Optimization of Internal Monitoring Programmes for Tritium in Urine

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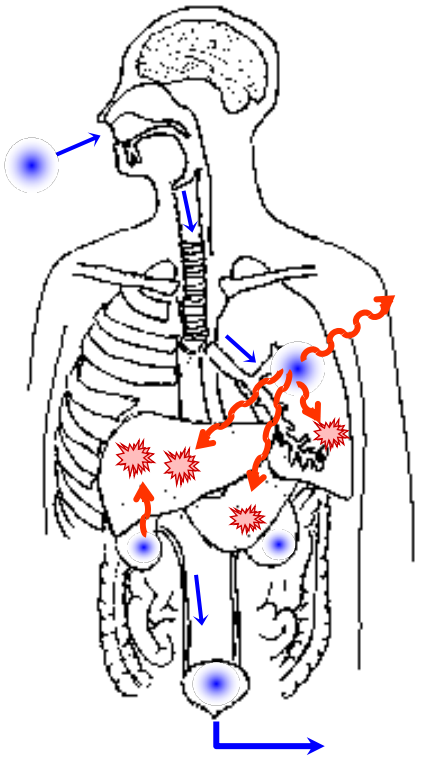


Monitoring for Internal Exposures

- Objectives

  To verify and document that the workers are protected adequately against risks, and that the protection complies with legal requirements

- Categories of monitoring for internal exposures

  Routine/Confirmatory/Task-related monitoring
  Special monitoring

- Needs for monitoring

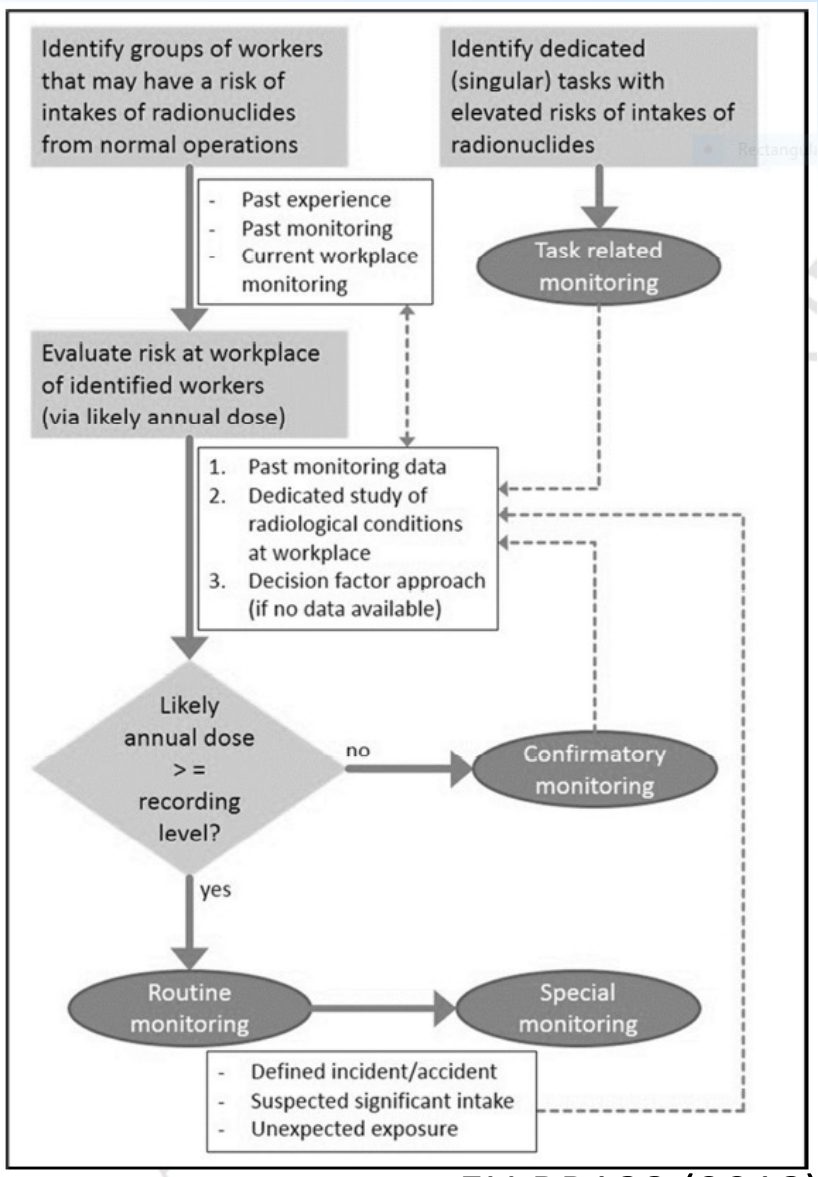
  It is necessary to identify groups of workers for whom individual monitoring is needed.
  The use of individual monitoring for workers whose annual effective doses could exceed 0.1-1 mSv is common practice in many organisations (0.1mSv/single measurement : Critical value, 1mSv/y : Recording Level)

It is important to optimize internal monitoring programmes using the latest IAEA, ICRP publications (OIR series) and ISO

Confirmatory/ Routine/ Special Monitoring

- Confirmatory Monitoring
  monitoring programme carried out to confirm assumptions about working conditions
- Routine Monitoring
  monitoring programme associated with continuing operations and intended to demonstrate that working conditions remain satisfactory, and to meet regulatory requirements
- Special Monitoring
  monitoring programme performed to quantify significant exposures following actual or suspected abnormal events

Need for individual monitoring
Solid lines: decisions taken
Dashed lines: information flow



EU RP188 (2018)

Ad hoc Monitoring at IAEA

Safeguards inspectors and other staff visit potentially radioactive areas in the course of their work. The works are not always continuous (Ad hoc monitoring)

According to ISO 20553,

Individual monitoring as part of task-related monitoring programmes normally takes the form of confirmatory monitoring programmes

Confirmatory monitoring?

So far,
the frequency of measurements is not always dependent on radionuclide
(e.g. Monitoring Interval : at least twice a year)

Optimization of Monitoring Programmes

The frequency of measurements depends on the physical decay and the biokinetic behavior of the radionuclides, the sensitivity of the measurement technique and the acceptable uncertainty on the assessed dose

- A confirmatory monitoring programme can be required to confirm assumptions about working conditions (< 0.1 mSv)
- A routine monitoring programme must be able to reliably detect all annual exposures that can exceed the recommended maximum recording level of 1 mSv y^{-1}
- In special monitoring programmes, the uncertainties in the assessed doses resulting from an unknown time interval between intake and measurement are limited so that:
  - The maximum underestimate of the dose resulting from a single intake does not exceed a factor of three
  - On average, over many monitoring intervals, doses are not underestimated


INTERNATIONAL STANDARD

ISO 20553

First edition 2006-04-15

Radiation protection — Monitoring of workers occupationally exposed to a risk of internal contamination with radioactive material

Radioprotection — Surveillance professionnelle des travailleurs exposés à un risque de contamination interne par des matériaux radioactifs

Reference number ISO 20553:2006(E)

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Optimized individual monitoring taking into account the latest ICRP publications (OIR series) which ISO does not reflect

Uncertainty in Measured Bioassay Data

Type A: components can be described by the Poisson distribution
(i.e. counting errors)

Type B: all other components
(e.g. variability of background, uncertainty in the activity of a calibration standard, variability in chemical recovery for an *in vitro* measurements, etc.)

The overall uncertainty on an individual monitoring value can be described in terms of a log-normal distribution and the scattering factor (SF) is defined as the geometric standard deviation (GSD)

$$SF = e^{\frac{\sigma}{M}}, \quad GSD = \frac{\sigma}{M} \qquad \frac{\sigma}{M} \ll 1$$

Confidence Interval 68% → $(SF)^{1.0} = (e^{\frac{\sigma}{M}})^{1.0}$

Confidence level 32% → $M/SF^{1.0}$

Confidence level 66% → $M \cdot SF^{1.0}$

M: the measurement

Confidence Interval 97.5% → $(SF)^{2.0} = (e^{\frac{\sigma}{M}})^{2.0}$

Typical Scattering Factor

Typical values for the components of lognormal uncertainty (Type B) for *in vitro* measurements of radionuclides

Quantity	Type B Scattering Factor (SF)
True 24 h urine or Activity concentration of ^{3}H in urine	1.1
Simulated 24 h urine, creatinine or specific gravity normalised	1.7
Spot urine sample	2.0
Faecal 24 h sample	3
Faecal 72 h sample	1.9

The maximum underestimate of the dose resulting from a single intake does not exceed a factor of three.

For routine monitoring (Urine analysis), it is recommended by ISO to assign ^{3}HTO to a maximum monitoring interval of 30 days.

DRL and MDD

To express recording levels in terms of the quantities actually measured, DRL are calculated separately for each radionuclide

DRLs (IAEA GSG-7, 2018) can be calculated by

$$DRL_j = \frac{E}{N \cdot e(g)_j} m(t_0)_j$$

where E is the committed effective dose (0.1 mSv or 1 mSv), $m(t_0)_j$ is the fraction of the intake of radionuclide j remaining in the body or in the excretion sample after an elapsed time periods t_0 (=365/2N), N is monitoring periods per year, and $e(g)_j$ is the dose coefficient for ingestion or inhalation of radionuclide j

MDD concept can be used to support decisions

MDD (RPD 105, 2003) can be calculated by

$$MDD_j = z(t)_j \cdot MDA_j$$

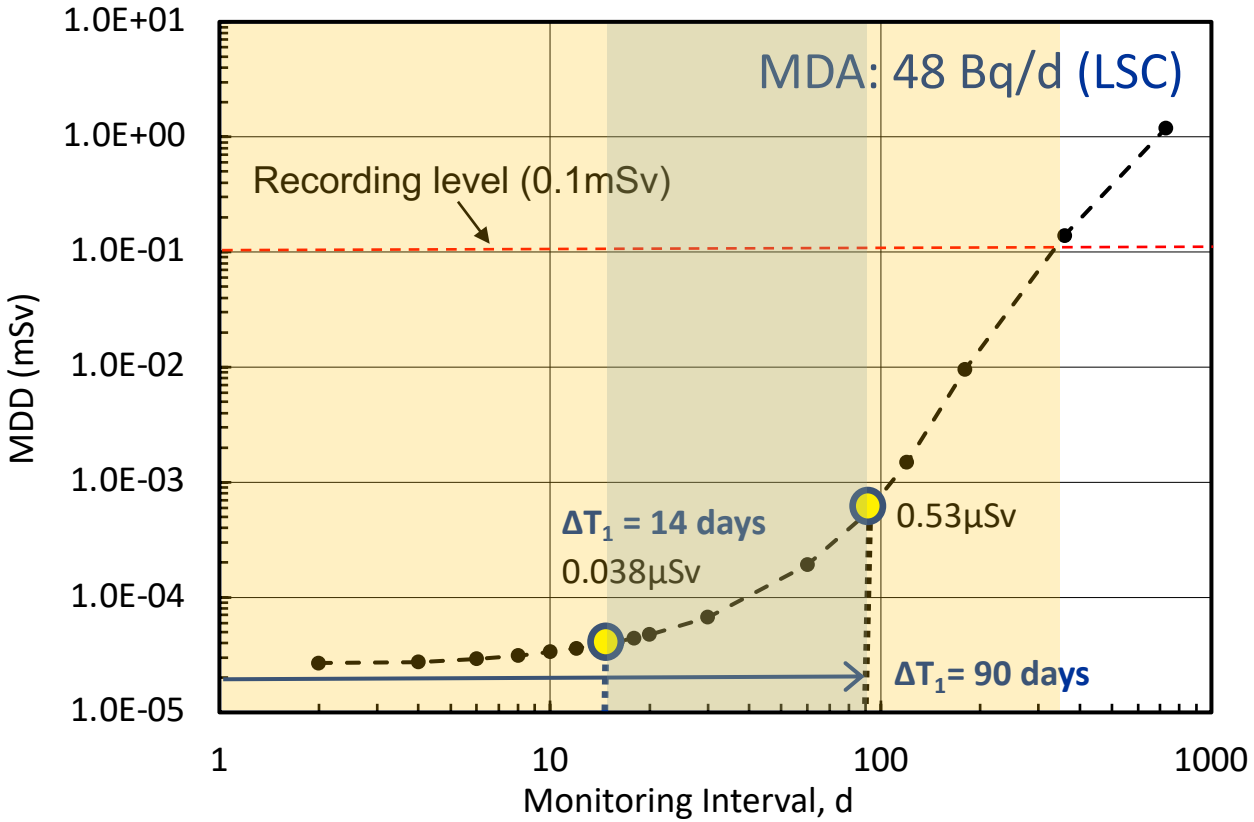
$$z(t)_j = \frac{e(50)_j}{m(t)_j}$$

where MDA_j is the minimum detectable amount of *in vivo/in vitro* measurement

DRLs and MDDs were evaluated using the biokinetic behavior (ICRP OIR series) for each radionuclide

Design of Monitoring Interval using MDD

-MDD for Urine Samples (e.g. ^{3}H)-



The working conditions during the monitoring interval, with respect to the potential for tritium exposure, are representative of working conditions during the period in which a urine analysis frequency is employed (RPOs have the responsibility).

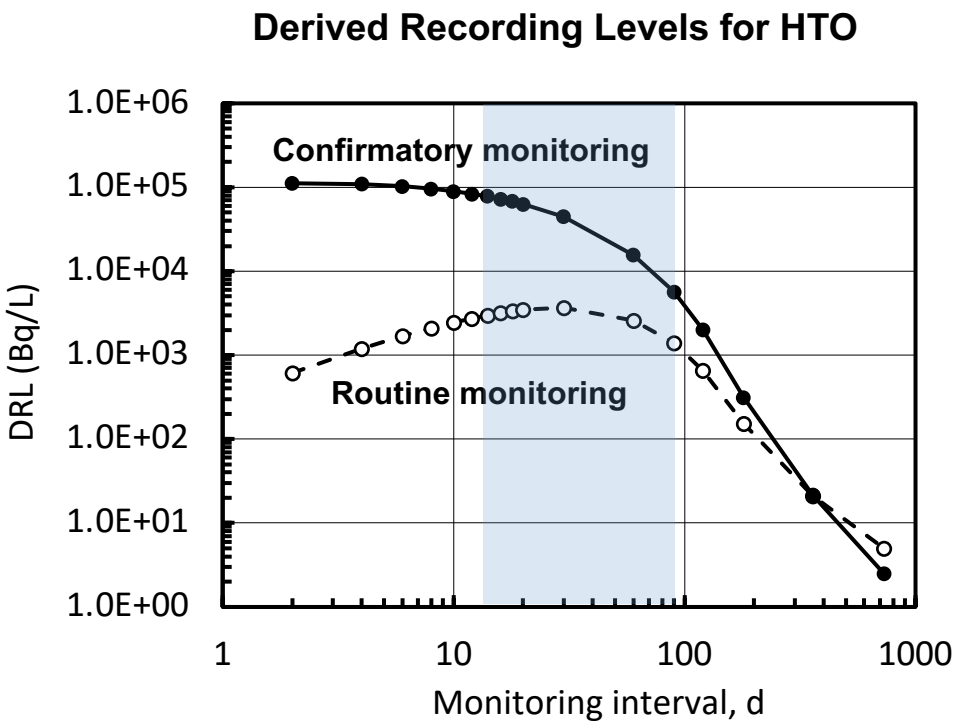
In the routine/confirmatory/task-related monitoring,
the tritium exposure level << 0.1 mSv (during 14-90 days): recorded as 0.00 mSv

Optimum Urine Monitoring Intervals (e.g. ^{3}H)

According to ANSI/HPS N13.14-2018,

- The optimum monitoring period for routine tritium bioassay is 14.4 d (standard monitoring period of 2-wk)
- Special bioassay should continue on a 2-wk schedule until the estimated tritium level in the individual decline to less than the screening level(0.002 ALI)
- The confirmatory monitoring period shall not exceed 90 d

If the potential exposure to tritium is anticipated only for a very limited interval, starting and ending bioassay samples might be more suitable than participation in a continuing monitoring program



Monitoring intervals for ^{3}H(HTO) urine: 14-90 days

Developments of Datasheets for WI (e.g. ^{3}H)

Routine Monitoring

IAEA	Code	Revision Number	Date of entry into force	Page	of pages
	DS-RM-02-Tritium	1	2019-04-04	1	4

Quality Management System
Radiation Safety Technical Services Laboratory

DOSIMETRIC DATASHEET TRITIUM/ ROUTINE MONITORING

Table 1 — Method and maximum time interval for routine monitoring programme [ISO 20553]

Radionuclide	Absorption type	WI-UA-03
		Urine (days)
^{3}H	HTO	30

Table 2 — Default value for the lognormal scattering factor [ISO 27048]

Urine (Type B uncertainty)	Scattering factor
True 24-hour sample or ^{3}H concentration	1.1

Table 3 — Committed effective dose coefficient ($Sv \cdot Bq^{-1}$) for inhalation of HTO [ICRP Publication 134]

Inhaled gases or vapours	Effective dose coefficient ($Sv \cdot Bq^{-1}$)
Tritiated water (HTO)	2.0E-11

Confirmatory Monitoring

IAEA	Code	Revision Number	Date of entry into force	Page	of pages
	DS-CM-02-Tritium	0	2019-04-04	1	4

Quality Management System
Radiation Safety Technical Services Laboratory

DOSIMETRIC DATASHEET TRITIUM / CONFIRMATORY MONITORING

Table 1 — Method and maximum time after intake to achieve minimum detectable dose of 0.1 mSv from a single intake

Radionuclide	Absorption type	*In vitro* analysis
		Urine (days)
^{3}H	HTO	90

Table 2 — Default value for the lognormal scattering factor [ISO 27048]

Urine (Type B uncertainty)	Scattering factor
True 24-hour sample or ^{3}H concentration	1.1

Table 3 — Committed effective dose coefficient ($Sv \cdot Bq^{-1}$) for inhalation of HTO [ICRP Publication 134]

Inhaled gases or vapours	Effective dose coefficient ($Sv \cdot Bq^{-1}$)
Tritiated water (HTO)	2.0E-11

Table 4 — Derived recording level for HTO in urine in the case of confirmatory monitoring, assuming a typical number of 10 assessments per year and a typical monitoring interval of 14 days

Monitoring interval (d)	Derived recording level ($Bq \cdot L^{-1}$)
14	7.8E+03

Datasheets have been developed for ^{3}H, ^{14}C, ^{90}Sr, ^{90}Y, and ^{137}Cs using ICRP 134&137 (^{60}Co, ^{131}I, ^{133}Ba, ^{232}Th, ^{238}U, $^{238,239,240,241,242}Pu$, and ^{241}Am, in progress)

Summary and Future Plans

Internal monitoring programmes for ^{3}HTO in urine were assessed using the ICPR OIRs in conjunction with MDD concept.

- Ad hoc monitoring programmes at IAEA would be dramatically changed. Confirmatory monitoring programmes using DRLs would be developed for non-continuous works at IAEA.

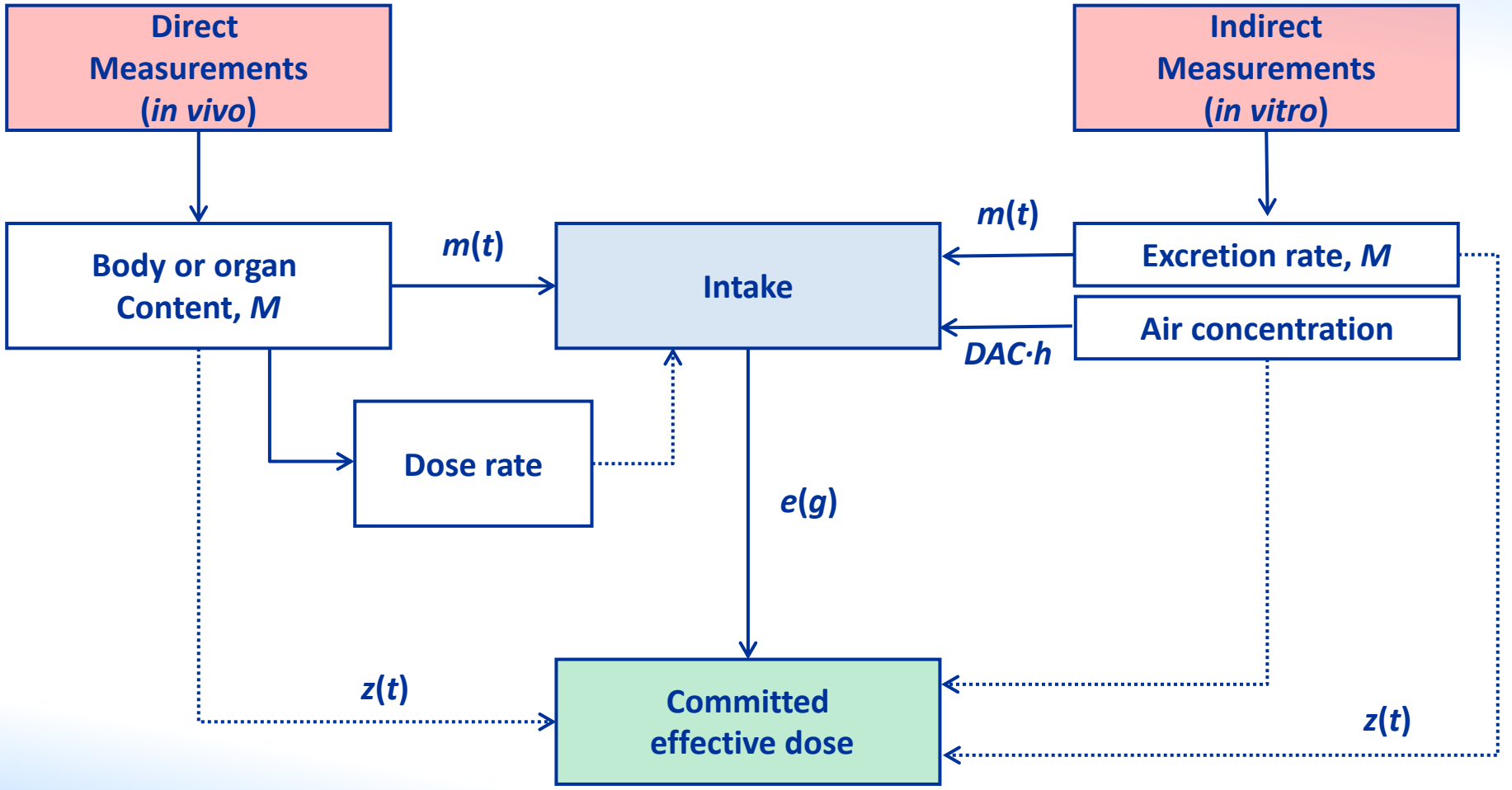
- Routine/confirmatory monitoring programmes based on the ICRP OIRs would be pioneer work in the field of radiation protection.

- For routine/confirmatory monitoring, it is determined to assign ^{3}HTO in urine to the monitoring interval of 30-90 days.

Routine/confirmatory/task-related/special monitoring programmes should be developed using up-to-date ICRP models.
MDDs should be evaluated as the 95th percentile of the probability distribution of committed effective dose considering all the sources of uncertainty.
Treatment of chronic, acute or mixed intake should be developed for their dosimetry.

Thank you for your kind attention!

Evaluation of Measurements



possible alternative approaches for calculation are indicated as dashed lines

Inhalation Intakes from Workplace Monitoring

Calculation of the radionuclide intake from a measurement of the activity concentration of a radionuclide in an air sample, using data on reference breathing rates

$$I = B \cdot T_{work} \cdot C_m$$

where

B	mean breathing rate of a sedentary worker ($1.2 m^3 h^{-1}$) ($9.6 m^3 d^{-1}$ for occupational activity) For ^3H, it shall be multiplied by a factor of 1.5 in order to account for uptakes via skin
T_{work}	time spent by the worker in areas where the radionuclide is present in the air breathed (h)
C_m	airborne concentration of the radionuclide ($Bq m^{-3}$)

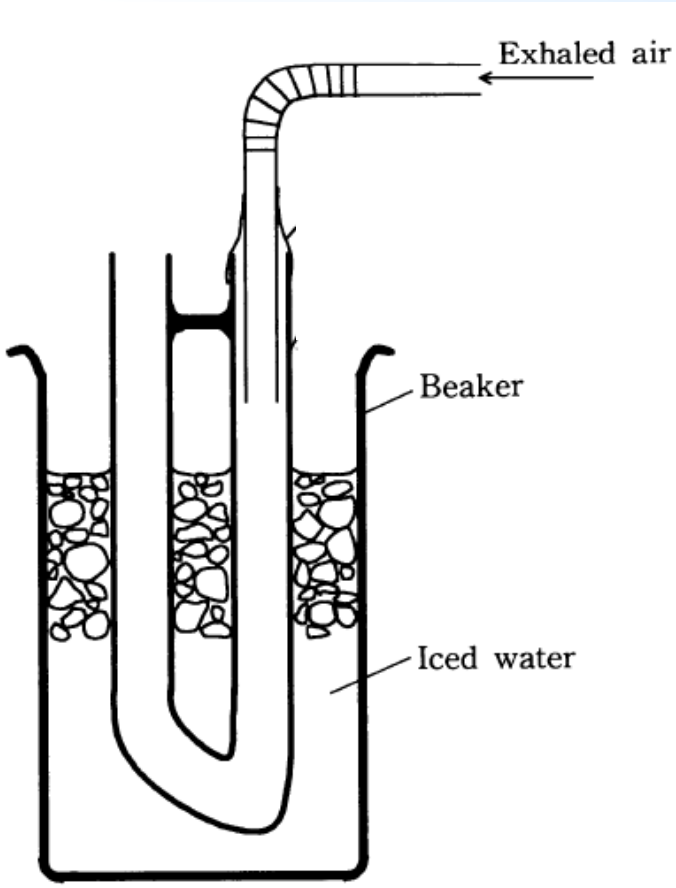
Inhalation Intakes from Exhaled Water

Total intake I is obtained from a measurement of HTO concentration with a cold trapping method

$$I = 42 \cdot C_B$$

where

C_B HTO concentration in exhaled water (BqL^{-1}), a values of 42.6 L can be calculated for the total volume of body water for adult male



This method should be carried out about three hours after works

Intakes of Tritiated Water (HTO)

For dosimetry purposes, it can be assumed that the activity concentration in urine equals that of total body water

- If A_u is the area under the urine activity concentration data (Bq L^{-1} d) from the time of the first intake (t=0) to infinity then the total number of nuclear transformations, U_s is given by:

$$U_s = A_u \cdot 42 \cdot b$$

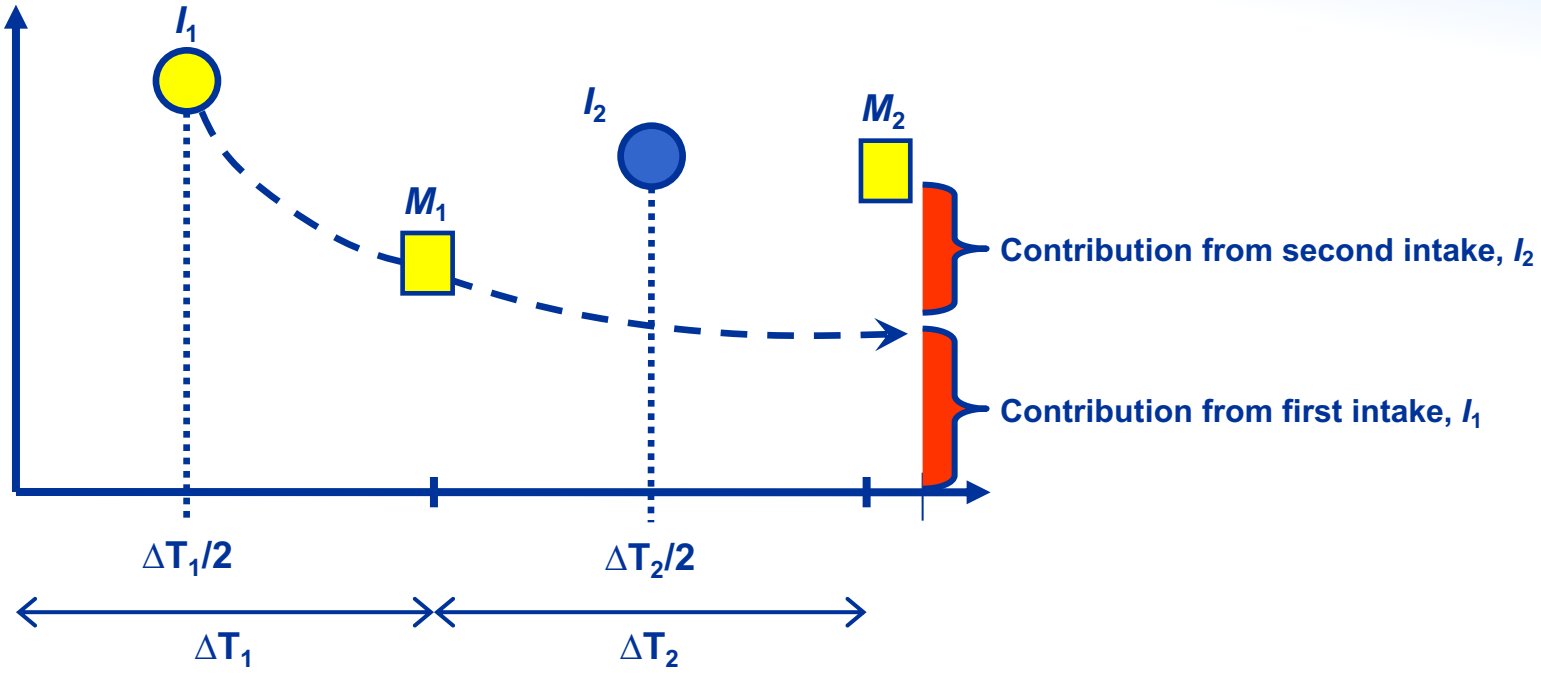
where b is a numerical constant converting days to seconds: 86400 s d^{-1}, a values of 42.6 L can be calculated for the total volume of body water for adult male

- Total intake I is given by:

$$I = 2.9 \cdot A_u$$

where a values of 2.9 L d^{-1} is given as the total water loss per day for an adult male (ICRP Publ.89)

Interpretation of Measurement Results



- Time, duration, pattern and route of intake
- Chemical and physical form of radionuclide → absorption type
- Particle size (AMAD)