BRIN

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ASSESSMENT OF INTERNAL EXPOSURE DOSE

Follow-up Training Course on
Radiological Emergency Preparedness and Response

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Biography

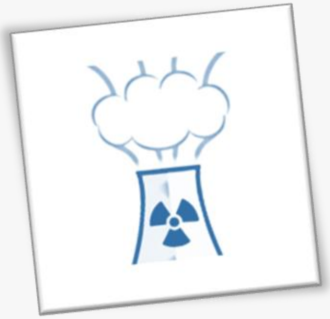
Name : Teguh Permana
Education : Bachelor of Nuclear Engineering, Gadjah Mada University, Yogyakarta.
Occupation : Personnel Dose and Environmental Monitoring Laboratory Serpong
Environmental Safety – Radioactive Waste Management Facility
Directorate of Nuclear Facility Management
National Research and Innovation Agency (BRIN)

Training Courses :

*) Advanced Instructor Training Course on Environmental Radioactivity Monitoring, Japan (2024)
*) Regional Workshop on Development of National Radiation Emergency Plan (NREP) (Including Hazard Assessment), Thailand (2024)
*) Monitoring Training of Terrestrial Radioactivity in the Nuclear Emergency System, Ukraine (2021)
*) Advanced Instructor Training Course on Nuclear / Radiological Emergency Prepareddness (Online Training Course), JAEA (2021)
*) Instructor Training Course on Environmental Radioactivity Monitoring, Japan (2019)

Background

- Nuclear Facility
- Radiation Protection
- Dose Assessment
- Internal Exposure Dose is Important



Benefit of this training

Participants will understand how to assess internal doses in radiation workers from radionuclide intake.

General Objectives

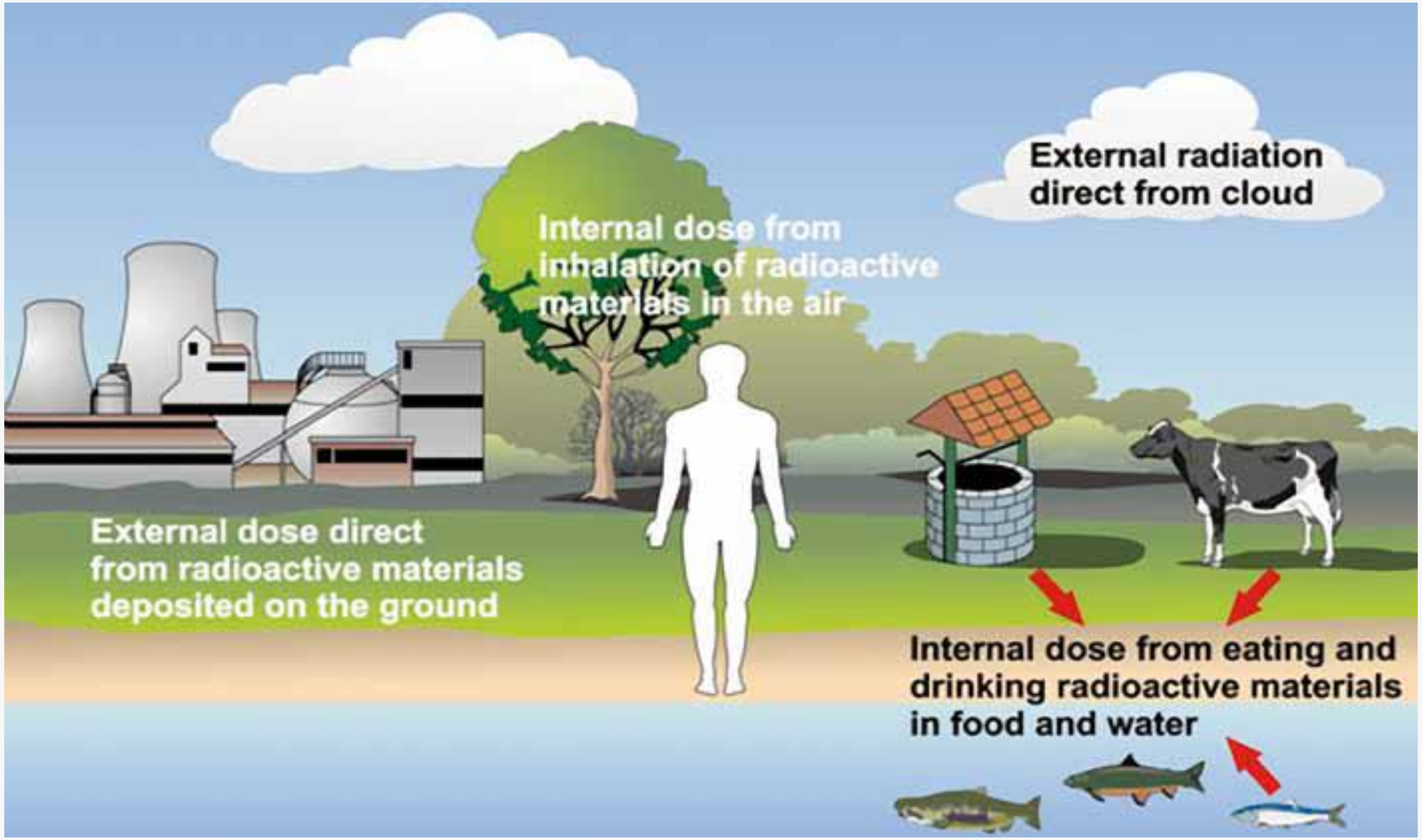
Basic Competencies

Participants can explain internal dose radiation which public and worker received from a nuclear facility.

Success Indicators

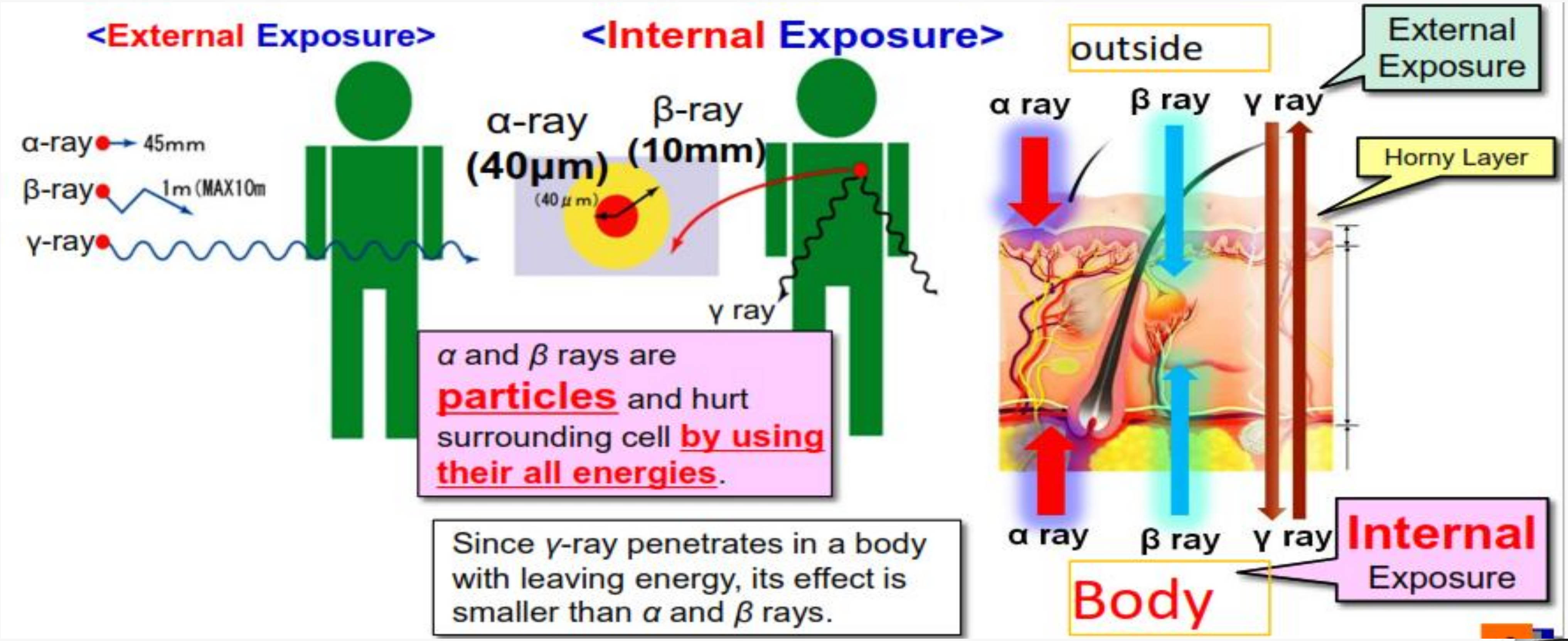
- Understand overview of internal dose radiation process
- Explain the methods of internal dose radiation assessment

Background

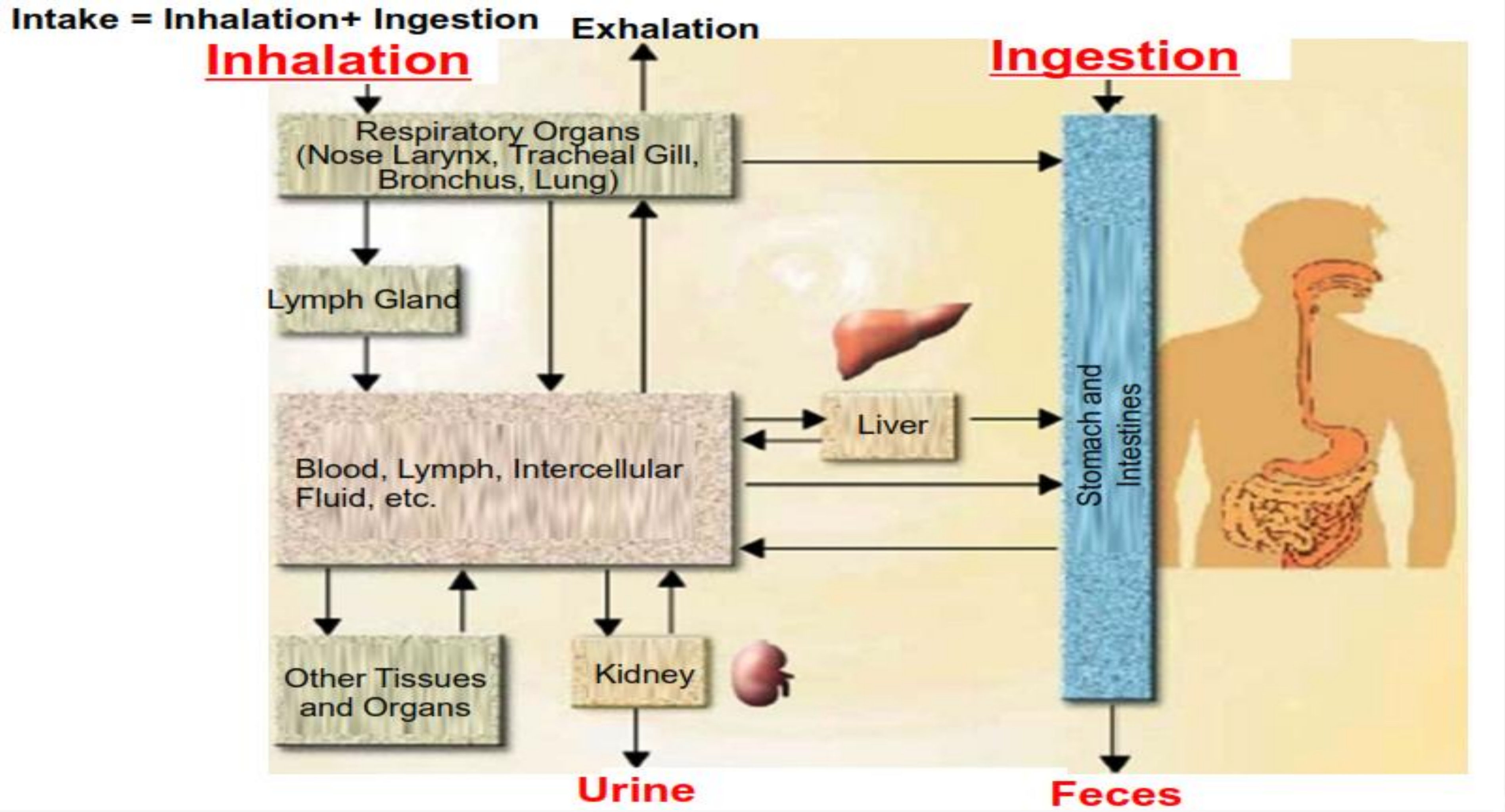

External radiation direct from cloud
Internal dose from inhalation of radioactive materials in the air
External dose direct from radioactive materials deposited on the ground
Internal dose from eating and drinking radioactive materials in food and water

Difference of Internal and External Exposure

- Exposure Divided into **External** and **Internal** Exposure



Route and Excretion of Internal Exposure



Difference of Deposition of Radionuclides

Difference by Kinds of Radionuclides (Internal-organs Affinity)

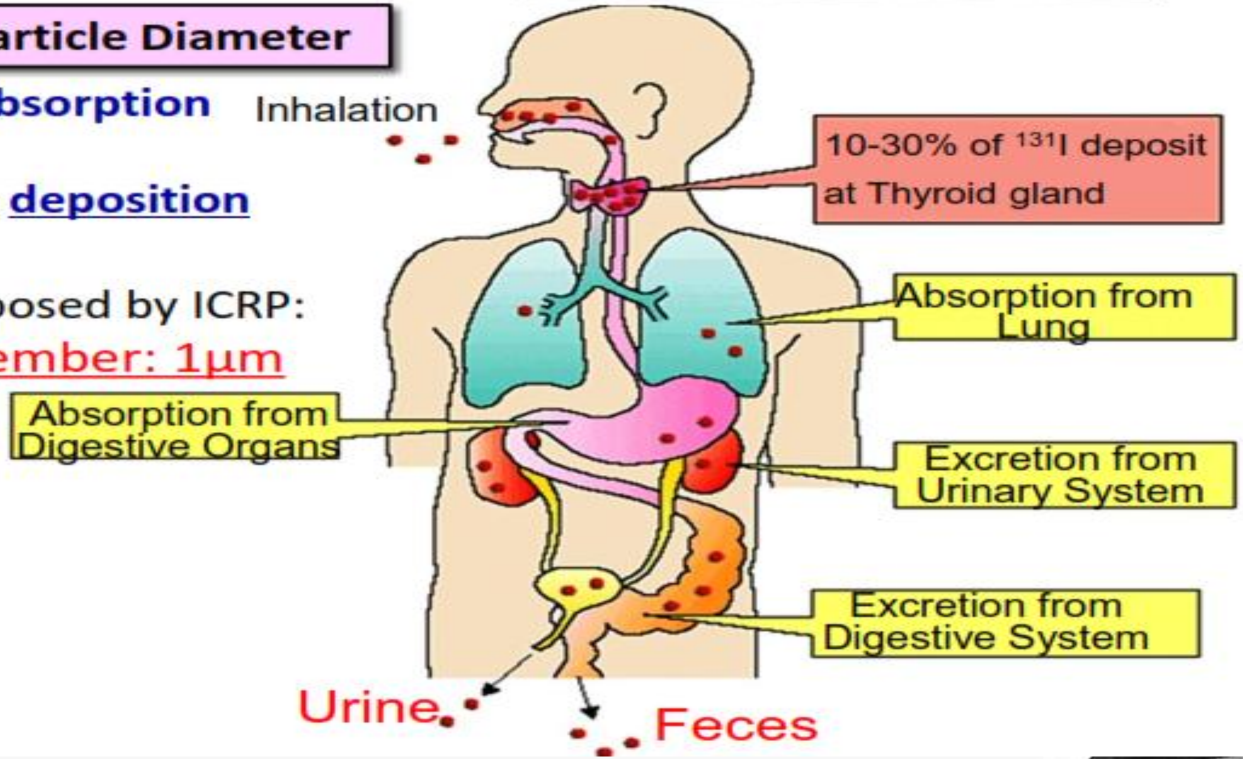
- **Thyroid Gland** → **I-131** (to make Thyroid Hormone), etc.
- Bone → Sr-90, Pu-239, etc.
- **Whole Body** → H-3, **Cs-137**, etc.

Difference by Chemical Form and Particle Diameter

- **Chemical Form** greatly influences **absorption** to each organ and tissue.
- **Particle Diameter** greatly affect the **deposition rate** in a respiratory airway.

☞ Default value on assessment proposed by ICRP: For Worker: 5μm, for Public member: 1μm

<In case of Inhalation of I-131>



Radionuclide Target Organs in case of internal exposure

Nuclides	Affinity
H-3 (HTO, tritiated water)	whole body
Fe-55	hematopoietic system, liver, spleen
Co-60	liver, spleen
Sr-90	bone
I-125, I-131	thyroid
Cs-137	whole body (muscle)
Rn-222	lung (by breathing)
Ra-226	bone
Th-232	bone, liver
U-238	bone, liver
Pu-239	bone, liver, lung (insoluble form)
Am-241	bone, liver

PRINCIPLES OF INTERNAL DOSIMETRY

- The kinetics of metabolism of a radionuclide is the relationship among exposure, intake, uptake, deposition, and excretion of a radionuclide.

- This can be used to calculate the radiation dose from a given exposure. The potential risk associated with an internal contamination is evaluated by **calculating the effective dose.**

- This is a radiation protection quantity based on physical properties of the interaction of radiation with matter (energy released per unit mass of the biological target), subsequently weighted by some dimensionless factor called tissue **weighting factor, w_T.**

Dose Unit

Units of Radiation — **Relationship between Units**

Source of radiation

Radiation intensity*1

Becquerel (Bq)

Radioactive materials

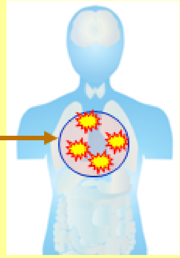
*1: Number of nuclei that decay per second

Receiving side

Absorbed dose*2

Gray (Gy)

Amount of energy absorbed by a substance of unit mass that received radiation



$$Gy = \frac{\text{Absorbed energy } \mathbf{(J)}}{\text{Mass of the part receiving radiation } \mathbf{(kg)}}$$

*2: Energy absorbed per 1 kg of substances (Joule: J; 1J≒0.24 calories); SI unit is J/kg.

Differences in effects depending on types of radiation

Equivalent dose (Sv)

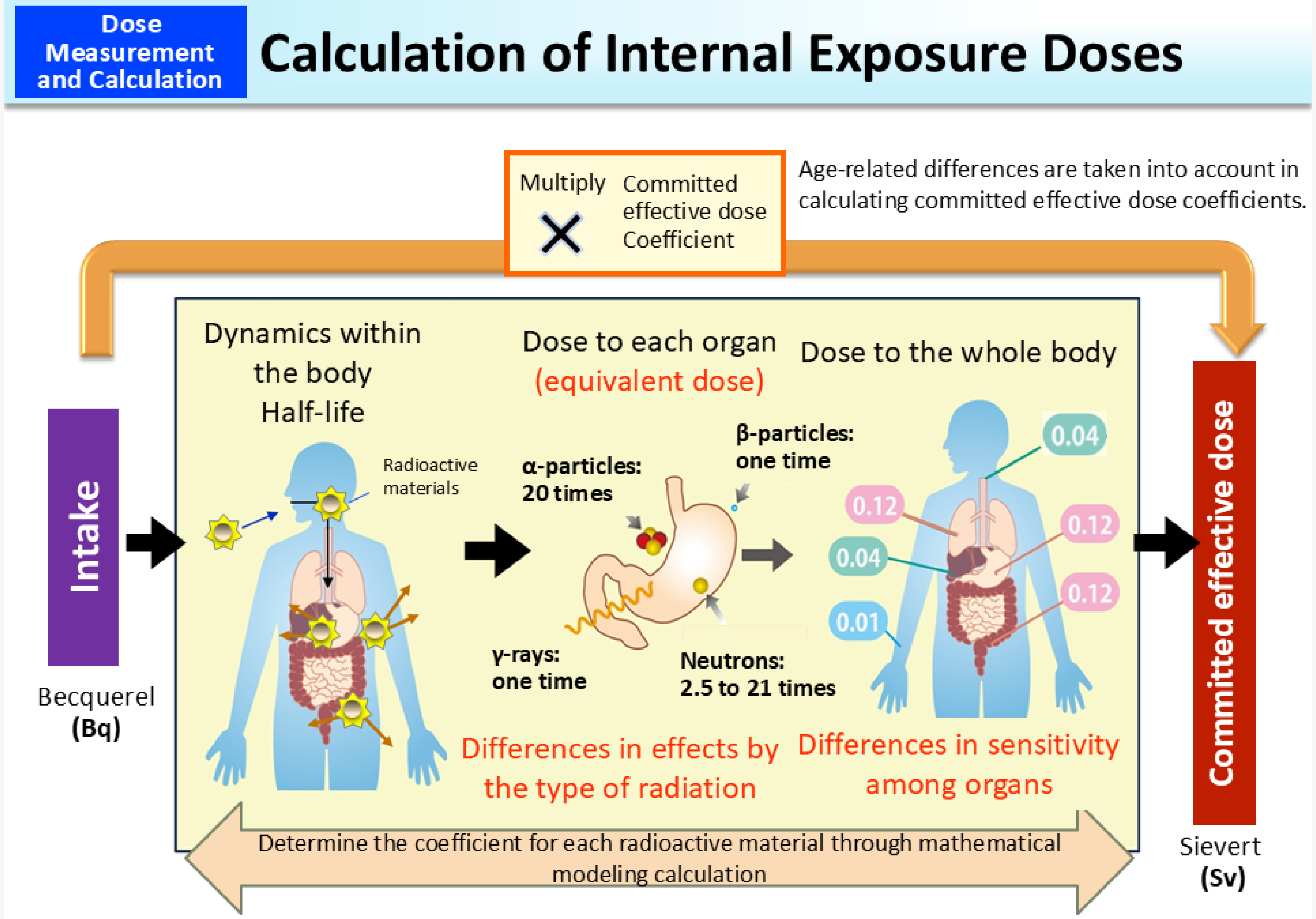
Differences in sensitivity among organs

Effective dose

Sievert (Sv)

Unit for expressing radiation doses in terms of effects on the human body

Calculation Process



Monitoring Methods

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

✓ In-vivo measurements of the retained activity M (Bq) in total body or in specific organs, using Whole/Partial Body Counters
✓ In-vitro measurements of the activity concentration in excreta samples M (Bqd-1 , BqL-1)
✓ Workplace Monitoring (Air sampling) - Activity concentration in the air M (Bq/m3)

In-vivo measurements

In-vitro measurements

U Total : Extraction of hexavalent uranium from nitric acid solution by tri-n-butyl phosphate/kerosene (TBP/kerosene)

In-vitro measurements

Beta Total : Precipitation using Sulkowitch reagent – Calcium chloride

In-vitro measurements

Alpha / Beta Counting System

Calculation Exercise of Internal Exposure Dose

The interpretation of the monitoring data for the assessment of the 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

Reference: Each ICRP Standard defined Intake Retention Function

Resources	Dosimetric Data
ICRP Publication 68	**Dose coefficients (DPUI) for workers** --- Inhalation (1μm,5μm), Ingestion
ICRP Publication 78	**Dose coefficients (DPUI) for workers** --- Inhalation (5μm), Ingestion **Retention/Excretion rates (up to 10 days after intake)**
ICRP Publication 71,72	**Dose coefficients (DPUI) for the public** --- Inhalation (1μm), Ingestion
ICRP CD-ROM	**Dose coefficients (DPUI) for workers and the public** --- Inhalation (0.001μm-10μm), Ingestion
IAEA Safety Series No.37 Methods of assessing occupational radiation dose due to intakes of radionuclides	**Dose coefficients (DPUI) for workers** --- Inhalation (1, 5μm), Ingestion, injection **Retention/Excretion rates**

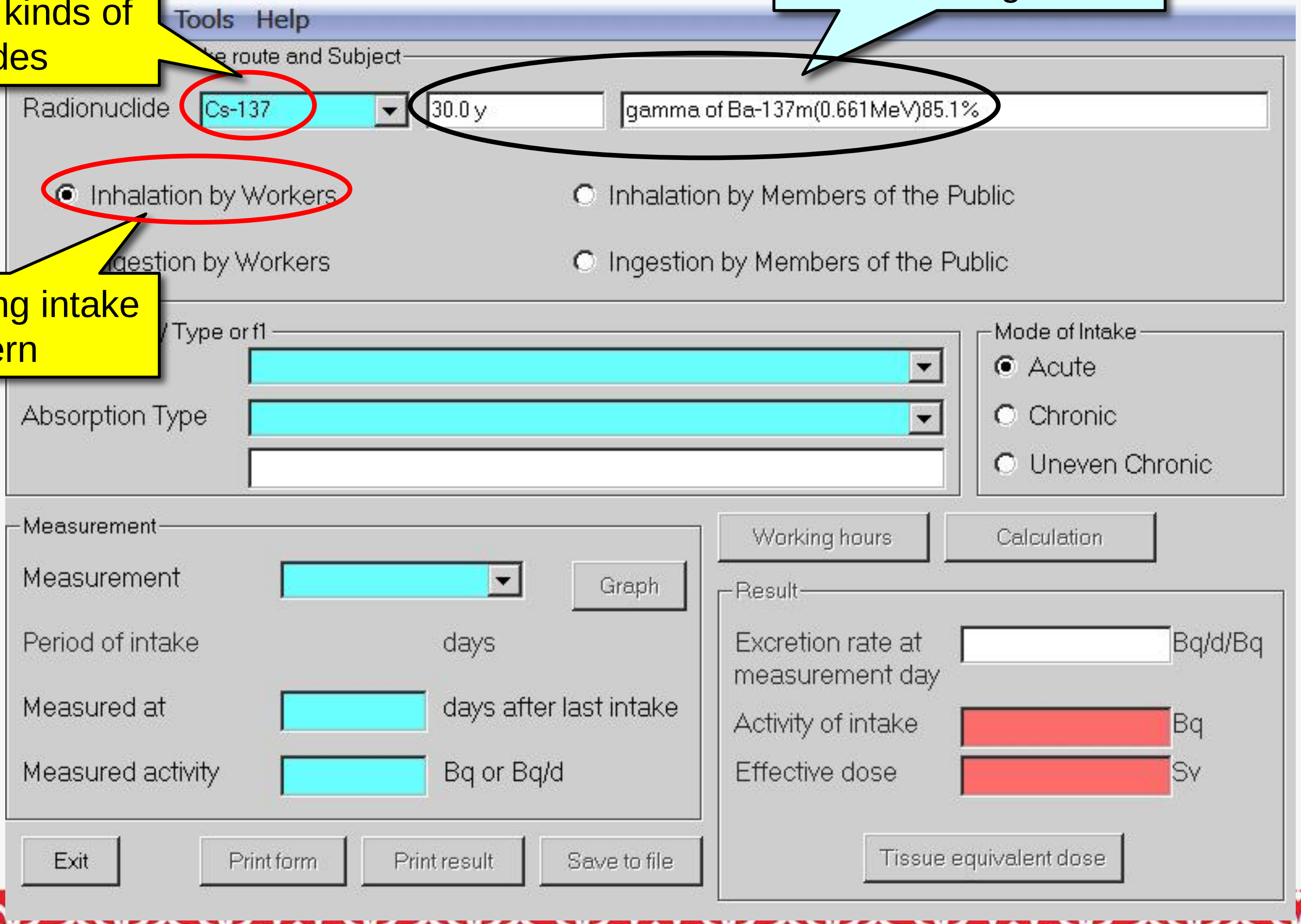
DPUI: Dose Per Unit Intake

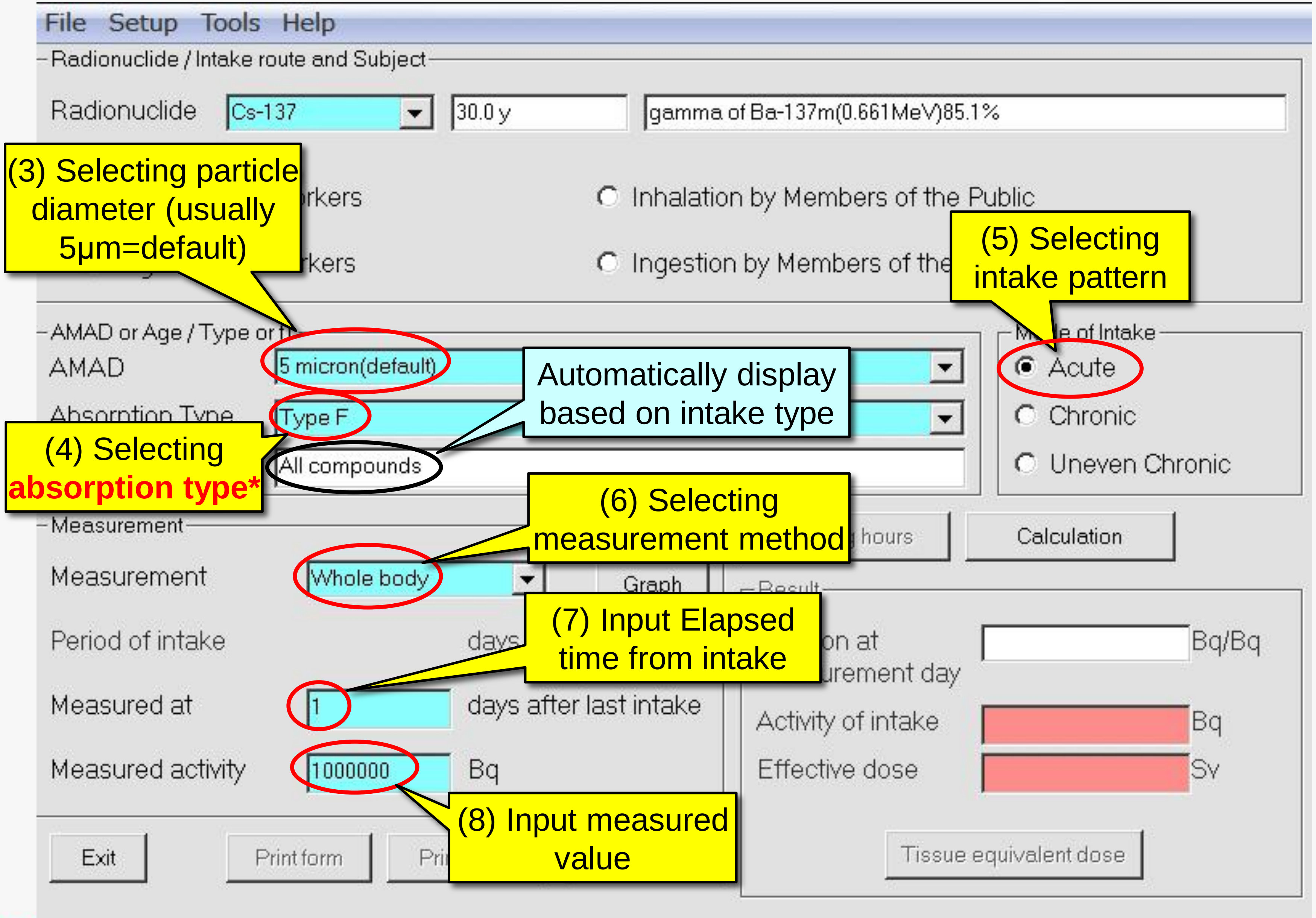
Mondal Software

(1) Selecting ^{137}Cs among 42 kinds of nuclides

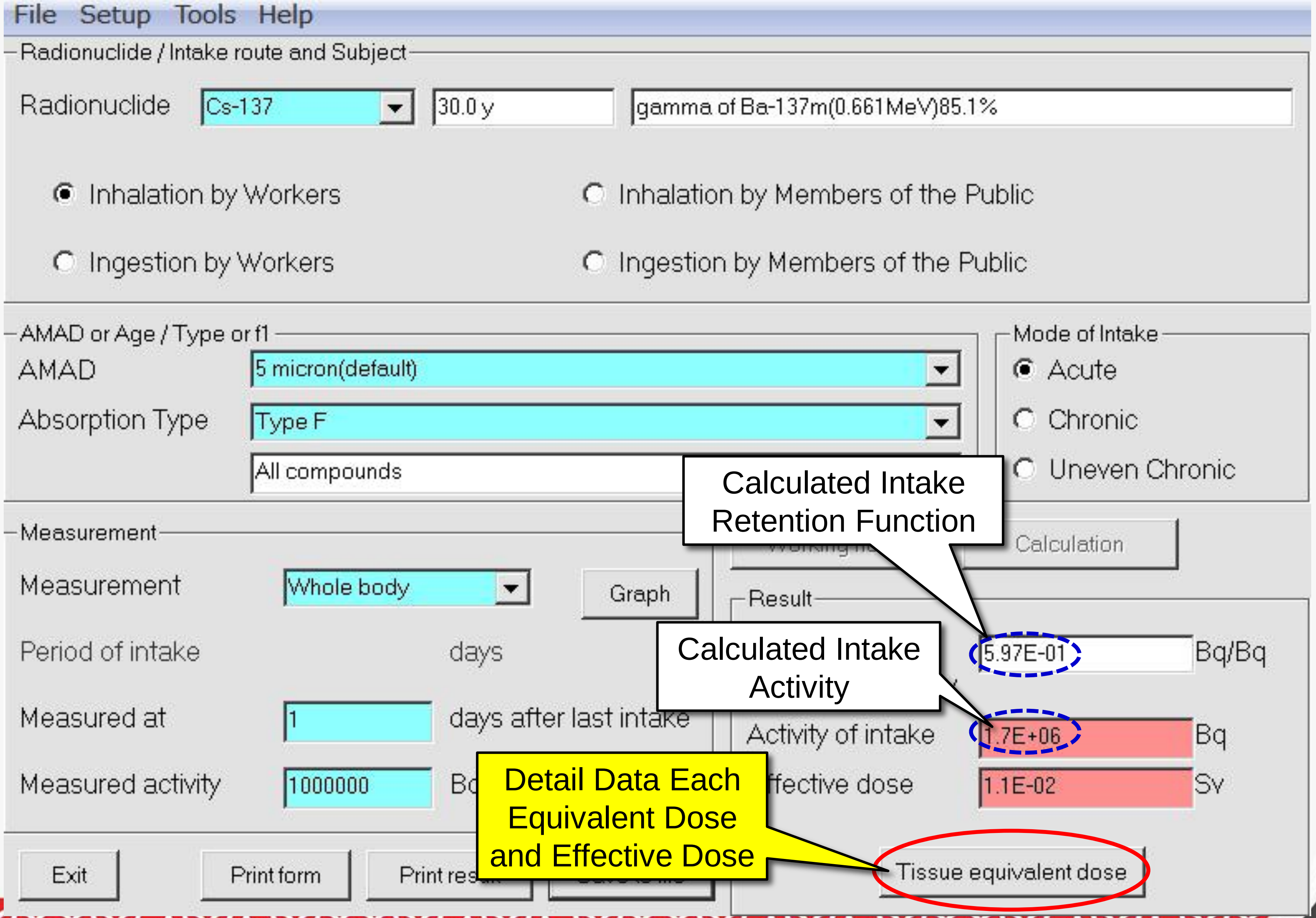
Automatically display after selecting nuclide

(2) Selecting intake pattern





File Setup Tools Help
Radionuclide / Intake route and Subject
Radionuclide
Cs-137
30.0 y
gamma of Ba-137m(0.661MeV)85.1%
rkers
kers
Inhalation by Members of the Public
Ingestion by Members of the
(3) Selecting particle diameter (usually 5μm=default)
(5) Selecting intake pattern
AMAD or Age / Type or f
AMAD
5 micron(default)
Absorption Type
Type F
All compounds
Automatically display based on intake type
(4) Selecting absorption type*
Mode of Intake
Acute
Chronic
Uneven Chronic
Measurement
(6) Selecting measurement method
hours
Calculation
Measurement
Whole body
Graph
Result
Period of intake
days
(7) Input Elapsed time from intake
on at
urement day
Bq/Bq
Measured at
1
days after last intake
Activity of intake
Bq
Measured activity
1000000
Bq
Effective dose
Sv
(8) Input measured value
Exit
Print form
Pri
Tissue equivalent dose



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Inhalation by Workers
Inhalation by Members of the Public
Ingestion by Workers
Ingestion by Members of the Public
AMAD or Age / Type or f1
AMAD
5 micron(default)
Absorption Type
Type F
All compounds
Mode of Intake
Acute
Chronic
Uneven Chronic
Calculation
Measurement
Measurement
Whole body
Graph
Period of intake
days
Measured at
1
days after last intake
Measured activity
1000000
Result
5.97E-01
Bq/Bq
Activity of intake
1.7E+06
Bq
1.1E-02
Sv
Exit
Print form
Tissue equivalent dose
Calculated Intake Retention Function
Calculated Intake Activity
Detail Data Each Equivalent Dose and Effective Dose

Tissue Equivalent Dose

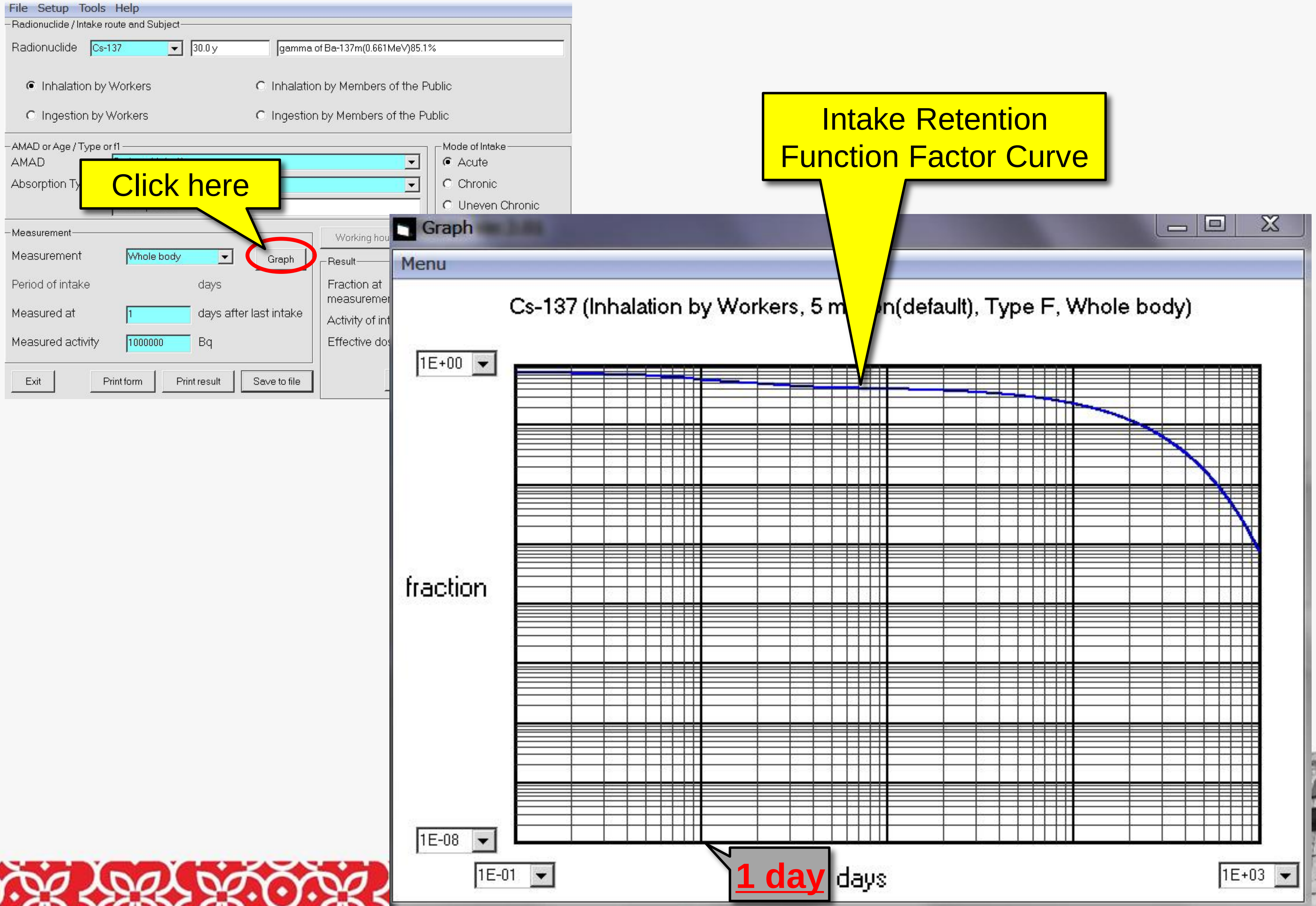
Cs-137, Inhalation by Workers
AMAD: 5 micron(default), Absorption Type: Type F
Intake = 1.7E+06 Bq

Print form | Export CSV file | Close

Unit: Sv	1 day	7 days	30 days	1 year	5 years	10 years	20 years	30 years	50 years
Adrenals	8.0E-05	5.2E-04	2.0E-03	1.0E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02
Bladder Wall	9.2E-05	6.0E-04	2.2E-03	1.1E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02
Bone Surface	8.9E-05	5.2E-04	2.0E-03	1.0E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02
Brain	8.4E-05	4.5E-04	1.7E-03	8.5E-03	9.5E-03	9.5E-03	9.5E-03	9.5E-03	9.5E-03
Breast	6.7E-05	4.2E-04	1.6E-03	8.2E-03	9.0E-03	9.0E-03	9.0E-03	9.0E-03	9.0E-03
Oesophagus	9.2E-05	5.2E-04	1.8E-03	9.5E-03	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02
ST Wall	1.8E-04	5.9E-04	2.0E-03	9.5E-03	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02
SI Wall	[illegible]	[illegible]	.0E-03	1.0E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02
ULI Wall	[illegible]	[illegible]	.2E-03	1.0E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02
LLI Wall	[illegible]	[illegible]	.5E-03	1.2E-02	1.3E-02	1.3E-02	1.3E-02	1.3E-02	1.3E-02
Colon	[illegible]	[illegible]	.3E-03	1.1E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02
Kidney	7.7E-05	5.0E-04	1.8E-03	9.7E-03	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02
Liver	7.7E-05	5.0E-04	1.8E-03	9.9E-03	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02
Muscle	8.4E-05	4.9E-04	1.8E-03	9.2E-03	1.0E-02	1.0E-02	1.0E-02	1.0E-02	1.0E-02
Ovaries	8.0E-05	5.4E-04	2.0E-03	1.0E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02
Pancreas	8.5E-05	5.4E-04	2.0E-03	1.0E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02
Red Marrow	8.2E-05	5.0E-04	1.8E-03	9.5E-03	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02
ET Airways	7.4E-03	1.2E-02	1.3E-02	2.0E-02	2.2E-02	2.2E-02	2.2E-02	2.2E-02	2.2E-02
Lungs	1.2E-04	5.2E-04	1.8E-03	9.2E-03	1.0E-02	1.0E-02	1.0E-02	1.0E-02	1.0E-02
Skin	6.5E-05	4.0E-04	1.5E-03	7.9E-03	8.7E-03	8.7E-03	8.7E-03	8.7E-03	8.7E-03
Spleen	7.9E-05	5.0E-04	1.8E-03	9.7E-03	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02
Testes	6.9E-05	4.7E-04	1.8E-03	9.0E-03	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Thymus	9.2E-05	5.2E-04	1.8E-03	9.5E-03	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Thyroid	9.0E-05	5.0E-04	1.8E-03	9.5E-03	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Uterus	8.0E-05	5.4E-04	2.0E-03	1.0E-02	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Remainder	3.7E-03	6.0E-03	7.4E-03	1.5E-02	1.6E-02	1.6E-02	1.6E-02	1.6E-	.6E-02
Effective Dose	2.8E-04	8.2E-04	2.2E-03	1.0E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02	1.1E-02

Each Tissue Equivalent Dose

Calculated Committed Effective Dose (Integrated for 50y=11mSv)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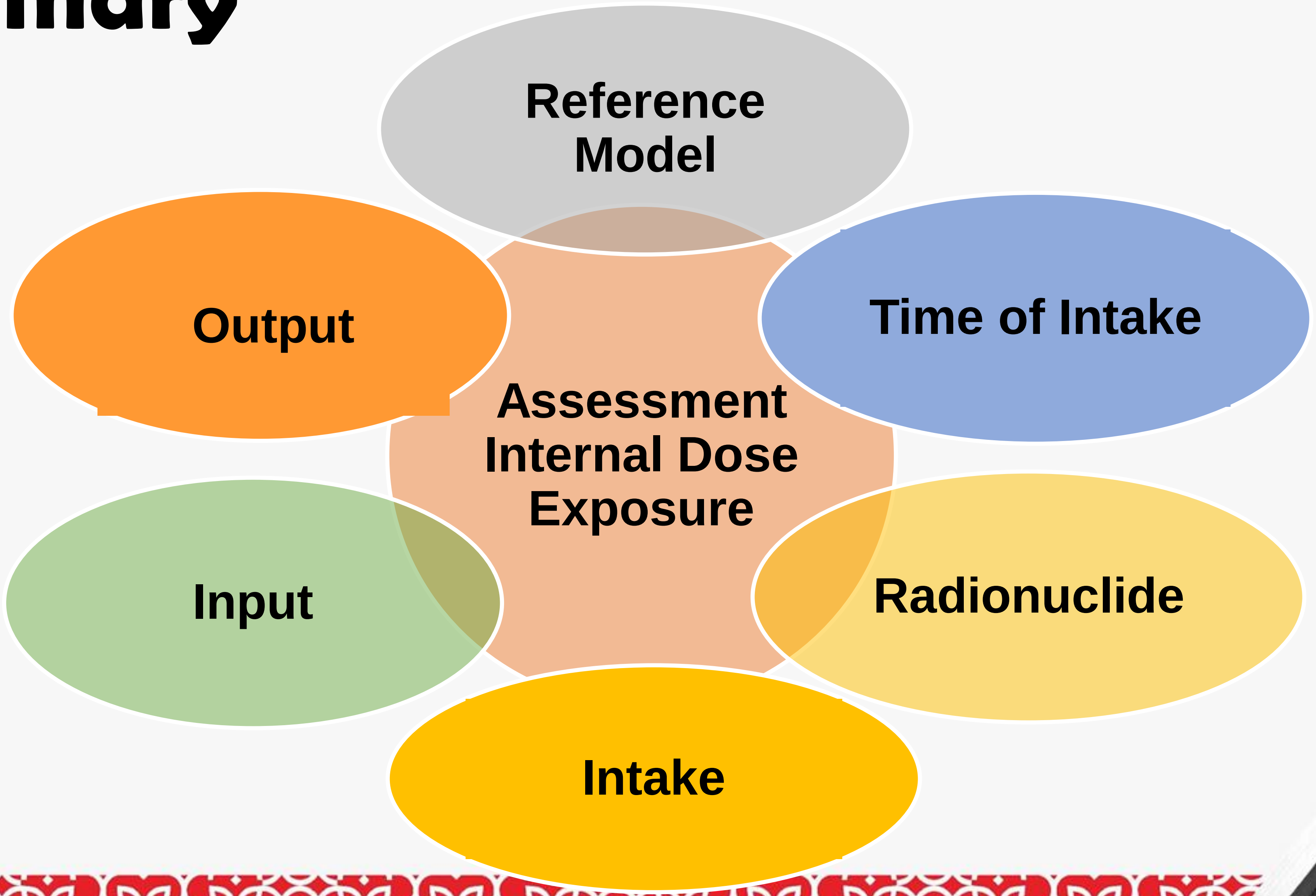
AMAD or Age / Type or f1
AMAD
Mode of Intake
Acute
Chronic
Uneven Chronic
Click here
Measurement
Measurement
Whole body
Graph
Period of intake
days
Measured at
1
days after last intake
Measured activity
1000000
Bq
Exit
Print form
Print result
Save to file
Result
Intake Retention Function Factor Curve
Graph
Menu
Cs-137 (Inhalation by Workers, 5 m n(default), Type F, Whole body)
1E+00
fraction
1E-08
1E-01
1 day
days
1E+03

Summary


Reference Model
Output
Time of Intake
Assessment Internal Dose Exposure
Input
Radionuclide
Intake

References

- HEALTH PHYSICS SOCIETY, ***Performance Criteria for Radiobioassy***, An American National Standard, HPS N13.30-1996 (1996).
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- International Commission On Radiological Protection, **Individual Monitoring for Internal Exposure of Workers**, Publication No. 78, 1997
- Ministry of Environment, Government of Japan, **Booklet to Provide Basic Information Regarding Health Effects of Radiation**.

Thank you!

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