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Monitoring for Dose Assessment

4th EURADOS Winter School
Radiological emergencies – Internal exposures
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Occupational vs. emergency monitoring

	Normal	Emergency	
	Occupational Exposures	**Accident with off-site consequences**	**Malevolent use incident**
Location	Known	Known	Unknown
Site-specific plans	Yes	Yes	No
Environment	Nuclear site	Rural	Urban
Numbers of people affected	Low	Low → Moderate	Low → Moderate → High
Response time	Fast	Fast	? (especially if covert)
Level of exposure	Low	Low → Moderate	Low → Moderate → High
Conventional injuries to public	No	No	Possible

A lesson from Goiânia

Group	Number	% of population
Total population	~ 1,000,000	100
People monitored	112,000	11
People with significant external and internal doses	249	0.025
People admitted to hospital	49	0.005
People needing intensive medical care	22	0.002
Deaths	4	0.0004
Severe trauma (amputation)	1	0.0001

Objectives of individual monitoring

1. To quantify absorbed doses to organs for people who may be at risk of deterministic effects on their health (e.g. acute radiation syndrome)
   - providing an input to decisions on medical treatment

2. To quantify effective doses for people exposed at lower levels but still potentially at risk of stochastic effects on their health (cancer induction)
   - providing an input to decisions on “decorporation” (e.g. use of Prussian Blue for radiocaesium intakes)

3. To identify the potentially large numbers of people for whom exposures are unlikely to have an effect on health
   - e.g. the “worried well”

Triage

Triage: Simple procedures for rapidly sorting people into groups for further actions

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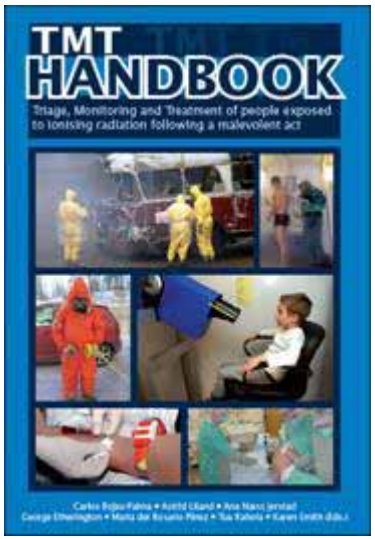

Triage Stage		Typical time period when triage decisions will be made	Information available
Trauma		0-12 h	Severity of physical injuries to individuals
Radiological	Pre-monitoring	2-36 h	Location, etc., at time of incident
		0 h – 6 days	Clinical signs and symptoms, and in the later stages, the results of complete blood counts
	Post monitoring	6-72 h	Results of initial screening measurements made at incident location
		12 h – 6 d	Results of measurements made with transportable *in vivo* monitoring facilities close to incident location
		24 h – 6 d	Results of laboratory *in vivo* monitoring measurements
		72 h – 6 d	Results of laboratory *in vitro* measurements of biological samples (e.g. radionuclides in urine, cytogenetic measurements of blood, etc.)

Notes.
1. The results of radiological monitoring will continue to be received well beyond the end of the period where triage decisions are expected to be made. For some cases, the same will apply to the results of observations of clinical signs and symptoms.
2. For some types of incident, not all of these triage stages would arise.

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Monitoring equipment & techniques

NaI(Tl) monitor, © HPA

A simple NaI(Tl) gamma spectrometer

© STUK

Portal monitor,

© HPA

Portable radionuclide identifier, © HPA

Lap geometry "whole body" measurement

© STUK

Monitoring equipment & techniques

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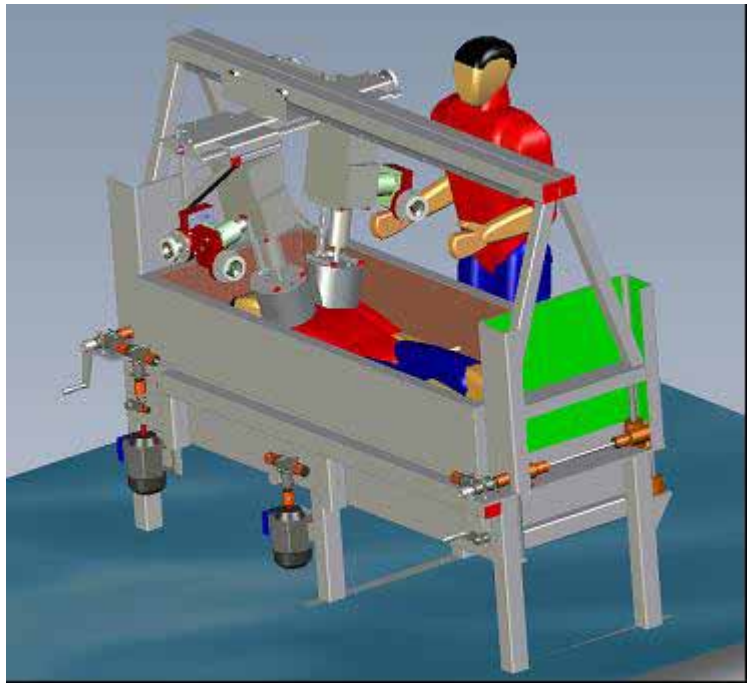
Truck-based whole body counter
STUK, Finland

Monitoring equipment & techniques

© IRSN

IRSN's new mobile vehicle for body counting
IRSN, France



© IRSN

Measurement station of IRSN's new mobile vehicle for body counting

Monitoring equipment & techniques

HPA's transportable body monitoring system
HPA, UK © HPA

Monitoring equipment & techniques

Medical imaging system
(gamma camera)

Laboratory whole body monitor

Monitoring equipment & techniques

Bioassay sample analysis:

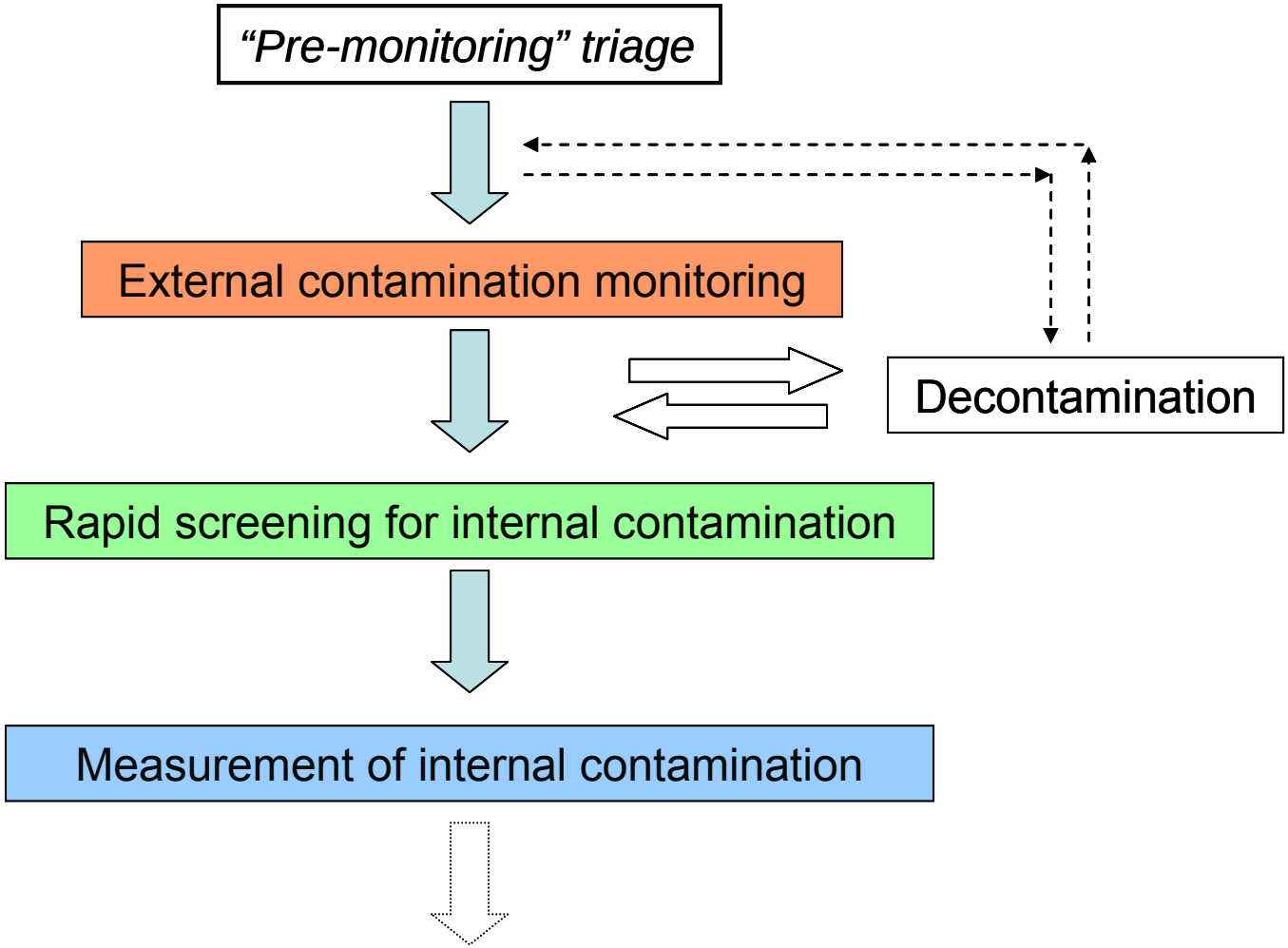
Urine monitoring

Screening vs. measurement

Screening (triage)

Measurement of internal contamination

Stages of monitoring



Specifying a monitoring strategy

- Identification and characterisation of radionuclide(s)
- Identification of the people to be monitored
- Locations for individual monitoring
- Stages of monitoring
- Individual monitoring methods
- Action Levels corresponding to the various actions that should be performed after individual monitoring
- Dose Assessment
- Long term follow-up monitoring
- Recording and reporting of monitoring results

Monitoring strategy: methods

Radionuclide (absorption type)		Radiation type emitted	Rapid screening method	Primary monitoring method
Manganese-54 (F)	^{54}Mn	γ (EC)	Whole body (rapid)	Whole body
Cobalt-60	^{60}Co	β, γ	Whole body (rapid)	Lung
Strontium-90	^{90}Sr	β	Nose blow/nasal swab	Urine
Selenium-75	^{75}Se	γ (EC)	Whole body (rapid)	Whole body
Silver-110m	^{110}Ag	β, γ	Whole body (rapid)	Whole body
Cadmium-109	^{109}Cd	γ (EC)	Whole body (rapid) Nose blow/nasal swab	Whole body, urine
Iodine-131	^{131}I	β, γ	Thyroid (rapid)	Thyroid
Barium-133	^{133}Ba	γ (EC)	Whole body (rapid)	Whole body
Caesium-137	^{137}Cs	β, γ	Whole body (rapid)	Whole body
Europium-152	^{152}Eu	β, γ	Whole body (rapid)	Whole body
Europium-154	^{154}Eu	β, γ	Whole body (rapid)	Whole body
Iridium-192 (F)	^{192}Ir	β, γ	Whole body (rapid)	Whole body
Polonium-210	^{210}Po	α	None	Urine
Radium-226	^{226}Ra	α	Nose blow/nasal swab	Lung, Urine
Plutonium-238	^{238}Pu	α	Nose blow/nasal swab	Urine, Faeces[1] (Lung[2])
Americium-241	^{241}Am	α, γ	Nose blow/nasal swab	Lung
Californium-252	^{252}Cf	α	Nose blow/nasal swab	Urine, Faeces[1] (Lung[2])

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Upper Action Levels on dose

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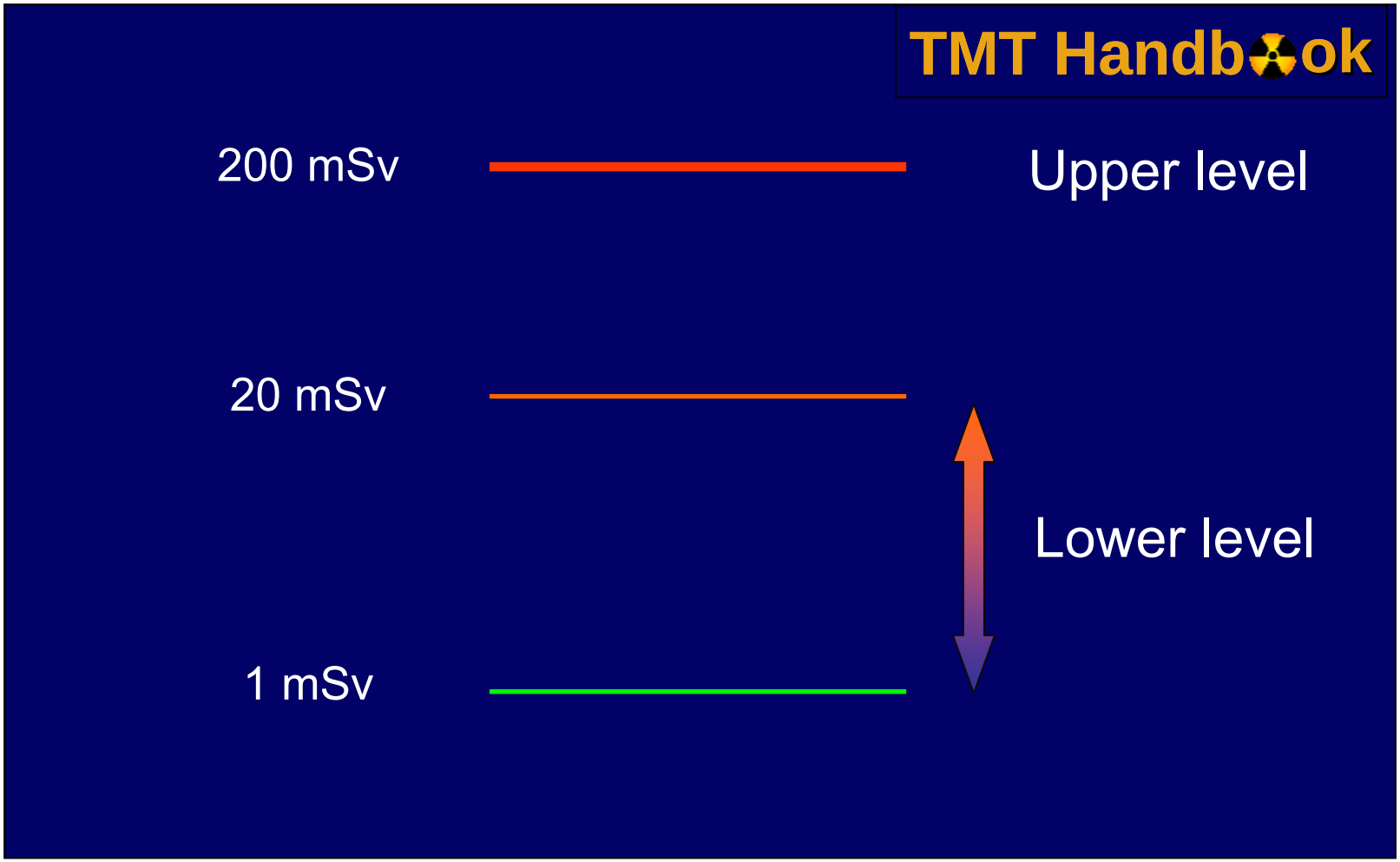
Internal contamination

- **E_{50} = 200 mSv**
  - Level proposed by TIARA project above which medical treatment to reduce doses (e.g. by decorporation) should be considered (Menetrier et al., 2005)

External contamination

- **D = 2 Gy to skin**
  - 20% of the level recommended by IAEA (Generic Procedures for Medical Response (IAEA-EPR-MEDICAL 2005)) for immediate decontamination, immediate medical examination, and medical treatment.

Upper & Lower Action Levels



Action Levels on measured quantities

Example #1: ^{60}Co inhalation

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Table A10.3b. Action levels for Cobalt-60, Inhalation, Type S

Radio-nuclide	Action Level on:	Method	ALu					Initial value for AL_u /AL_l
			12 h	1 d	3 d	7 d	14 d	
Co-60 *Type S*	External contamination	External scan	2,1E+05	1,1E+05	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	6,7E+06	5,0E+06	1,6E+06	8,4E+05	7,6E+05	10
	Internal contamination - primary monitoring method	Lung	8,3E+05	8,0E+05	7,7E+05	7,4E+05	6,9E+05	10

Notes
ALu - Upper Action Level
ALl - Lower Action Level
- Comparison with Action Level not valid at these times
Action levels are expressed in Bq, except for external contamination (Bq cm-2) and urinary excretion (Bq d-1)
Dose calculations were performed using the assumptions specified in Annex 13

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Action Levels on measured quantities

Example #2: ^{210}Po ingestion

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Table A10.14b. Action levels for Polonium-210, Ingestion

Radio-nuclide	Action Level on:	Method	ALu					Initial value for AL_u /AL_l
			12 h	1 d	3 d	7 d	14 d	
Po-210	External contamination	External scan	2,4E+11	1,2E+11	-	-	-	10
	Internal contamination - rapid initial screening	None	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Urine	-	1,6E+02	3,6E+02	3,4E+02	2,9E+02	10

Notes
ALu - Upper Action Level
ALl - Lower Action Level
- Comparison with Action Level not valid at these times
Action levels are expressed in Bq, except for external contamination (Bq cm-2) and urinary excretion (Bq d-1)
Dose calculations were performed using the assumptions specified in Annex 13

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Action Levels for children

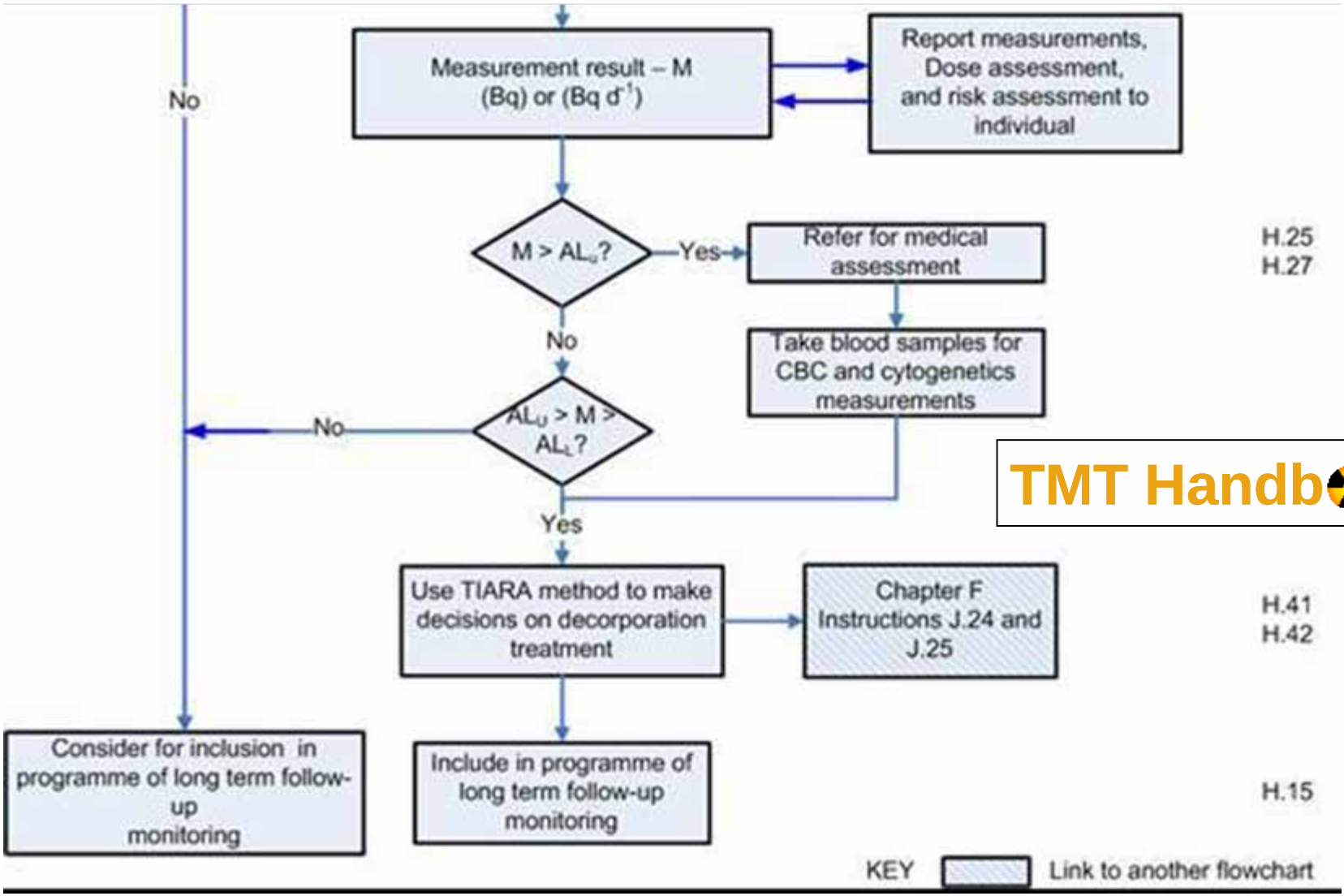
- **In some cases, assessed doses for children are significantly greater than for adults**
- **Action Levels for children should therefore be reduced from their adult values**
- **Reduction by a factor of 10 is appropriate**
- **Action Levels may be revised subsequently on the basis of more realistic dosimetry calculations**

Accuracy of Action Levels

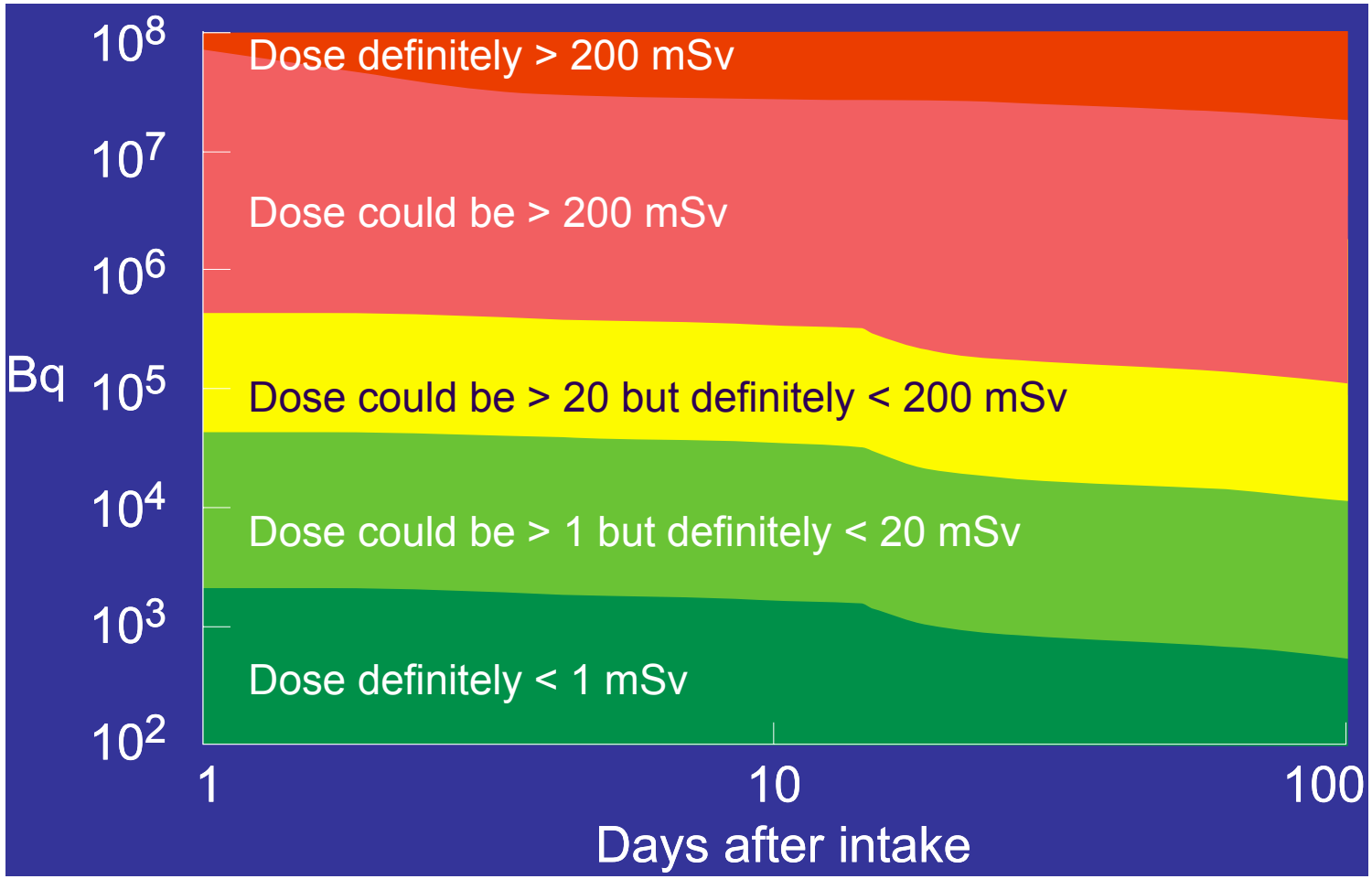
- **TMT's Action Levels on measured quantities were determined using bioassay calculations that used default assumptions and model parameter values**
- **Relationship between measured quantity and dose is not intended to have a high level of accuracy**
- **Nevertheless, Action Levels should be adequate for the intended purpose, i.e.**

to facilitate decisions about further actions

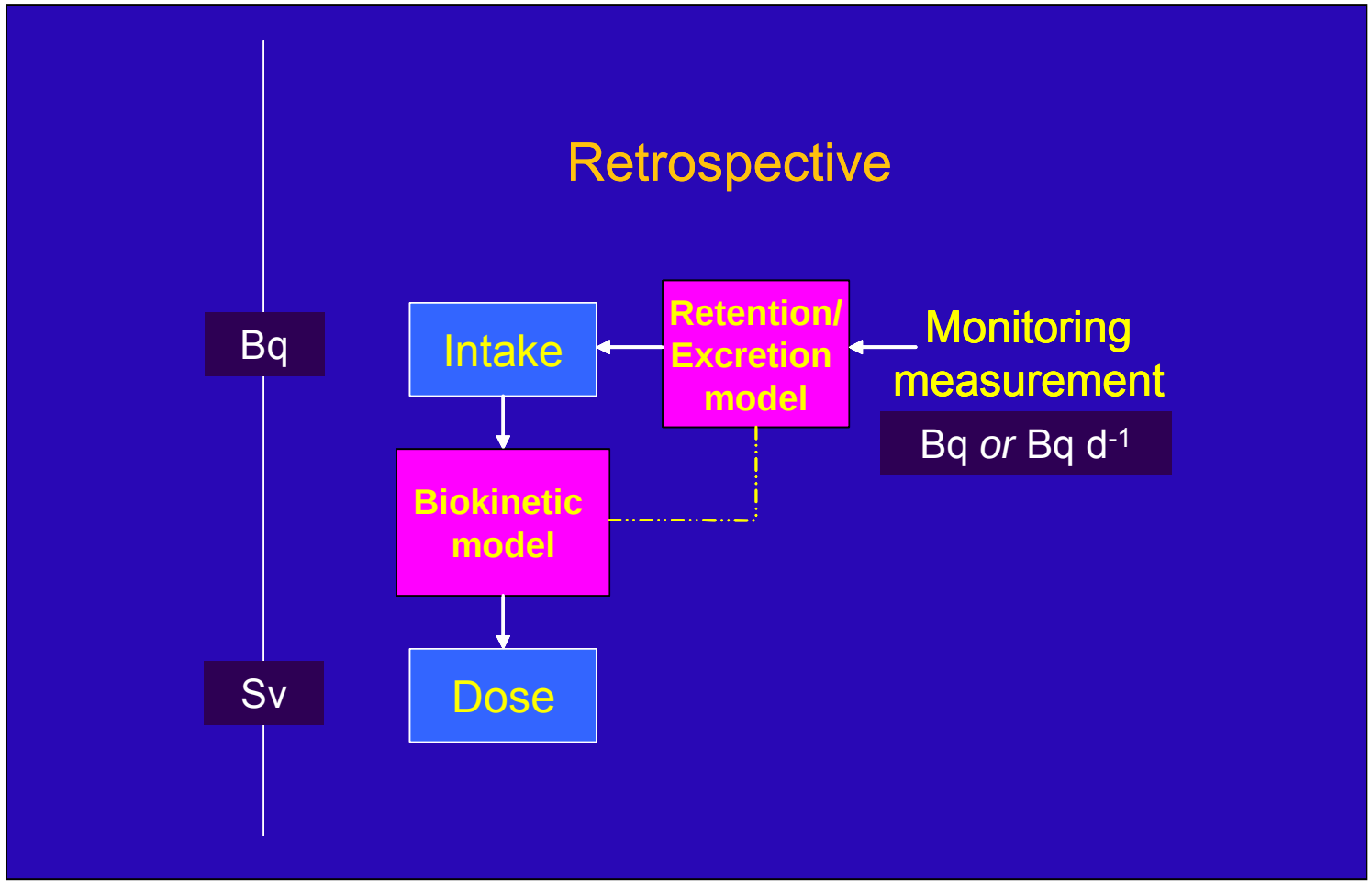
Actions after internal contamination measurement



TIARA method: ^{137}Cs whole body measurement



Assessment of internal doses from monitoring data



RBE factors for severe deterministic effects (IAEA)

Table H4 Relative Biological Effectiveness (RBE) for severe deterministic effects

Radiation	**RBE**
Gamma-radiation & X-radiation	1
Beta particles	1
Alpha particles irradiating lungs	7
Alpha particles irradiating red bone marrow	2
Alpha particles irradiating colon	0
Iodine-131 irradiating thyroid	0.2

From Table F1, Generic procedures for medical response during a nuclear or radiological emergency. IAEA / WHO EPR-Medical 2005

Action Levels on organ absorbed doses (IAEA)

Table H6 Generic reference levels on RBE-weighted absorbed dose [1]

Organ	RBE-weighted absorbed dose (Gy-Eq) [2]
Red marrow (intakes of actinides)	0.2
Red marrow (intakes of other radionuclides)	2
Thyroid [3]	2
Lung	30
Colon	20

Notes
1. From Table F2, Generic procedures for medical response during a nuclear or radiological emergency. IAEA / WHO EPR-Medical (2005).
2. Integration period = 30 d.
3. For use only when the thyroid is the critical organ

If these values are exceeded, then:

- **refer immediately for medical assessment**
- **consider for:**
  - **treatment**
  - **decorporation therapy**
  - **stable iodine, as appropriate**

Dose per unit measurement “look-up“ tables

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Table 2c. Doses from an Intake by INGESTION of ^{60}Co (f_1 = 0.1) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single Intake						
Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ :	Lungs	Red bone marrow	Colon	-
		Integration period :	30 d			To age 70 y
Measurement time						
6 h	1.01		2.1E-10	5.8E-10	7.0E-09	3.4E-09
12 h	1.09		2.2E-10	6.2E-10	7.5E-09	3.7E-09
1 d	1.41		2.9E-10	8.0E-10	9.8E-09	4.8E-09
2 d	2.89		6.0E-10	1.7E-09	2.0E-08	9.8E-09
3 d	6.13		1.3E-09	3.5E-09	4.2E-08	2.1E-08
4 d	11.5		2.4E-09	6.6E-09	8.0E-08	3.9E-08
5 d	17.9		3.7E-09	1.0E-08	1.2E-07	6.1E-08
6 d	23.3		4.8E-09	1.3E-08	1.6E-07	7.9E-08
7 d	27.0		5.6E-09	1.5E-08	1.9E-07	9.2E-08
10 d	33.4		6.9E-09	1.9E-08	2.3E-07	1.1E-07
14 d	39.6		8.2E-09	2.3E-08	2.7E-07	1.3E-07
21 d	48.3		1.0E-08	2.8E-08	3.3E-07	1.6E-07
28 d	54.7		1.1E-08	3.1E-08	3.8E-07	1.9E-07

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Dose per unit measurement: Assumptions

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- All calculations performed for adults
- Single (acute) intake
- Activity Median Aerodynamic Diameter (AMAD) = 5 μm
- Occupational exposure defaults for other particle size parameters
- Default physical activity levels as given in ICRP Publication 71
- Models: calculations performed using the ICRP Publication 66 Respiratory Tract Model, the current biokinetic models described in ICRP Publications 30, 56, 67 and 69, and the ICRP Publication 30 gastro-intestinal tract model.

Limitations on use of TMT dose assessment tables

Calculations use a combination of default parameter values

- Particle size distribution could be highly variable
- Absorption Type is dependent on chemical form, on which information would be sparse
- Intake pathway may be uncertain
- Measurements (particularly rapid screening measurements) could have large uncertainties

Therefore, while dose assessments based on default values for input data may be adequate for initial dose assessments ..

… they may not be adequate as a final assessment if doses are significant

Some other issues

- Time needed to initiate response
- Triage procedures
- Monitoring throughput
- Locations for monitoring, and other practical issues
- Control of exposure for workers
- Collecting information from people
- Providing information to people
- Recording and reporting individual monitoring data
- Press and public relations
- Psychological issues (public and workers)

Selected information resources

- Radiation Event Medical Management website: http://www.remm.nlm.gov
- Radiation Emergency Assistance Centre (REAC/TS) website. http://orise.orau.gov/reacts/index.htm
- TMT Handbook website: http://www.tmthandbook.org
- IAEA Response Assistance Network: http://www-pub.iaea.org/MTCD/publications/PDF/Ranet2006_web.pdf
- IAEA Manual for First Responders to a Radiological Emergency. http://www-pub.iaea.org/MTCD/publications/PDF/EPR_First_Responder_web.pdf
- IAEA Generic Procedures for Assessment and Response during a Radiological Emergency. http://www-pub.iaea.org/MTCD/publications/PDF/te_1162_web.pdf
- IAEA Generic Procedures for Medical Response during a Nuclear or Radiological Emergency. http://www-pub.iaea.org/MTCD/publications/PDF/EPR-MEDICAL-2005_web.pdf
- Health Physics 2005; **89**(5). Several papers are of interest.

Acknowledgements

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