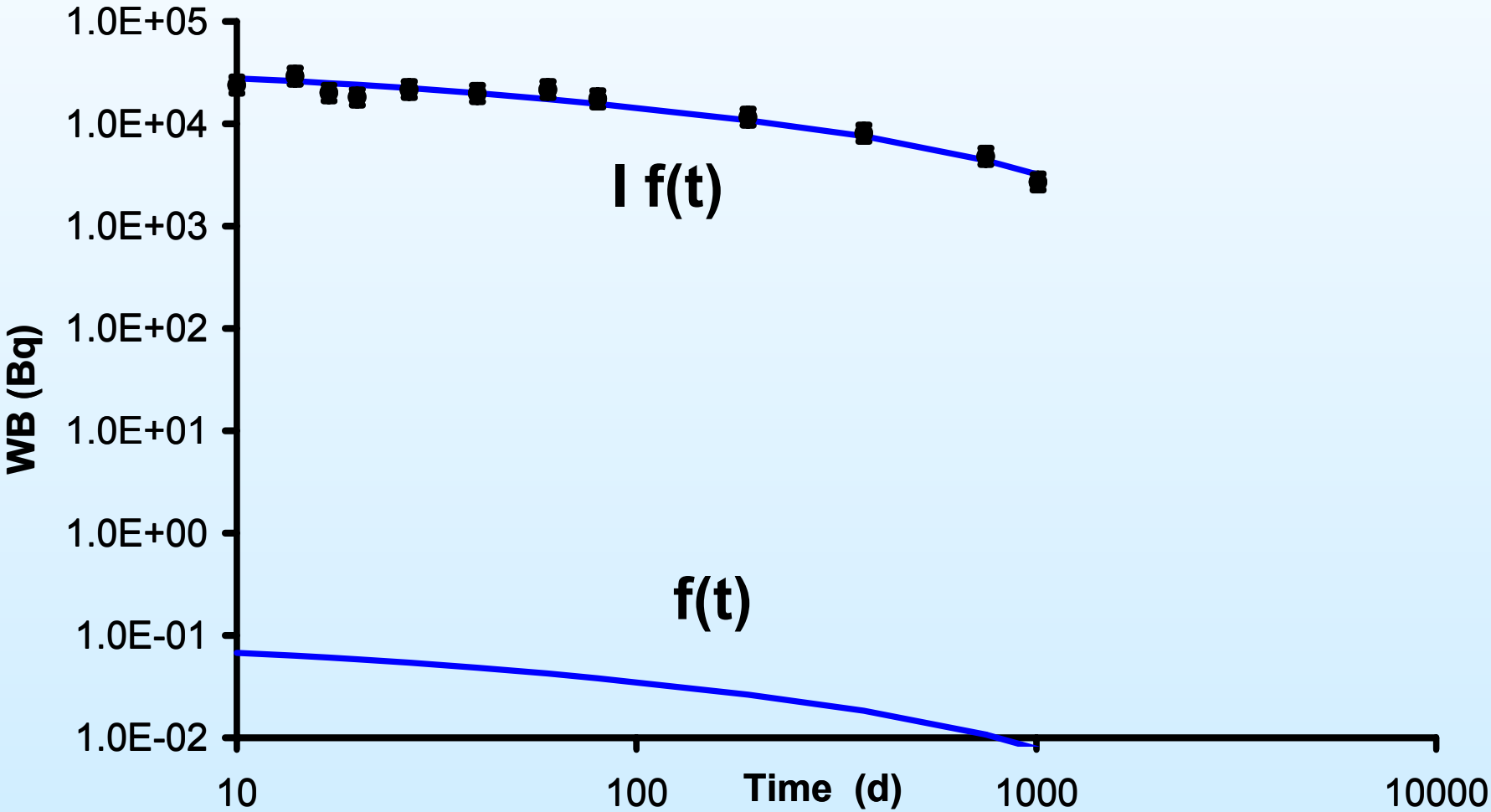
Step 5.1: Identification of data and assignment of realistic uncertainties

- Use both data sets to assess intake
- Use all the data to assess intake

Step 5.3: Assign default or site specific parameters

- 5 μm AMAD aerosol
- Absorption Type S (cobalt oxide)
- $f_1 = 0.05$
- Standard worker

Step 5.5: Calculate intake



Step 5.5: Calculate intake. (Maximum likelihood method)

- Probability of observing the measurements is calculated for a given intake. (Likelihood function)
  - Assume distribution of measurements
  - Lognormal distribution with a given SF
- Best estimate of intake is the intake for which the probability of observing the data is a maximum.

Maximum likelihood method (lognormal distribution of measurements)

- Calculate intake , I_i from each measurement value M_i:

$$I_i = \frac{M_i}{f(t_i)}$$

- where $f(t_i)$is the predicted value for unit intake of measured quantity.

- 19 intake estimates (12 from WB data and 7 from urine data).

Maximum likelihood method (lognormal distribution of measurements)

- Calculate best estimate of intake, I

$$\ln(I) = \frac{\sum_{i=1}^{N}\left(\frac{\ln(I_i)}{(\ln SF_i)^2}\right)}{\sum_{i=1}^{N}\frac{1}{(\ln SF_i)^2}}$$

I_i is the intake from each measurement value M_i

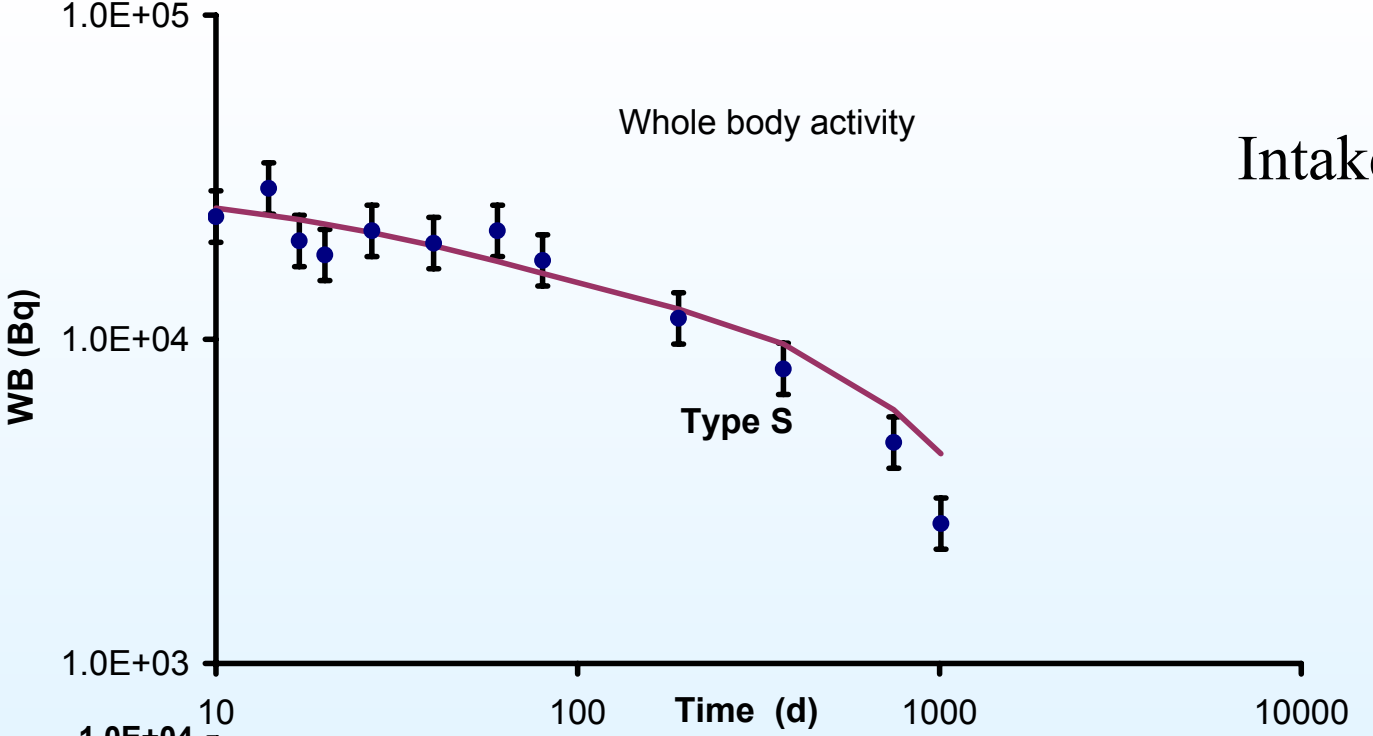
SF_i is scattering factor (geometric standard deviation)

Maximum likelihood method (lognormal distribution of measurements)

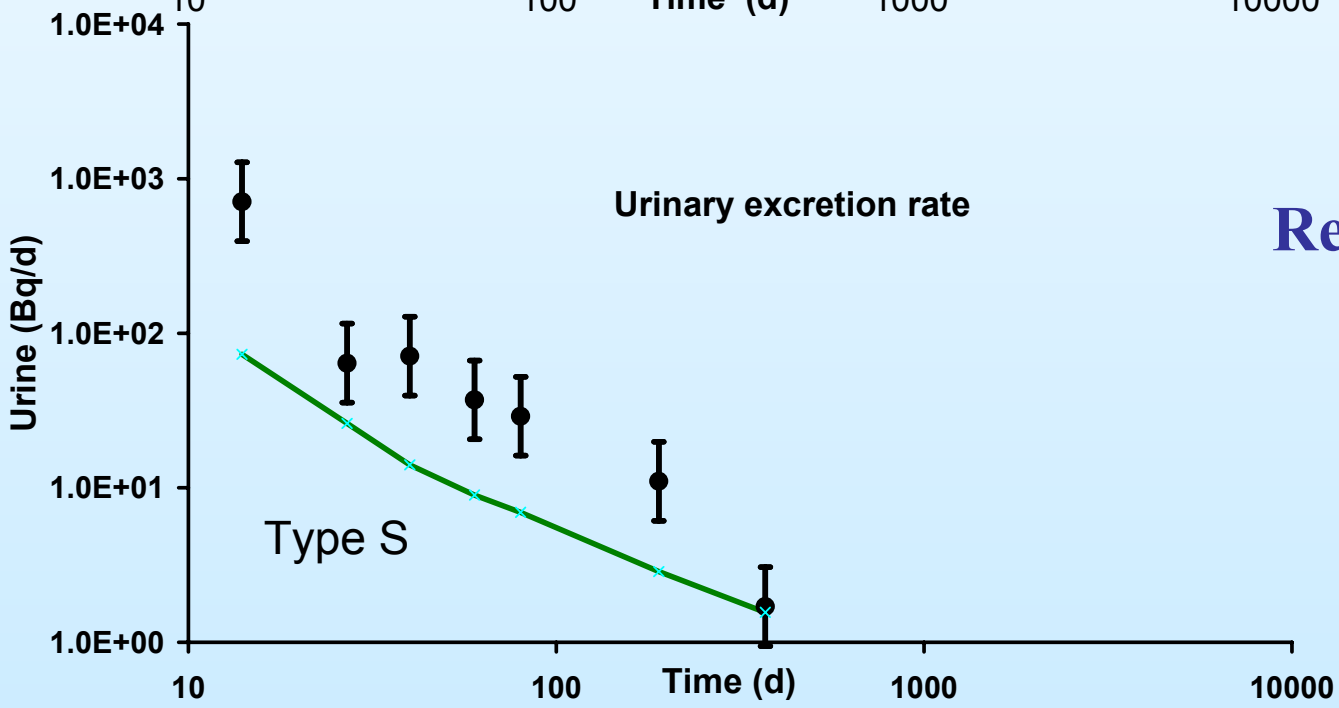
- Calculate best estimate of intake, I

$$\ln(I) = \frac{\sum_{i=1}^{12}\left(\frac{\ln(I_i)}{(\ln 1.2)^2}\right) + \sum_{j=1}^{7}\frac{\ln(I_j)}{(\ln 1.8)^2}}{\sum_{i=1}^{12}\frac{1}{(\ln 1.2)^2} + \sum_{j=1}^{7}\frac{1}{(\ln 1.8)^2}}$$

Whole body Urine



Intake = 389 kBq



Reject fits

Criteria for rejecting fit

Reject fit if:

- *Chi-squared* (χ^2) test fails

Or if

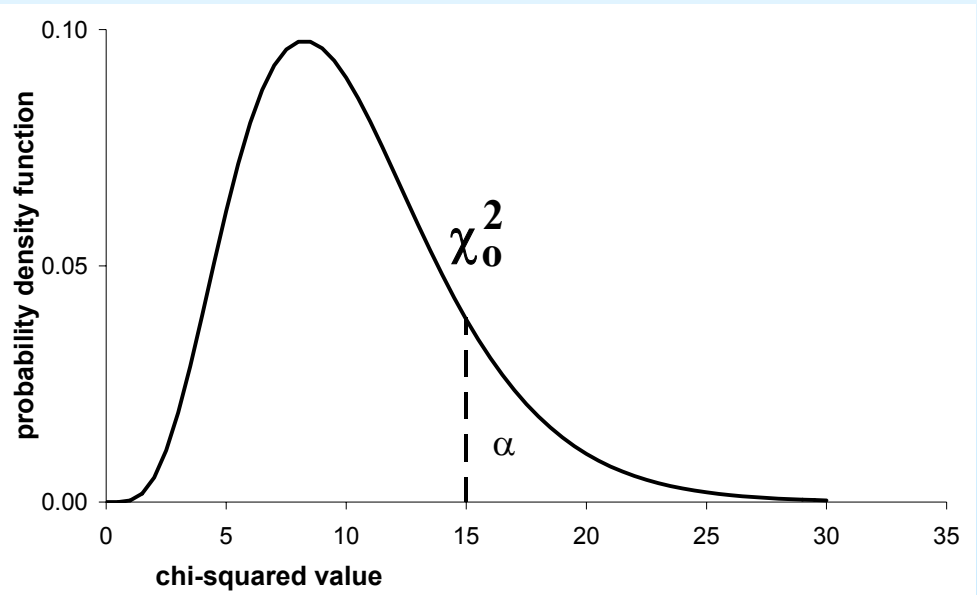
- the fit displayed graphically looks unreasonable by eye

Chi-squared test (χ^2)

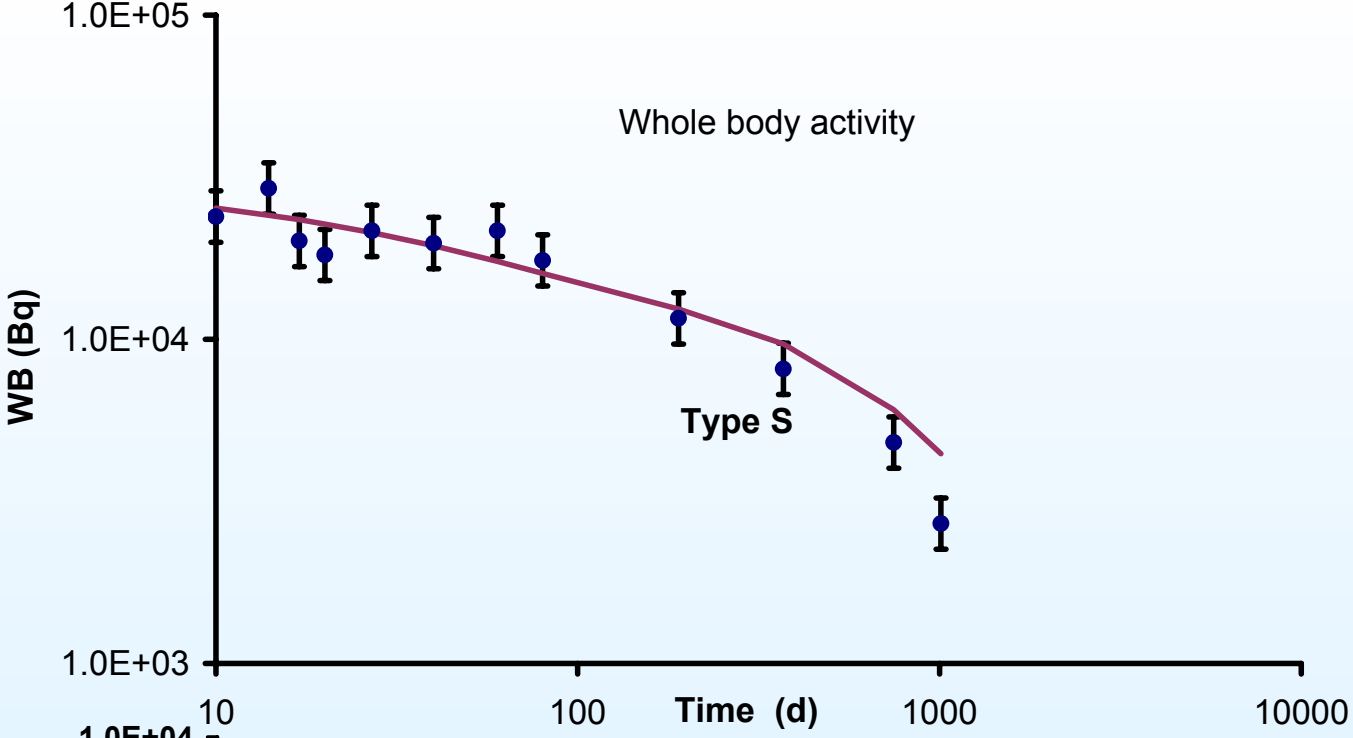
$$\chi_o^2 = \sum_{i=1}^{N} \left(\frac{\ln(M_i) - \ln[I f(t_i)]}{\ln(SF_i)} \right)^2$$

N-1 degrees of freedom

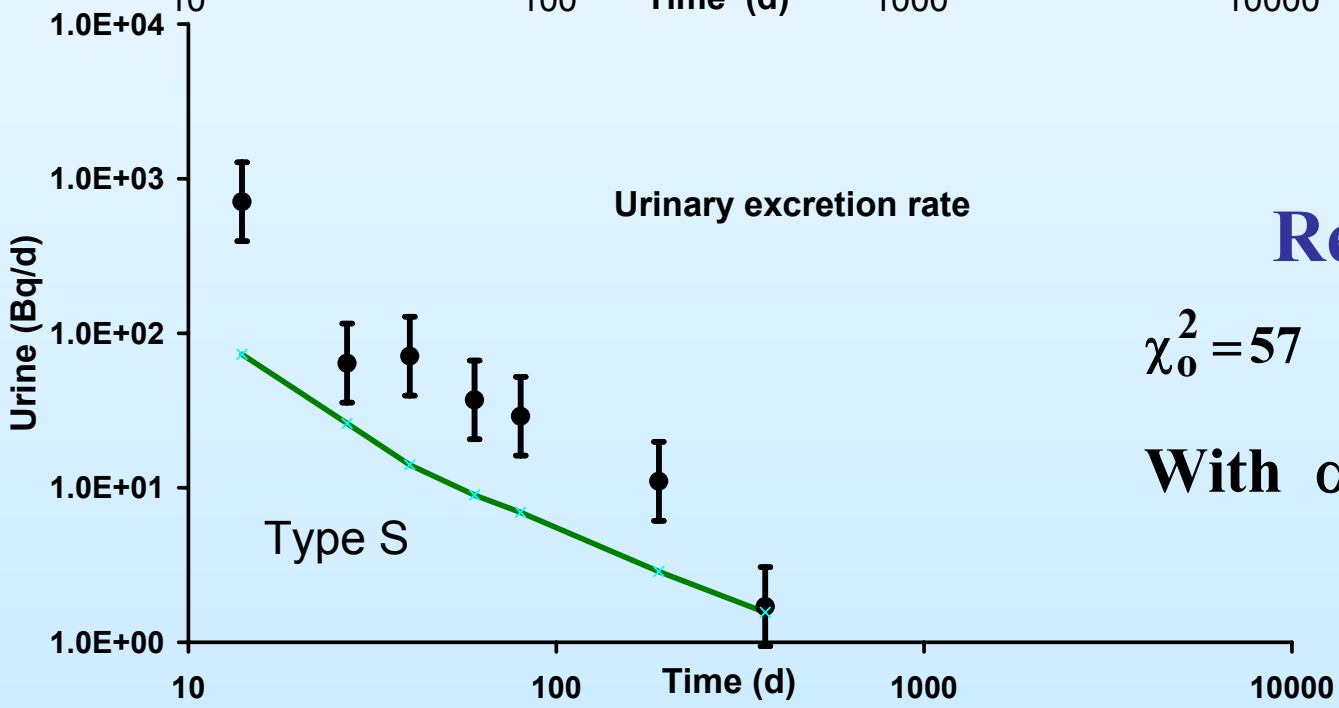
→ α-value



If α-value is less than 0.05 then reject fit



Type S



Reject fits

$\chi^2_o = 57$ N-1=18

With α-value = 0.000006

Step 5.5: Calculate dose with default or site specific parameters

- Type S (cobalt oxide) ; f_1 = 0.05
- 5 μm AMAD aerosol; standard worker

Intake is 389 k Bq

Dose coefficient 1.7E-8 Sv Bq^{-1}

(ICRP Publication 68)

Effective dose:

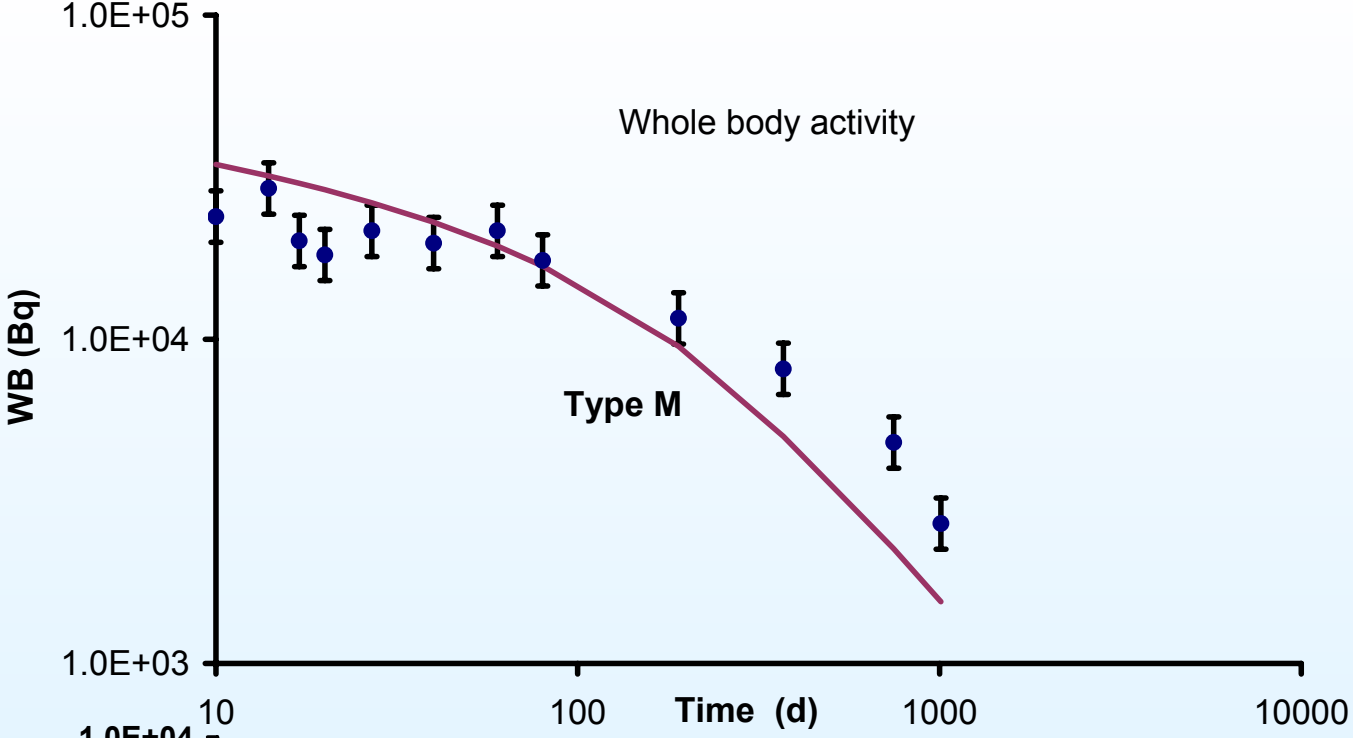
6.6 mSv

Inadequate fit to data

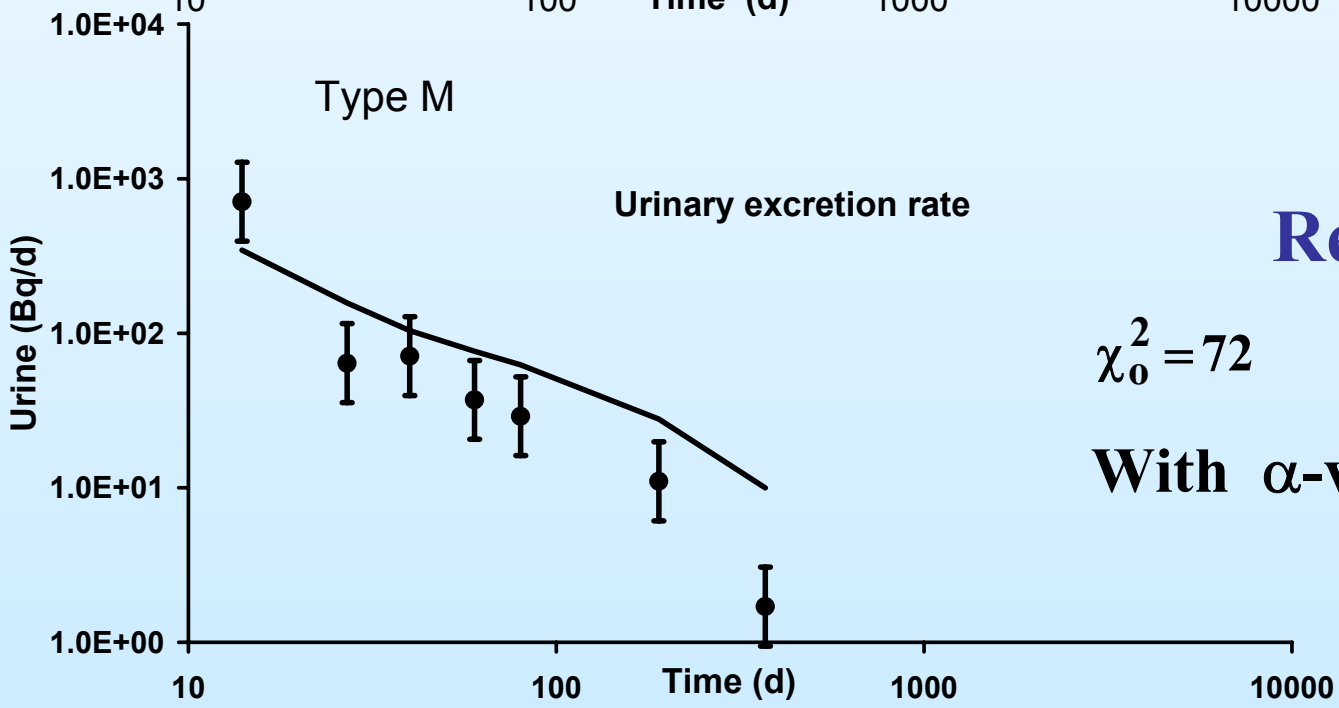
Reject model parameter values and proceed to next step

Step 5.11: Assessment of dose by fitting absorption Type

- Absorption Type M
- $f_1 = 0.10$
- 5 μm AMAD aerosol
- Standard worker



Type M



Reject fits

$\chi^2_o = 72$ N-1=18

With α-value = 0.00000002

Step 5.11: Calculate dose Type M

- Type M (cobalt oxide) ; f_1 = 0.1
- 5 μm AMAD aerosol; standard worker

Intake is 481 k Bq

Dose coefficient 7.1E-9 Sv Bq^{-1}

(ICRP Publication 68)

Effective dose:

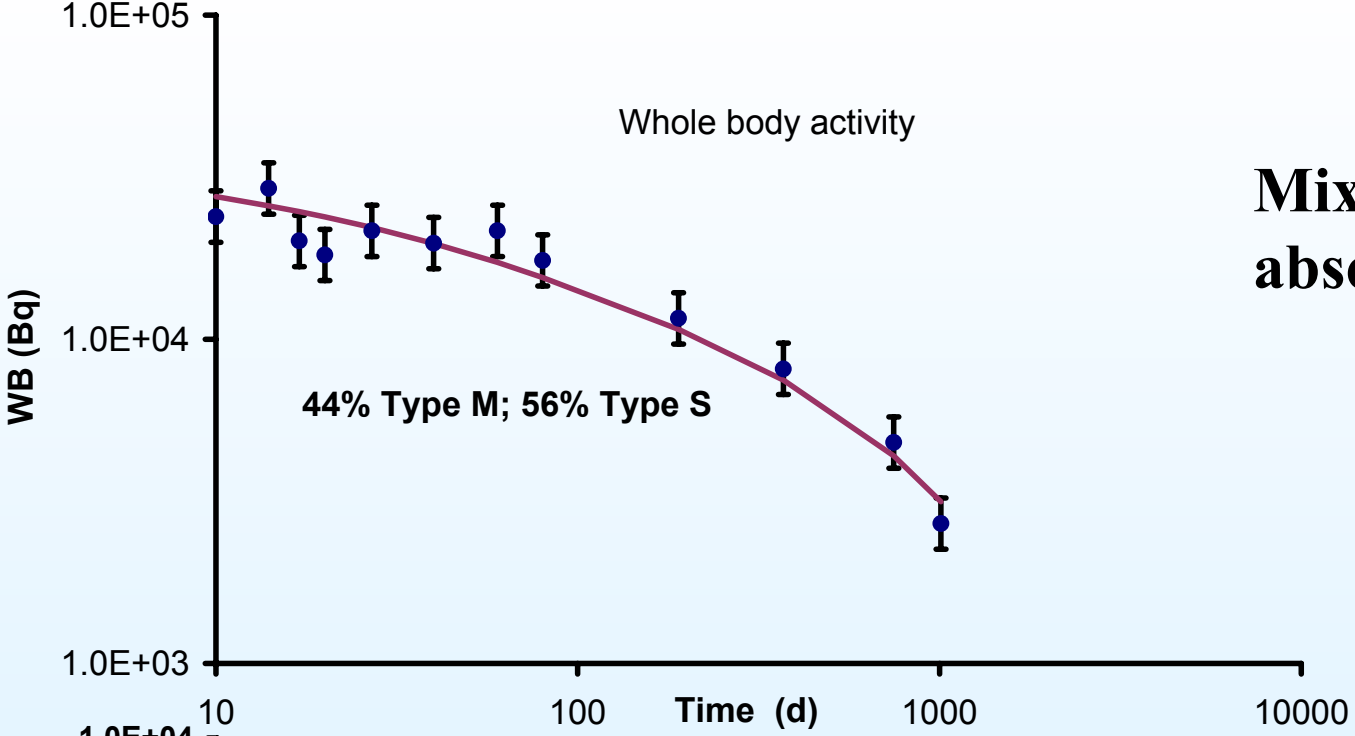
3.5 mSv

Inadequate fit to data

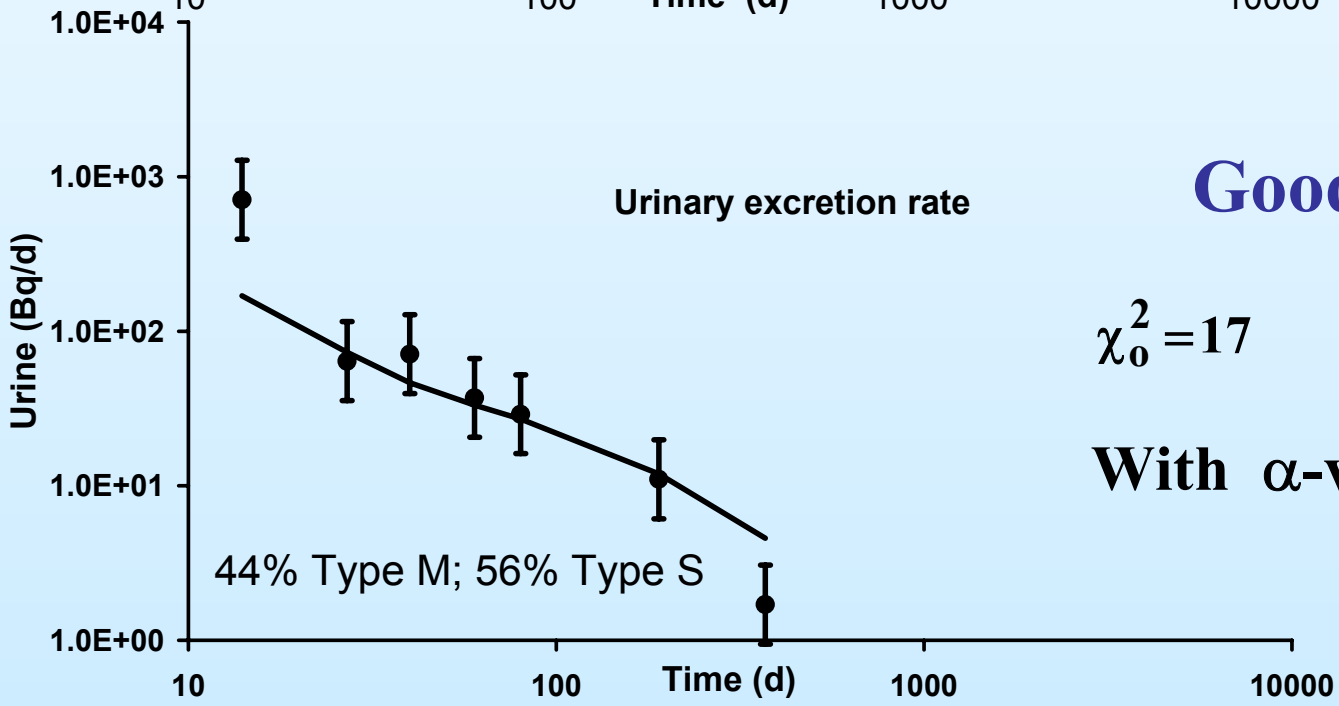
Reject model parameter values and proceed to next step

Step 5.13: Assessment of dose by fitting mixture of default absorption Types

- Mixture of Absorption Types M and S
  - **44% Type M; 56% Type S**
- f_1 = 0.10 (Type M); f_1 = 0.05 (Type S)
- 5 μm AMAD aerosol
- Standard worker



Mixture of absorption Types



Good fits

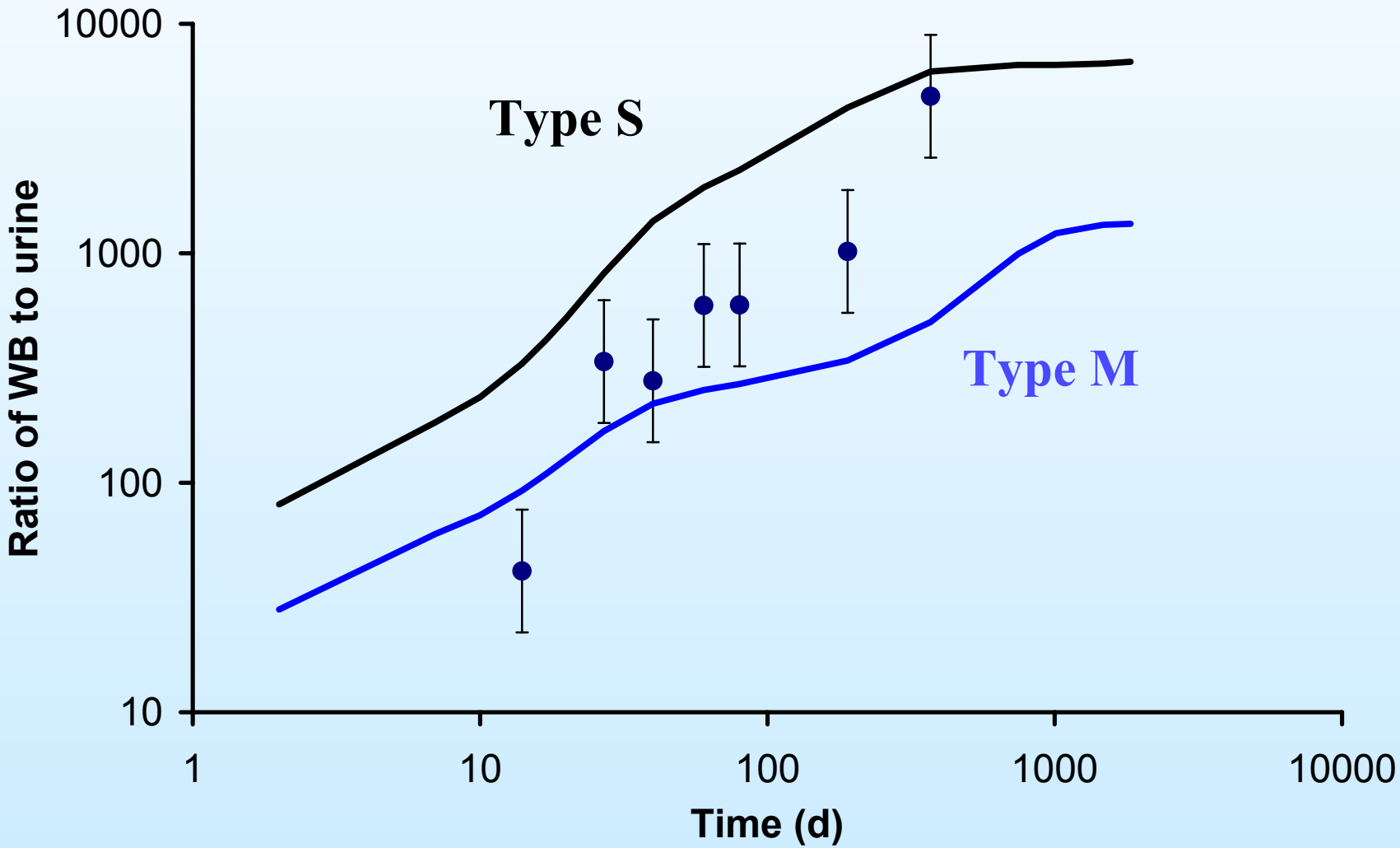
$\chi_o^2 = 17$ N-1=18

With α-value = 0.5

Step 5.15.1
Record dose with all parameter values

- Intake 404 kBq of Co-60
- Effective dose 5.0 mSv
- Parameters:
  - Mixture of Absorption Types M and S
    - **44% Type M; 56% Type S**
  - f_1 = 0.10 (Type M); f_1 = 0.05 (Type S)
  - 5 μm AMAD aerosol
  - Standard worker

Ratio of whole body activity to daily urine excretion activity



Summary of assessment

Absorption Type S

Data set used	Goodness of fit	Intake (kBq)	Effective dose (mSv)
WB & Urine	**Reject fits and proceed to next step**		**6.4**
WB only			6.0
Urine only		1418	23.4

Summary of assessment

Absorption Type M

Data set used	Goodness of fit	Intake (kBq)	Effective dose (mSv)
WB & Urine			**3.4**
WB only	**Reject fits and proceed to next step**	500	3.6
Urine only		244	1.7

Summary of assessment

Mixture of absorption Types: 44% Type M; 56% Type S

Data set used	Goodness of fit	Intake (kBq)	Effective dose (mSv)
WB & Urine	**Good**	**404**	5.0
Urine only	**Best estimate of intake and dose**	455	5.6

Artificially generated data

Intake:	400 kBq
AMAD:	5 μm
Absorption Type:	50% Type M; 50 Type S
Whole body data:	Lognormal; σ_g = 1.2
Urine data:	Lognormal; σ_g = 1.8
Effective dose:	4.7 mSv

'IDEAS Assessment':

Intake:	404 kBq
Absorption Type:	44% Type M; 56% Type S
Effective dose:	5.0 mSv