IAEA
International Atomic Energy Agency
Atoms for Peace and Development

ASSESSMENT OF OCCUPATIONAL EXPOSURE DUE TO INTERNAL RADIATION SOURCES

UNIT 9

ASSESSMENT OF INTAKE AND DOSES DUE TO INTERNAL EXPOSURES.

INTERPRETATION OF MONITORING DATA

ASSESSMENT OF INTAKE AND DOSES

CONTENT OF LECTURE

- **INDIVIDUAL MONITORING DATA**
  - ✓ Measurement of the activity retained in total/partial body
  - ✓ Measurement of activity concetration in excreta samples

– **ASSESSMENT OF INTAKE AND DOSE FROM MONITORING DATA- STRUCTURED APPROACHES TO INTERNAL DOSE ASSESSMENT:**
  - ✓ ISO Standard 27048, IDEAS Guidelines (EURADOS Report 2013-01)
  - ✓ EC RP 188 – Technical Recommendations, ICRP/OIR Reports

CONTENT OF LECTURE (CONT.)

- **ASSESSMENT OF INTAKE AND DOSE. INTERPRETATION OF MONITORING DATA**
  - ✓ Intake estimation
    - Single monitoring data
    - Multiple monitoring data. Uncertainties of monitoring data
    - Data fitting. Criteria for rejecting the fit of monitoring data with the retention/excretion model
  - ✓ Assessment of the Committed Effective Dose

ASSESSMENT OF INTAKE AND DOSES

- ## INDIVIDUAL MONITORING DATA

✓ The **doses due to intakes of radionuclides** can not be obtained directly, but must be assessed from:

  - In vivo measurement of the activity retained in total/partial body M(Bq)
  - In vitro measurement of activity concetration in excreta samples M(Bqd^{-1}, BqL^{-1})
  - Workplace monitoring, air sampling: measurement of activity concetration in air M(Bqm^{-3})

✓ The interpretation of individual (in vivo and in vitro) monitoring data **for the assessment of Intake I(Bq) and Committed Effective Dose E(50) Sv**

  - requires the application of biokinetic and dosimetric models (ICRP)
  - the evaluator needs to know or to make assumptions about:
    - Type of intake (acute, chronic),
    - Pathway of intake (inhalation, ingestion, injection, intact skin, wound)
    - Time of intake (elapsed time from the exposure and the measurement)
    - Physical (e.g. particle size) and chemical properties of internal contaminants

ASSESSMENT OF INTAKE AND DOSES

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- **COLLECTION, HANDLING AND PROCESSING OF MONITORING DATA**

✓Occupational Internal Dosimetry

1.- Characterization of internal exposure at the workplace

- Information to be provided (e.g. by the Radiation Protection Officer)

2.- Design of Individual Monitoring Programmes – internal exposures

- Selection of the Monitoring Techniques + monitoring period
- Selection of the workers to be included in the monitoring programmes

3.- Individual Monitoring of workers:

- Direct and Indirect techniques.
- Identification and quantification of incorporated radionuclides.
- Monitoring Data M(Bq), M(Bqd^{-1}, BqL^{-1})

4.- Assessment of intake and committed effective dose E(50)

- Interpretation of Monitoring Data
- Step by step procedure: calculation Intake I (Bq) and dose E(50) Sv
- ICRP Data viewer and available commercial software

ASSESSMENT OF INTAKE AND DOSES

- **INDIVIDUAL MONITORING DATA**

  ✓ Dietary intakes of naturally occurring radionuclides

  - Radionuclides from the three natural radioactive decay series of ^{238}U, ^{235}U and ^{232}Th are present in food, water and air leading to intakes by humans
  - Daily intakes of these nuclides depends on food diet and drinking water.
  - **For workers exposed to Naturally Occurring Radioactive Materials (NORM)** it is needed **to distinguish between non-occupationally intakes and occupation intakes**.

    - Take **'blank' bioassay samples** from:
      - worker at beginning of employment, or
      - non-occupationally exposed workers, or
      - The population living in the same area.

    - **Subtract blank sample activity from corresponding occupational monitoring measurements**

ASSESSMENT OF INTAKE AND DOSES

- **INDIVIDUAL MONITORING DATA**

✓**Uranium daily intake**

Comparison of the estimated daily intake (µg U/day) in different countries

Country	Total intake (µg U/day)	Source of U-intake
Brazil (Sao Paulo)[a]	0.97	Mean value of U-content in various food type
USA (New York)[b]	1.30	
USA (Chicago)[c]	1.40	
USA (San Francisco)[c]	1.30	
United Kingdom[d]	1.00	
Japan(Yokohama)[e]	0.10	
Vietnam[f]	0.70	
Italy[g]	3.90	Mean value of food diet and drink water
Poland[h]	1.80	
Ukraine[i]	0.60	
Japan[j]	0.70	
India[k]	2.20	
Hong Kong[l]	15.30	
France[m]	1.00	
Russian Federation[m]	3.50	
Worldwide[m]	1.30	
Worldwide[m]	1.30	

Range 0.1 – 15.3 µg

[A] Garcia et al. (2006)
[B] Fisenne et al. (1987).
[C] Welford and Baird (1967).
[D] Hamilton (1972).
[E] Kuwahara et al. (1997).
[F] Giang et al. (2001).
[G] Galletti et al. (2003).
[H] Pietrzak-Flis et al. (2001).
[I] Shiraishi et al. (1997).
[J] Shiraishi et al. (1992).
[K] Dang et al. (1992).
[L] Yu and Mao (1999).
[M] UNSCEAR (2000).

Taken from F. Garcia et al. / Environment International 32 (2006) 697–703

ASSESSMENT OF INTAKE AND DOSES

- **INDIVIDUAL MONITORING DATA**

  ✓ **Uranium intake in the diet:**

  Background uranium activity concentration in urine.
  Ref. IDEAS Guidelines (EURADOS Report 2013-01)

IDEAS Guidelines (Version 2) for the Estimation of Committed Doses from Incorporation Monitoring Data

Table 4.1. Background uranium activity concentration in urine.

^{234}U (mBq/d)		^{238}U (mBq/d)		Comments	Reference
Mean	Range	Mean	Range		
1.41	0.25 - 2.5	1.30	0.17 - 2.6	control subjects US	Fisher 1983
0.89		0.52		dietary study UK	Spencer 1990
		0.46		non-occupationally exposed volunteers US	Wrenn 1992
		0.26		normal background environment, IN	Dang 1992
0.23	0.056 - 2.7	0.20	0.051 - 0.94	worker potentially exposed, Mol, BE	Hurtgen 2001
		8437	20 - 112000	population from Southern Finland	Kurttio 2002
		3.95	0.23 - 15.2	unexposed subjects, JO	Al-Jundi 2004
0.46	0 - 2.5	0.41	0 - 3.0	Dounreay not exposed to uranium UK	Spencer 2007
		0.17	0.037 - 0.29	unexposed subjects from South of DE	Oeh 2007
		0.17	0.032 - 0.44	general population CZ	Malatova 2011
		0.53	0.19 - 1.26	U worker family CZ	Malatova 2011

Data given in mass have been recalculated and expressed in mBq/d for ^{238}U. The daily urinary excretion has been taken as 1.6 L (ICRP2002a).

Taken from Table 4.1 IDEAS Guidelines V2, EURADOS Report 2013-01

ASSESSMENT OF INTAKE AND DOSES

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- **INDIVIDUAL MONITORING DATA**

✓ **Uranium intake in the diet:**

Background uranium activity concentration in feces
Ref. IDEAS Guidelines (EURADOS Report 2013-01)

Table 4.2 Background uranium activity concentration in faeces.

^{234}U (mBq/d)		^{238}U (mBq/d)		comments	Reference
Mean	Range	Mean	Range		
37		26		dietary study, US	Spencer 1990
		17.4	5.0 - 27	persons in the Berlin area, DE	Naumann 1998
14	9.2 – 19.2	13.5	8.0 – 18.0	Poços de Caldas, BR	Taddei 2001
32	7.3 - 225	22	3.8 - 170	worker potentially exposed, BE	Hurtgen 2001
46		47		Buena, BR	Juliao 2003
32		28.5		Rio de Janeiro, BR	Juliao 2003

Taken from Table 4.1 IDEAS Guidelines V2, EURADOS Report 2013-01

ASSESSMENT OF INTAKE AND DOSES

- **INDIVIDUAL MONITORING DATA**

Taken from Table 4.3 IDEAS Guidelines V2, EURADOS Report 2013-01

✓ **Thorium intake in the diet:**

Background Thorium activity concentration in urine and feces
IDEAS Guidelines (EURADOS Report 2013-01)

Table 4.3 Background thorium activity concentration in urine

^{228}Th (mBq/d)		^{230}Th (mBq/d)		^{232}Th (mBq/d)		Comments	Reference
Mean	Range	Mean	Range	Mean	Range		
				0.03		urine natural background (DE)	Dalheimer 1994
				2.1		daily excretion in Buena (BR)	Juliao 1998
0.63	0.19 - 2.6	0.53	0.11 - 3.7	0.23	0.11 - 0.50	worker not exposed to Th, (BE)	Hurtgen 2001
				0.007		unexposed adult (DE)	Roth 2005

Table 4.4. Background thorium activity concentration in faeces.

^{228}Th (mBq/d)		^{230}Th (mBq/d)		^{232}Th (mBq/d)		Comments	Reference
Mean	Range	Mean	Range	Mean	Range		
				12		faeces natural background (DE)	Dalheimer 1994
23	11 - 39	9.8	1.7 - 16	5.4	1.6 - 12	persons in the Berlin area (DE)	Naumann 1998
				30	5.6 - 104	daily excretion in Buena (BR)	Juliao 1998
35	5.8 - 161	7.7	1.87 - 31	3.4	0.97 - 22	worker not exposed to Th (BE)	Hurtgen 2001
290	218 - 442	12.4	7.5 - 17.5	7.4	4.5 - 12.0	Poços de Caldas (BR)	Taddei 2001
947				26		inhabitants of Buena (BR)	Juliao 2003
60				10		inhabitants of Rio de Janeiro(BR)	
		4.1	1.0 - 34			general population (DE)	Schäfer 2006

Taken from Table 4.4 IDEAS Guidelines V2, EURADOS Report 2013-01

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- **INDIVIDUAL MONITORING DATA**
  - ✓ **Background subtraction**

    ISO 16638-1: 2015 requires that:

    - Natural background due to dietary intakes should be subtracted from the measurement data

    But

    - It shall be demonstrated that the reference value is representative of the natural background level for the worker to whom is it applied.

INTERNATIONAL STANDARD

ISO 16638-1

First edition
2015-12-15

Radiological protection — Monitoring and internal dosimetry for specific materials —

Part 1:
Inhalation of uranium compounds

Radioprotection — Contrôle et dosimétrie interne des éléments spécifiques —

Partie 1: Inhalation de composés d'uranium

ASSESSMENT OF INTAKE AND DOSES

- **INDIVIDUAL MONITORING DATA**

✓ **Isotopic ratios of the natural occurring contaminant** is helpful information

- ^{234}U /^{238}U activity ratio is about **1.7** (in urine and faeces) - (Hurtgen, 2001)
  Compared with values for enriched uranium (7) and depleted uranium (0.1)

- The isotopic ratio ^{234}U /^{238}U in excreta sample can be directly correlated to the ratio in the drinking water - (Hurtgen, 2001)

- ^{228}Th /^{232}Th activity ratio can vary between individuals and is between 2.3 and 10 (in urine and faeces) – (Karpas et al. 2005)

ASSESSMENT OF INTAKE AND DOSES

- **INDIVIDUAL MONITORING DATA**

  - ✓ **Urine measurements**

    - The activity excreted over a 24 hour period is required for comparison with ICRP model predictions. Monitoring data: Activity in the sample (Bq), Collection period (h)

    - Samples collected over periods less than 24 h should be normalised to an equivalent 24 h value, following ICRP Publication 89:

      - **Normalise to volume**:
        reference daily values are 1.6 litres male, 1.2 litres female
      - **Normalise to amount of creatinine:**
        reference daily values are 1.7 g male, 1.0 g female

ASSESSMENT OF INTAKE AND DOSES

- **INDIVIDUAL MONITORING DATA**

  ✓ **Faecal measurements**

  Faecal samples are generally collected if the material is relatively insoluble.

  - The activity excreted over a 24 hour period is required for comparison with ICRP model predictions. Monitoring data: Activity in the sample (Bq), Collection period (h)

  - If the sample is less than 60 g then normalisation should be considered, following ICRP Publication 89:

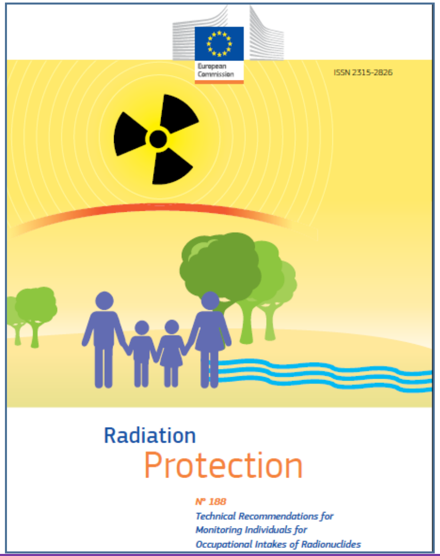
    Reference values are: 150 g male, 120 g female

  - **Variability** - large subject variations for transit times through gastrointestinal tract.

    - Excretion in the first few days after intake is **very** variable but correlated.
    - **It is therefore recommended to use cumulative excretion over 0-3 days.**

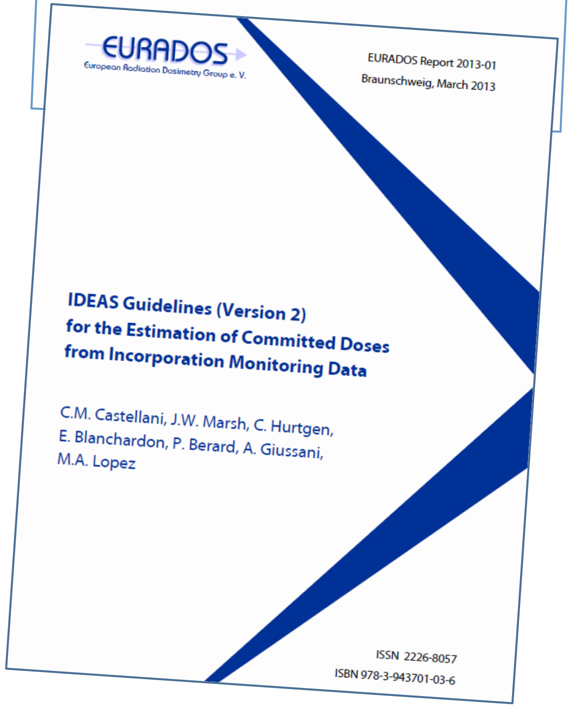
ASSESSMENT OF INTAKE AND DOSES

– ASSESSMENT OF INTAKE AND DOSE FROM MONITORING DATA-STRUCT APPROACHES TO INTERNAL DOSE ASSESSMENT:



EC RP 188 - Technical Recommendations for Monitoring Individuals for Occupational Intakes of Radionuclides (ec.europa.eu/energy/sites/ener/files/rp_188.pdf)

- ✓ **ISO Standard 27048:** Dose Assessment for the monitoring of workers for internal radiation exposure
- ✓ **IDEAS Guidelines** (EURADOS Report 2013-01): General Guidelines for the Estimation of Committed Effective Dose from Incorporation monitoring data
- ✓ **EC RP 188** – Technical Recommendations for monitoring individuals for occupational intakes of radionuclides



ASSESSMENT OF INTAKE AND DOSES

- **ICRP Reference documents –**

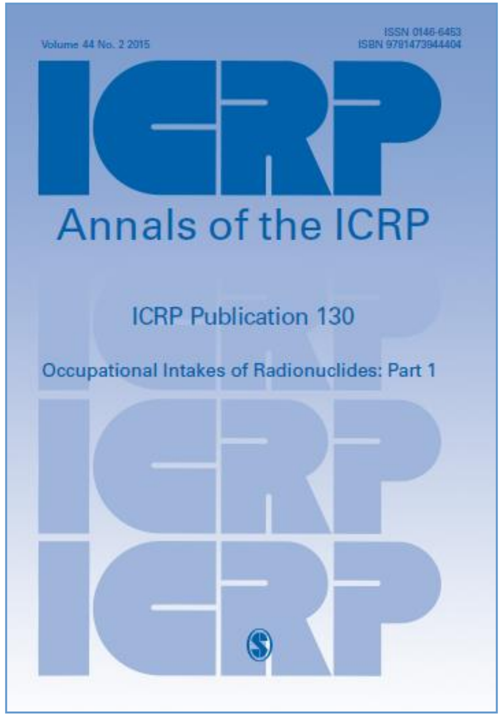
✓ Assessment of **Committed Effective Dose E(50) Sv <u>for workers</u>**

- **ICRP Publications 78, 68, 119** (based on **ICRP 60 recommendations**)

- **ICRP OIR (Occupational Intakes of Radionuclides) reports**, **Parts I-V** (based on **ICRP 103 recommendations**)
  - ✓ OIR Part 1- ICRP Publication 130
  - ✓ OIR Part 2 - ICRP Publication 134
  - ✓ OIR Part 3 - ICRP Publication 137
  - ✓ OIR Part 4 - ICRP Publication 141
  - ✓ OIR Part 5 - In progress

$$E(50)Sv = \sum_T W_T \left[\frac{H_T^M(50) + H_T^F(50)}{2} \right]$$

E(50) is calculated with the use of male and female committed equivalent doses to individual target organs or tissues T, and the integration time following the intake is taken to be 50 years



ASSESSMENT OF INTAKE AND DOSES

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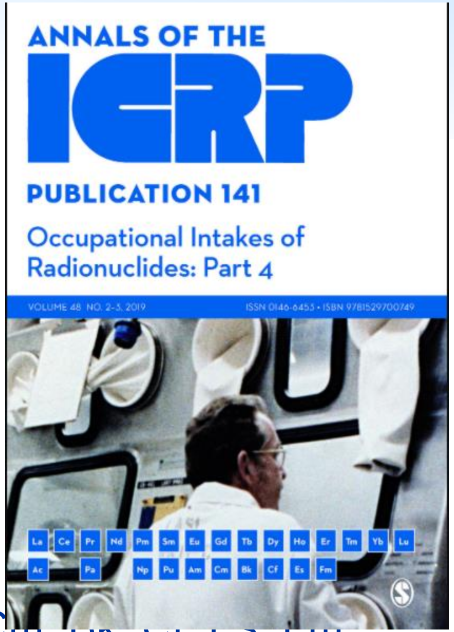
- **ICRP Reference documents –**
  - ✓ **Occupational Intakes of Radionuclides (OIR) – Parts 1-5**
    - **ICRP Publication 130** – OIR Part 1 (2015)
      Generic principles, monitoring + revised HRTM
    - **ICRP Publication 134** – OIR Part 2 (2017)
      H, C, P, S, Ca, Fe, Co, Zn, Sr, Y, Zr, Nb, Mo, Tc
    - **ICRP Publication 137** – OIR Part 3 (2017)
      Ru, Sb, Te, I, Cs, Ba, Ir, Pb, Bi, Po, Ra, Th, U and Rn (dose coeff for radon derived using biokinetic and dosimetric models)
    - **ICRP Publication 141** – OIR Part 4 (2019)
      La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Ac, Pa, Np, Pu, Am, Cm, Bk, Cf, Es, Fm
    - **ICRP Publication OIR Part 5** (in press): Be, F, Na, Mg, Al, Si, Cl, K, Sc, Ti, V, Cr, Mn, Ni, Cu, Ga, Ge, As, Br, Rb, Ag, Cd, In, Sn, Pt, Au, Hg, Tl, La, Hf, At, Fr, Se, Rh, Pd, W, Re, Os and noble gases Ne, Ar, Kr, Xe



ASSESSMENT OF INTAKE AND DOSES

- **ASSESSMENT OF INTAKE AND DOSE. INTERPRETATION OF MONITORING DATA**

✓ **Intake estimation - Single monitoring data**

- Date/Time of Intake T_0 (dd/mm/yyyy)
- Date/Time of Monitoring: t (days) after Intake

  In vivo monitoring data (from Whole/partial body counters): M(Bq) retained activity, t= time of measurement

  In vitro monitoring data: M(Bqd^{-1}) Activity concentration in excreta samples, t= time of the sample collection

- Assessment of Intake I (Bq) from a single monitoring data M(Bq):

$$I(Bq) = \frac{M(Bq)}{m(t)}$$

M(Bq)= monitoring data (from WBC or excreta)

m(t) = fraction of retained/excreted activity per Bq of intake - (reference bioassay functions provided by ICRP, OIR reports)

- Assessment of the Committed Effective Dose E(50) mSv:

$$E(50)\ \ Sv = I(Bq) * e(50)(\ SvBq^{-1})$$

e(50) mSv/Bq: dose coefficient (provided by ICRP) = committed effective dose PER UNIT INTAKE

ASSESSMENT OF INTAKE AND DOSES

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$$I(Bq) = \frac{M(Bq)}{m(t)}$$

→ **ICRP provides m(t): reference bioassay (retention/excretion) functions.**

ICRP: <u>m(t) REFERENCE BIOASSAY FUNCTION</u>
From ICRP Publication 130 (OIR Part 1):

In the OIR series of reports, the reference bioassay function is defined as a set of tabulated values m(t) predicted by a reference biokinetic model describing the time course of the activity in the body ("retention function") or the activity excreted in urine and faeces ("excretion function") following an <u>acute intake at time t=0.</u>
A **retention function m(t)** *represents the predicted activity of a radionuclide in the body , organ or tissue at a time t after intake, whereas*
an **excretion function m(t)** *represents the predicted activity of a radionuclide in a 24-h excreta sample at a time t after intake. In the case of an excretion function, in the OIR series of reports t is the number of days up to the end of the of the 24-h sample collection period; tha radioactive decay in the sample during the sample collection period is taken into account*

ASSESSMENT OF INTAKE AND DOSES

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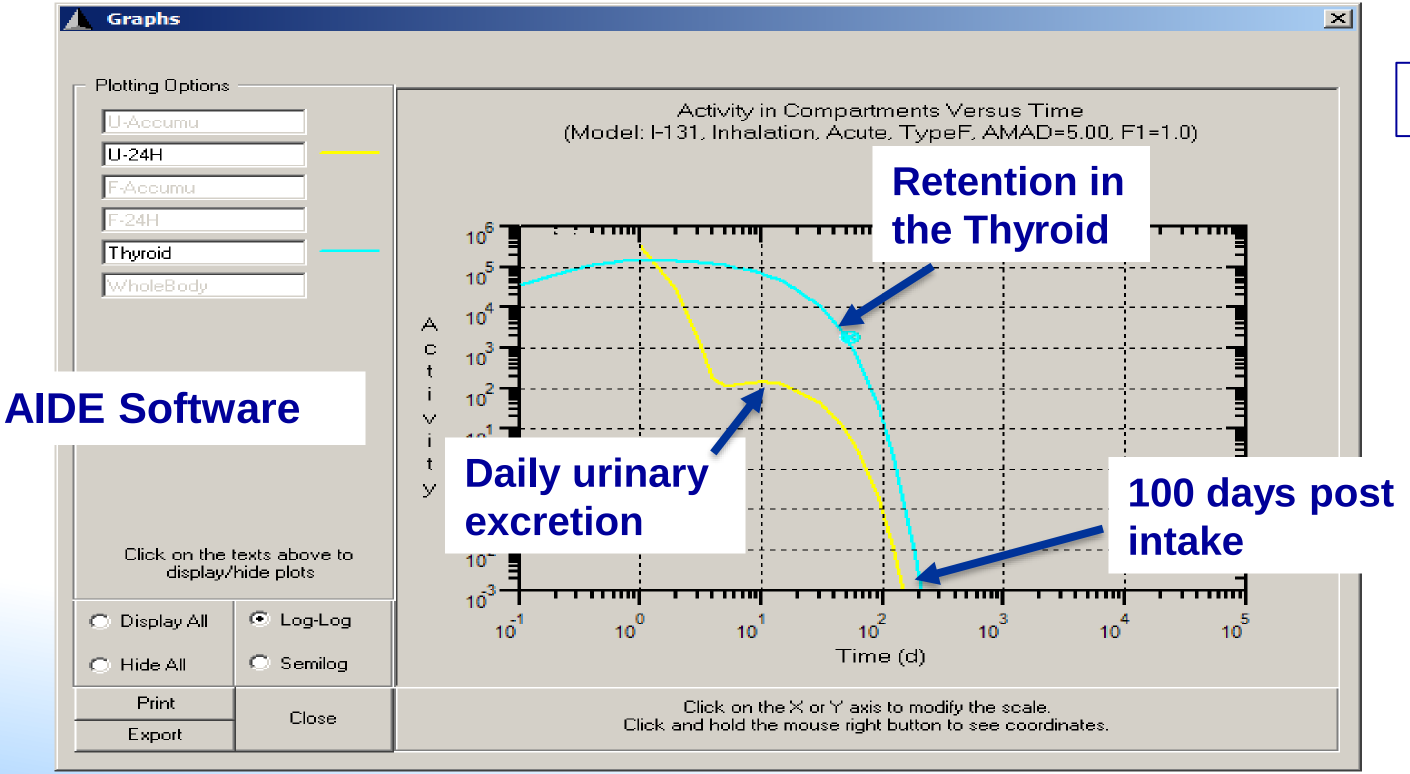
$$I(Bq) = \frac{M(Bq)}{m(t)}$$

ICRP provides m(t): reference bioassay (retention/excretion) functions.

ICRP: m(t) ^{131}I inhalation, type F, AMAD= 5 μm



Acute intake = 1 Bq at time t=0

m(t) depends on:

- Physical half-life
- Biokinetics of the radionuclide
- Is a function of the time since intake

ASSESSMENT OF INTAKE AND DOSES

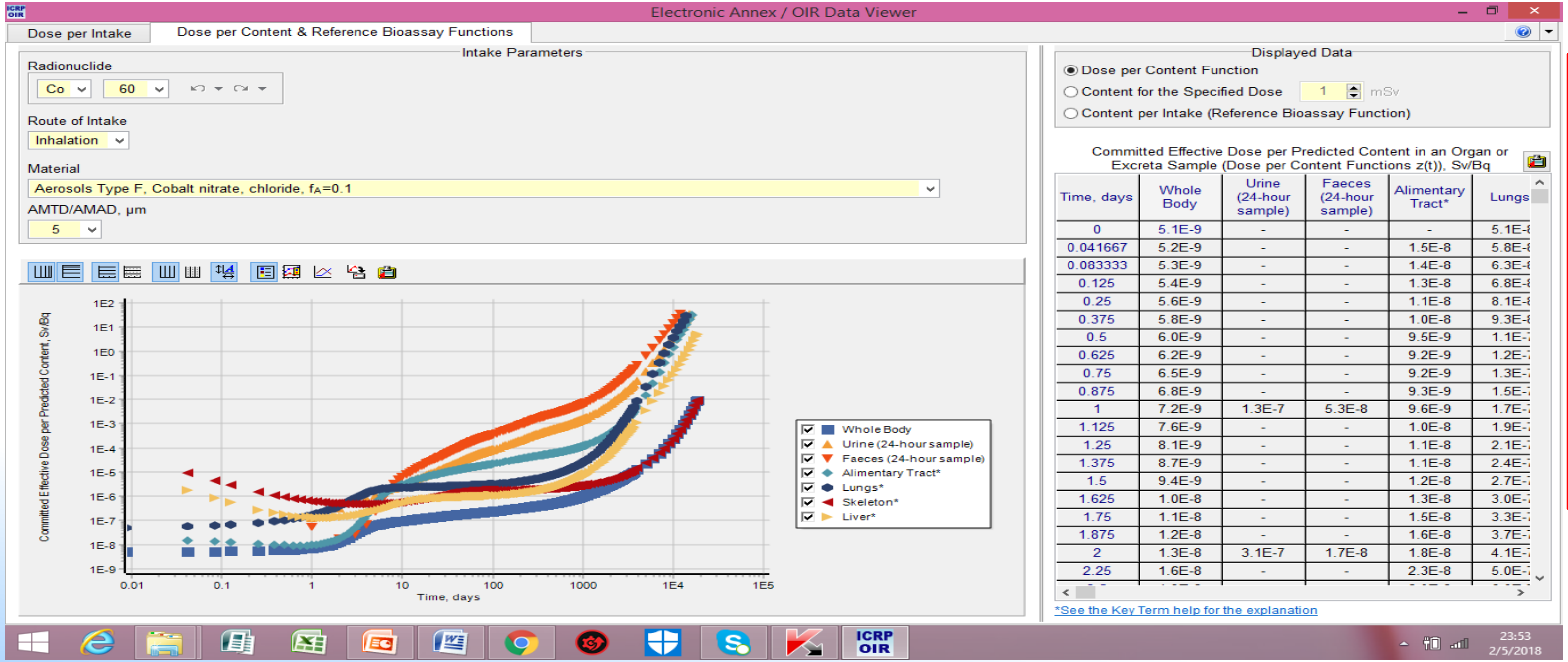
- **ASSESSMENT OF INTAKE AND DOSE. INTERPRETATION OF MONITORING DATA**
  - ✓**Intake estimation - <u>Single monitoring data M(Bq)</u>**

$$z(t) = \frac{e(50)}{m(t)}\, SvBq^{-1}$$

Values of **dose per unit content** functions ***Z(t)*** are provided by ICRP in its Occupational Intakes of Radionuclides (OIR) report series

$$E(50)\ \text{Sv} = M\ (\text{Bq}) * Z(t)\ \text{Sv Bq}^{-1}$$

where M(Bq) represents the monitoring data



Time, days	Whole Body	Urine (24-hour sample)	Faeces (24-hour sample)	Alimentary Tract*	Lungs
0	5.1E-9	-	-	-	5.1E-
0.041667	5.2E-9	-	-	1.5E-8	5.8E-
0.083333	5.3E-9	-	-	1.4E-8	6.3E-
0.125	5.4E-9	-	-	1.3E-8	6.8E-
0.25	5.6E-9	-	-	1.1E-8	8.1E-
0.375	5.8E-9	-	-	1.0E-8	9.3E-
0.5	6.0E-9	-	-	9.5E-9	1.1E-
0.625	6.2E-9	-	-	9.2E-9	1.2E-
0.75	6.5E-9	-	-	9.2E-9	1.3E-
0.875	6.8E-9	-	-	9.3E-9	1.5E-
1	7.2E-9	1.3E-7	5.3E-8	9.6E-9	1.7E-
1.125	7.6E-9	-	-	1.0E-8	1.9E-
1.25	8.1E-9	-	-	1.1E-8	2.1E-
1.375	8.7E-9	-	-	1.1E-8	2.4E-
1.5	9.4E-9	-	-	1.2E-8	2.7E-
1.625	1.0E-8	-	-	1.3E-8	3.0E-
1.75	1.1E-8	-	-	1.5E-8	3.3E-
1.875	1.2E-8	-	-	1.6E-8	3.7E-
2	1.3E-8	3.1E-7	1.7E-8	1.8E-8	4.1E-
2.25	1.6E-8	-	-	2.3E-8	5.0E-

Dose per content function z(t)
for ^{60}**Co** from
ICRP DATA VIEWER
Last update:
Electronic Annex
OIR P4 (ICRP 141)
www.icrp.org

ASSESSMENT OF INTAKE AND DOSES

- **ASSESSMENT OF INTAKE AND DOSE. INTERPRETATION OF MONITORING DATA**

  ✓ **Intake estimation - <u>Multiple monitoring data</u> M(Bq), taking into account u**ncertainties of monitoring data

  - ***ISO 27048, IDEAS Guidelines*** *:*

    - Measurements are assumed to be lognormally distributed with a given **scattering factor (SF)**

$$SF_i = \exp\sqrt{\left[\ln(SF_A)\right]^2 + \left[\ln(SF_B)\right]^2}$$

$$SF_A = \exp(\sigma_M / M)$$

    - **Assessment of the Intake I (Bq) from a set of <u>n monitoring data</u>:**
      <u>MAXIMUM LIKELIHOOD METHOD</u> is recommended
      that takes account of monitoring data **M(Bq, Bqd^{-1} , BqL^{-1})**
      and associated Scattering Factors (SF)

ASSESSMENT OF INTAKE AND DOSES

- **ASSESSMENT OF INTAKE AND DOSE. INTERPRETATION OF MONITORING DATA**

✓ **Intake estimation - Multiple monitoring data M(Bq). Uncertainties of monitoring data**

- Date/Time of Intake T_0 (dd/mm/yyyy)
- Date/Time of n Monitoring data: ti (days) post intake; i= 1,…, n
- Result of in-vivo monitoring (from Whole/partial Body Counters): Mi (Bq) retained activity i= 1,…, n

  In-vitro monitoring: Mi (Bqd^{-1}) Activity concentration in excreta i= 1,…, n
- Assessment of the Intake I (Bq) from a set of n monitoring data:

MAXIMUM LIKELIHOOD METHOD

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

✓SF_i is the scattering factor (uncertainty) associated to monitoring value M_i

✓I_i (Bq) is the value of intake obtained from M_i (Bq, Bqd^{-1}, BqL^{-1}):

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

ASSESSMENT OF INTAKE AND DOSES

- **ASSESSMENT OF INTAKE AND DOSE. INTERPRETATION OF MONITORING DATA**
  MAXIMUM LIKELIHOOD METHOD
  - ✓ **Assessment of the Intake I (Bq) from a set of n monitoring data:**

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

✓ SF_i is the scattering factor (uncertainty) associated to monitoring value M_i

✓ If the scattering factor Sf_i is the same for all measurements the equation results in the geometric mean as follows:

$$I = \sqrt[n]{\prod_{i=1}^{n} \frac{N_i}{m(t_i)}}$$

✓ If **n_1 measurements of radiobioassay of type 1 and n_2 measurements of radiobioassay of type 2** are available, **the assessment of the intake I(Bq) using Maximum Likelihood Method** is as follows:

$$\ln(I) = \frac{\sum_{i=1}^{n_1} \frac{\ln(M_{1,i}/m_1(t_i))}{\left[\ln(SF_{1,i})\right]^2} + \sum_{j=1}^{n_2} \frac{\ln(M_{2,j}/m_2(t_j))}{\left[\ln(SF_{2,j})\right]^2}}{\sum_{i=1}^{n_1} \frac{1}{\left[\ln(SF_{1,i})\right]^2} + \sum_{j=1}^{n_2} \frac{1}{\left[\ln(SF_{2,j})\right]^2}}$$

For example:
Type 1: urine data
Type 2: lung data

ASSESSMENT OF INTAKE AND DOSES

- **ASSESSMENT OF INTAKE AND DOSE. INTERPRETATION OF MONITORING DATA**
  - ✓ **Assessment of the Intake I (Bq) from a <u>set of n monitoring data. Data fitting.</u>**
    - **Criteria for rejecting the fit of monitoring data with the retention/excretion model:**

Evaluation of observed chi-square χ^2_0

- If only one dataset is available for the evaluation, the observed chi-square can be evaluated by :

$$\chi_o^2 = \sum_{i=1}^{n} \left(\frac{\ln(N_i) - \ln[I\, m(t_i)]}{\ln(SF_i)} \right)^2$$

χ^2 TEST: The **p-value is evaluated e.g. with the Excel function P=CHIDIST(χ_0^2,ν)**

The degrees of freedom (DoF) to be used are ν = n-1 (n= number of monitoring data)

To check if $P\left(\chi^2 > \chi_0^2\right) < 0.05$

ASSESSMENT OF INTAKE AND DOSES

- **ASSESSMENT OF INTAKE AND DOSE. INTERPRETATION OF MONITORING DATA**
  - ✓ **Assessment of the Intake I (Bq) from a <u>set of n monitoring data. Data fitting.</u>**
    - **Criteria for rejecting the fit of monitoring data** with the predictionof retention/excretion model:
      χ^2 **TEST: <u>Check for the goodness of fit</u>**. The fit is judged to be inadequate if:
      - **Criterion 1 for rejection:**

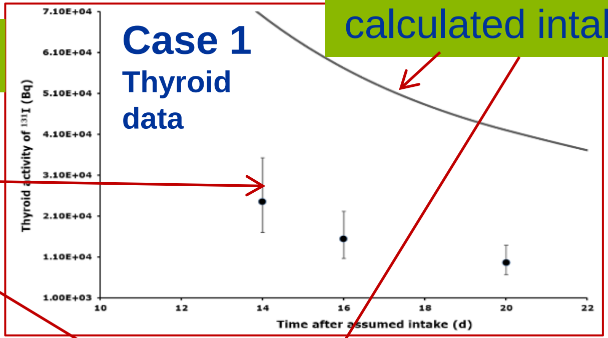
$$P\left(\chi^2 > \chi_0^2\right) < 0.05$$

If p-value < 0.05: the fit is inadequate
at the 5% level of significance

- **Criterion 2 for rejection :**
  The fit displayed graphically, looks unreasonable by eye
  i.e. if all or a long series of data were systematically underestimated or overestimated by the fit.

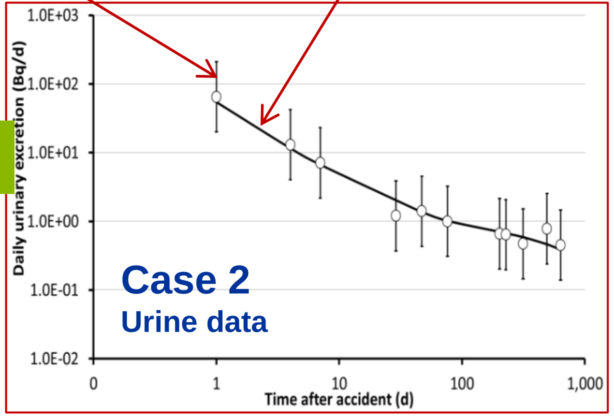
Plot of prediction of the model for the calculated intake

Bad fit, by eye:



Plot of the monitoring data with uncertainties

Good fit, by eye



- ✓ Assessment of the Committed Effective Dose E(50) mSv:

E(50) mSv = I(Bq) * e(50)(mSv/Bq)

REFERENCES- UNIT 7 - ASSESSMENT OF INTAKE AND DOSES DUE TO INTERNAL EXPOSURES. INTERPRETATION OF MONITORING DATA

EUROPEAN COMMISSION - RADIATION PROTECTION REPORT SERIES No.188 - Technical Recommendations for Monitoring Individuals for Occupational Intakes of Radionuclides (ec.europa.eu/energy/sites/ener/files/rp_188.pdf). EC RP 188 (2018).

EUROPEAN RADIATION DOSIMETRY GROUP [EURADOS] - IDEAS Guidelines (Version 2) for the Estimation of Committed Doses from Incorporation Monitoring Data. EURADOS Report 2013-01 ISBN 978-3-943701-03-6 (2013).

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Basic Anatomical and Physiological Data for Use in Radiological Protection. Reference Values. ICRP Publication 89. Ann. ICRP 32 (3-4) (2002).

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Occupational Intakes of Radionuclides Part 1. ICRP Publication 130. Ann. ICRP 44 (2) (2015).

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, International Commission on Radiological Protection. Occupational Intakes of Radionuclides, Part 2. ICRP Publication 134.Ann. ICRP 45 (3/4) (2016).

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Occupational Intakes of Radionuclides, Part 3. ICRP Publication 137.Ann. ICRP 46 (3/4) (2017).

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Occupational Intakes of Radionuclides, Part 4. ICRP Publication 141. Ann. ICRP 48(2/3).(2019).

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Occupational Intakes of Radionuclides, Part 5. ICRP Publication in press

REFERENCES- UNIT 9 - ASSESSMENT OF INTAKE AND DOSES DUE TO INTERNAL EXPOSURES. INTERPRETATION OF MONITORING DATA

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. RADIATION PROTECTION – Dose assessment for the monitoring of workers for internal radiation exposure ISO 27048:2011 (ISO: Geneva) (2011).

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. RADIATION PROTECTION – Monitoring and internal dosimetry for specific materials. Part 1: Inhalation of Uranium compounds. ISO 16638-1:2015 (ISO: Geneva) (2015).

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. RADIATION PROTECTION – Monitoring and internal dosimetry for specific materials. Part 2: Ingestion of Uranium compounds. ISO 16638-2:2019 (ISO: Geneva) (2019).

[Garcia, F. et al. 2006] Uranium levels in the diet of São Paulo City residents. Environment International. Oxford: Pergamon-Elsevier B.V., v. 32, n. 5, p. 697-703, (2006).

[Hurtgen, C. 2001] Natural radioactivity in bioassay by alpha-spectrometry measurements. Journal of Radioanalytical and Nuclear Chemistry volume 248, pages 477–482 (2001)

[Karpas Z. et al. 2005] Urine, hair and nails as indicators for ingestion of uranium in drinking water. Health Physics 88, 229-242 (2005).