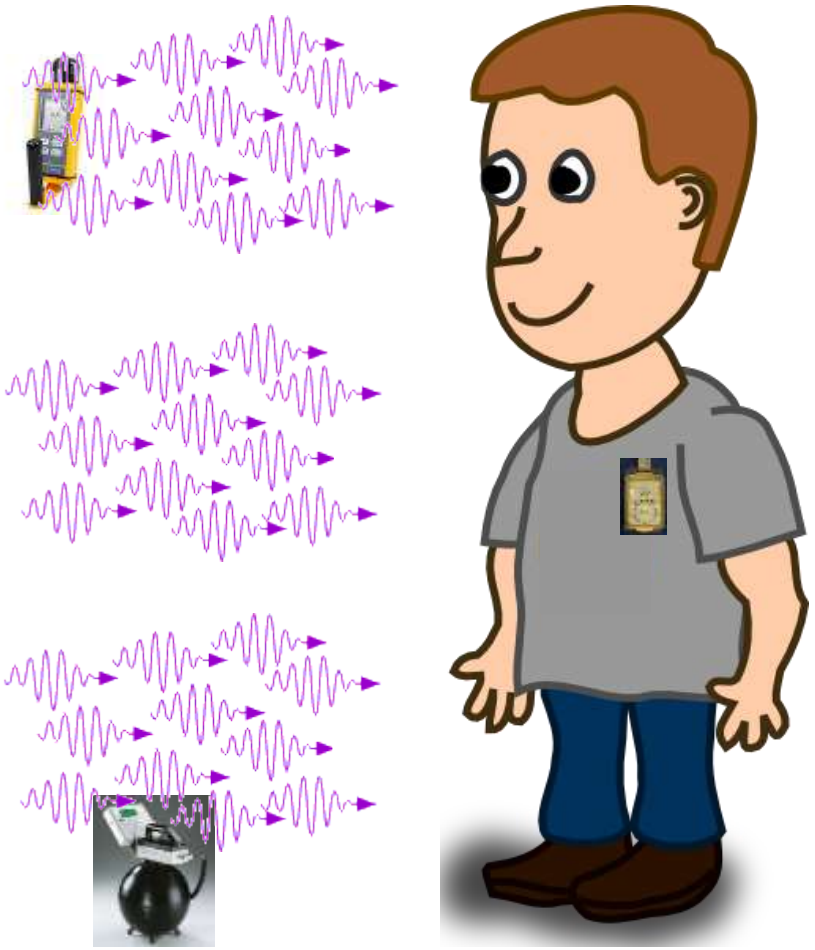
How to assess doses from internal emitters

in Radiation Protection and Medicine

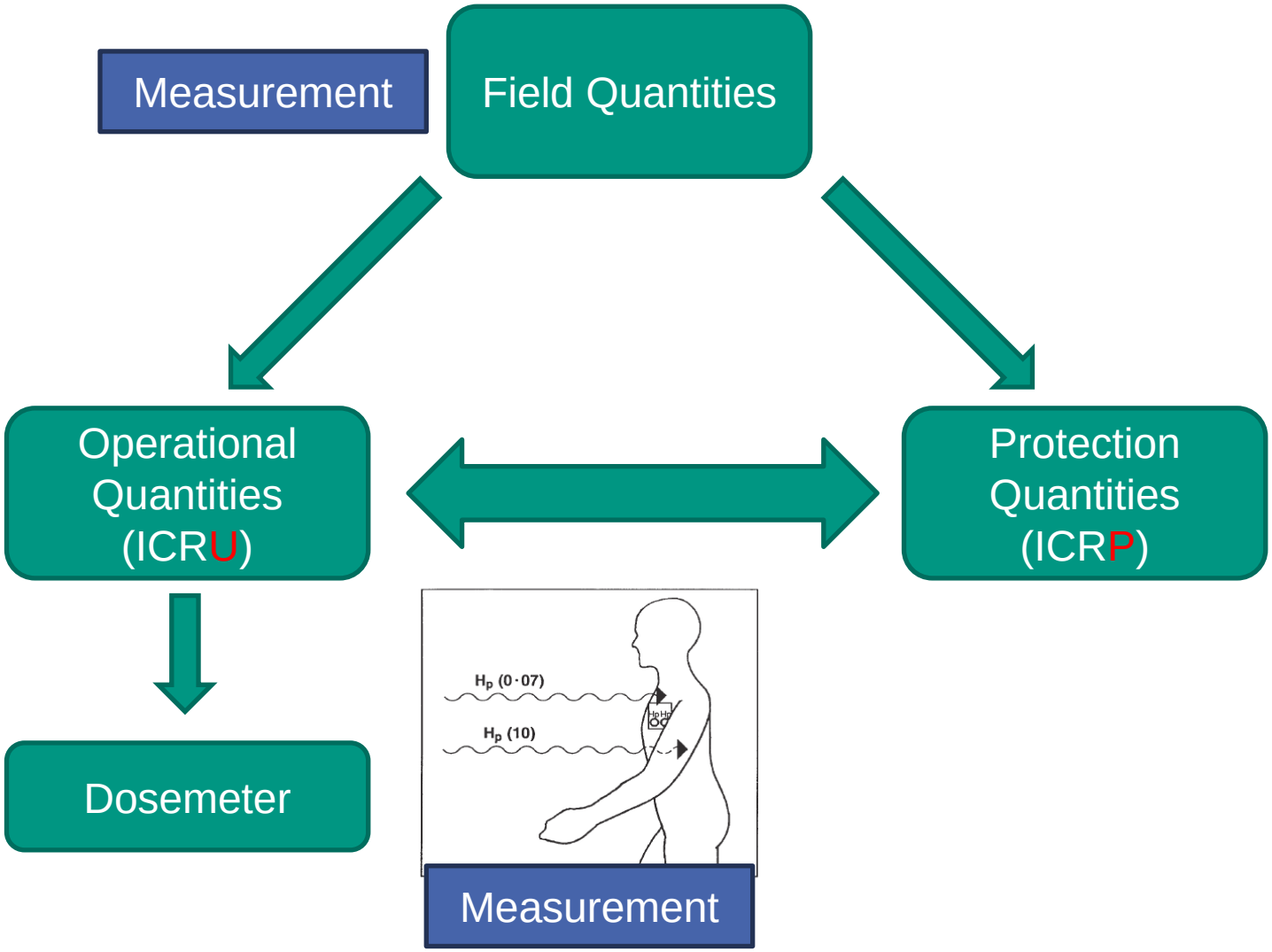
PD Dr. Bastian Breustedt, Safety and Environment (SUM)

Dosimetry

- External Radiation Fields
  - Field outside of body
  - Acute Exposure
  - Assessment of doses by quantification of field
    - Conversion factors
  - Direct measurement of doses
    - Area Dosimeter (Workplace Monitoring)
    - Personal Dosimeter (Individual Monitoring)

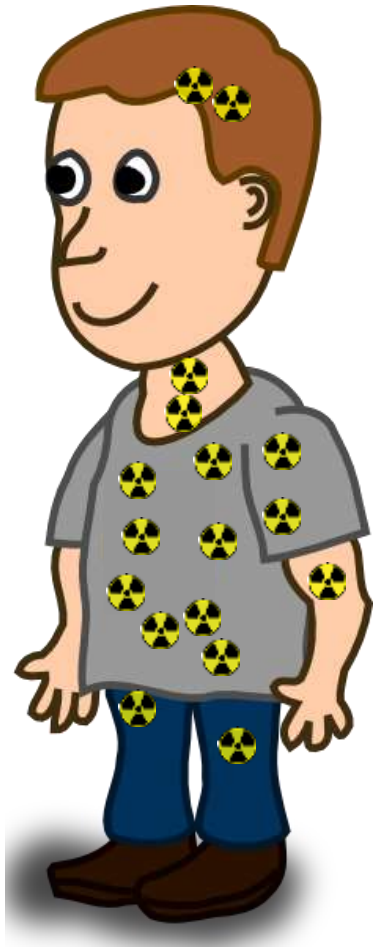


The Dosimetric System



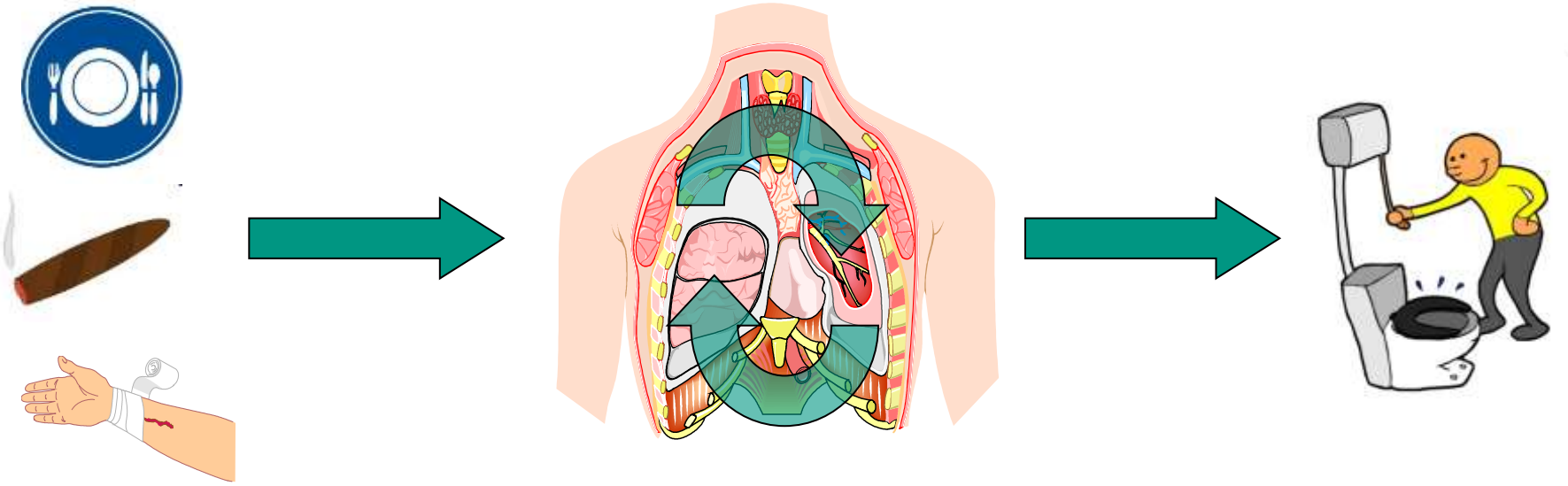
Dosimetry

- Internal Emitters
  - Source (radionuclide) inside body
  - Chronic Exposure
  - Direct measurement of dose **(mSv)** impossible
  - Measurement of Activity **(Bq)** in
    - Air/Water/Food
    - Body
    - Excretion



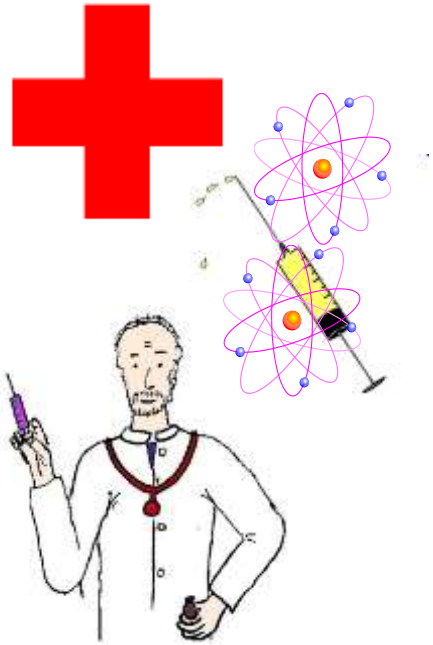
Radionuclides inside the human body

- Intakes (in public and occupational Exposures)
  - Ingestion
  - Inhalation
  - Wound
- Distribution/Redistribution in the Body
- Excretion

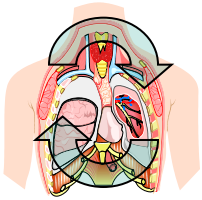


Radionuclides inside the human body

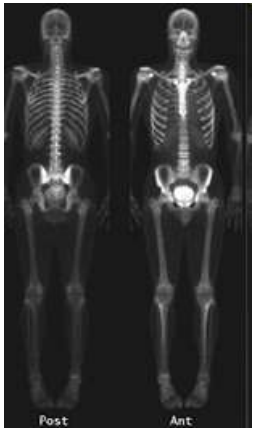
- Medical Application of Radionuclides – Nuclear Medicine



Injection of RN



Distribution in Patient



Imaging - Diagnosis

Therapy

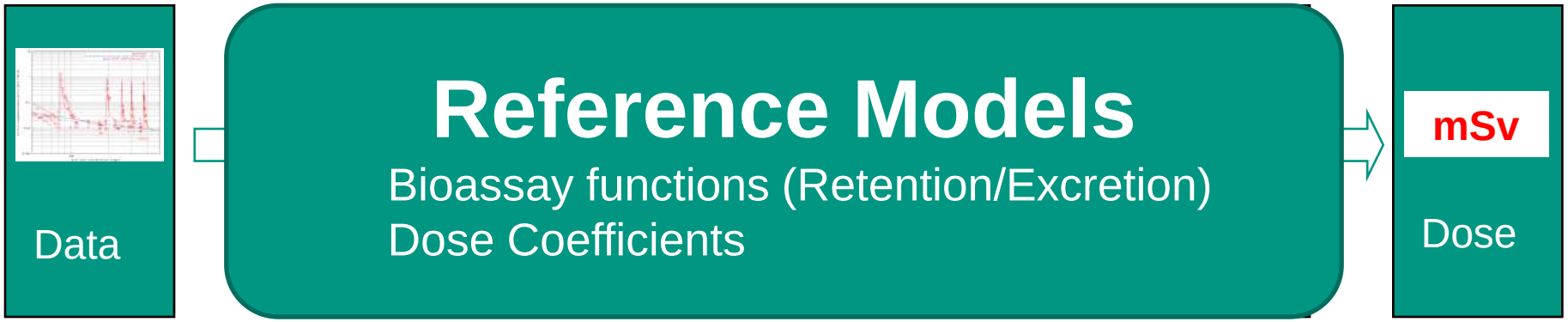
Medical and Occupational Intakes

- Example Case: I-131
  - Occupational Intake by Staff in Nuclear Medicine
  - Medical Intake by Patient (Radiotherapy of Thyroid Cancer)

	Staff	Patient (Therapy)
Method	Individual Monitoring	Imaging / Counting
Detection Limit	1,5E+1 Bq	nA
Intake	2,0E+2 Bq	1,0E+9 Bq
Dose to Thyroid	4,2E-5 Sv	2,5E+2 **Gy**
effective Dose	2,0E-6 Sv	nA
Biological Effects	Stochastic	Tissue Reaction

Dose Assessment for Occupational Exposures

- Monitoring → Data (Bq)
- Evaluation of Intake
  - Biokinetic model describes behaviour of RN in body
- Evaluation of Energy Deposition → **Committed** Dose (mSv)
  - (time dependent) Distribution of Source inside body (biokinetic model)
  - Energy Deposition per Decay (dosimetric model)

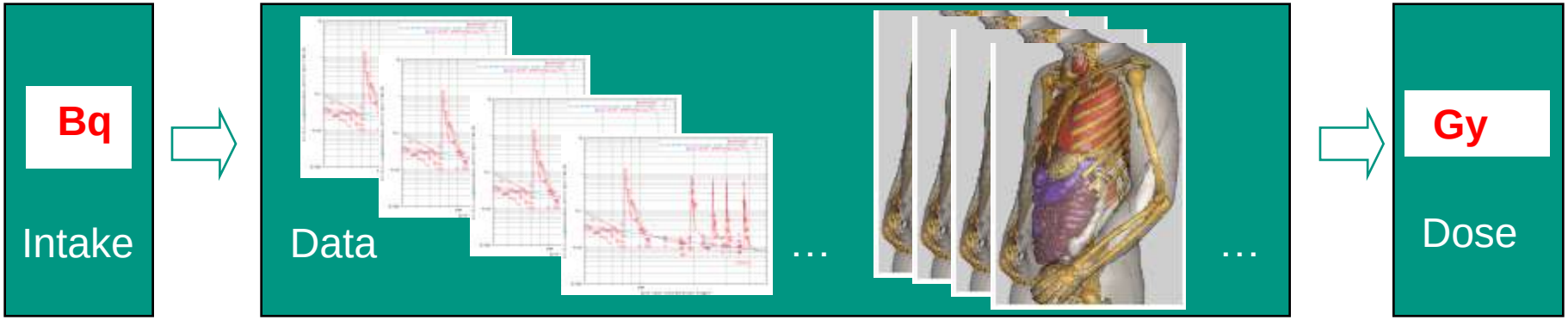


Dose Assessment for Medical Exposure

- Intake is (well) known
- Data acquisition (e.g. quantitative imaging)
- Dose Assessment based on models
  - Biokinetic Model describes behavior of RN in body (individual model required)
  - Dosimetric Model describes energy deposition

Dose Assessment for Medical Exposure

- Intake is (well) known
- Data acquisition (e.g. quantitative imaging)
- Dose Assessment based on data
  - Behavior of RN in body is observed
  - Individual Morphology of Patient can be used in the dosimetric model



Internal Dose Assessment – Methodology

- ICRP and MIRD developed methodology in 1960s
  - Concepts are the same but subtle differences

TABLE 1. Quantities, Parameters, Symbols, and Units Used in the MIRD and ICRP Dosimetry Schema (Listed in Order of Appearance in Equations 1–17)

Quantity or parameter	MIRD Pamphlet 21	MIRD Primer (1991) (4)	ICRP publications (7,8,18)	Units or special name
Source region (or tissue)	r_S	r_h	S	
Target region (or tissue)	r_T	r_k	T	
Absorbed dose rate to target region	$\dot{D}(r_T,t)$	$\dot{D}(r_k)$ or $\dot{D}_k$	$\dot{D}_{T,R}$	Gy s^{-1}
Activity in source region	$A(r_S,t)$	$A_h(t)$	$q_S(t)$	Bq
Absorbed dose rate per unit activity	$S(r_T \leftarrow r_S,t)$	$S(r_k \leftarrow r_h)$	Not defined	Gy $(Bq\ s)^{-1}$
Dose-integration period	T_D	Assumed to be ∞	τ	s
Absorbed dose to target	$D(r_T,T_D)$	$\bar{D}(r_k)$ or $\bar{D}_k$	$D_{T,R}$	Gy
Administered activity	A_0	A_0	q_0	Bq
Fraction of administered activity in the source region	$a(r_S,t) = A(r_S,t)/A_0$	$f_h(t)$	Not defined	Unitless
Absorbed dose coefficient	$d(r_T,T_D)$	Not defined	$d_T(\tau)$	Gy Bq^{-1}
Mean energy of the i^{th} transition	E_i	E_i	E_i	J or MeV
Number of i^{th} transitions per nuclear transformation	Y_i	n_i	Y_i	$(Bq\ s)^{-1}$
Mean energy of the i^{it} transition per nuclear transformation	Δ_i	Δ_i	Δ_i	J $(Bq\ s)^{-1}$ or MeV $(Bq\ s)^{-1}$
Absorbed fraction	$\phi(r_T \leftarrow r_S,E_i,t)$	$\phi(r_k \leftarrow r_h)$	$AF(T \leftarrow S,E_i)$	Unitless
Mass of target region	$M(r_T,t)$	m_k	m_T	kg
Specific absorbed fraction	$\Phi(r_T \leftarrow r_S,E_i,t)$	$\Phi(r_k \leftarrow r_h)$	$SAF(T \leftarrow S,E_i)$	kg^{-1}
Time-integrated activity in source region*	$\tilde{A}(r_S,T_D)$	$\tilde{A}_h$	U_S	Bq s
Time-integrated activity coefficient†	$\tilde{a}(r_S,T_D)$	τ	Not defined	s
Equivalent dose to target	$H(r_T,T_D)$	Not defined	H_T	Sv
Radiation weighting factor	w_R	Not defined	w_R	Unitless
Absorbed dose to target by radiation type R	$D_R(r_T,T_D)$	Not defined	$D_{T,R}$	Gy
Radiation-weighted S	$S_w(r_T \leftarrow r_S,t)$	Not defined	$SEE(T \leftarrow S)$	Sv $(Bq\ s)^{-1}$
Equivalent dose coefficient	$h(r_T,T_D)$	Not defined	$h_T(\tau)$	Sv Bq^{-1}
Effective dose	E	Not defined	E	Sv

*This quantity was termed *cumulated activity* in 1991 MIRD Primer.
†This quantity was termed *residence time* in 1991 MIRD Primer.

Bolch W. et al.: „MIRD Pamphlet 21: A Generalized Schema for Radiopharmaceutical Dosimetry—Standardization of Nomenclature“, J Nucl Med 2009; 50:477–484

10th EURADOS Winter School

Time	Topic	Speaker
09:00	Opening: Welcome – Introduction	
09:05	How to assess doses from internal emitters in Radiation Protection and Medicine	B. Breustedt (KIT, Germany)
09:30	ICRP Perspective on internal dosimetry – OIR and Radiopharmaceuticals	D. Nosske (BfS, Germany - retired)
10:00	Internal Dosimetry in occupational radiation protection – The TECHREC project	G. Etherington (PHE, UK)
10:30	Coffee Break	
11:00	Internal dosimetry in nuclear medicine – Status, Challenges and Perspectives	M. Lassmann (U. Würzburg, Germany)
11:30	The use of alpha-emitting radionuclides in medicine: status, challenges and perspectives	M. Bardies (CRCT, France)
12:00	Computational phantoms used in internal dosimetry for radiation protection and medicine	M. Zankl (HMGU, Germany)
12:20	Micro- and nanodosimetry for internal emitters– changing the scale	W. Li (HMGU, Germany)
12:40	Lunch	
13:50	Uncertainties and internal dosimetry	A. Giusssani (BfS, Germany)
14:10	Dosimetry for the Epidemiology of internal emitters – risk assessment vs. operational radiation protection	E. Davesne (IRSN, France)
14:30	Internal dosimetry in emergency situations – challenges and recent developments	M.A. Lopez (CIEMAT, Spain)
14:50	Standardization in internal dosimetry – Recent developments in ISO Standards for Radiation Protection	D. Bingham (AWE, UK)
15:10	Research Needs in internal dosimetry– updating EURADOS SRA	Round Table

- Developments in Models and Approaches

10th EURADOS Winter School

Time	Topic	Speaker
09:00	Opening: Welcome – Introduction	
09:05	How to assess doses from internal emitters in Radiation Protection and Medicine	B. Breustedt (KIT, Germany)
09:30	ICRP Perspective on internal dosimetry – OIR and Radiopharmaceuticals	D. Nosske (BfS, Germany - retired)
10:00	Internal Dosimetry in occupational radiation protection – The TECHREC project	G. Etherington (PHE, UK)
10:30	Coffee Break	
11:00	Internal dosimetry in nuclear medicine – Status, Challenges and Perspectives	M. Lassmann (U. Würzburg, Germany)
11:30	The use of alpha-emitting radionuclides in medicine: status, challenges and perspectives	M. Bardies (CRCT, France)
12:00	Computational phantoms used in internal dosimetry for radiation protection and medicine	M. Zankl (HMGU, Germany)
12:20	Micro- and nanodosimetry for internal emitters– changing the scale	W. Li (HMGU, Germany)
12:40	Lunch	
13:50	Uncertainties and internal dosimetry	A. Giusssani (BfS, Germany)
14:10	Dosimetry for the Epidemiology of internal emitters – risk assessment vs. operational radiation protection	E. Davesne (IRSN, France)
14:30	Internal dosimetry in emergency situations – challenges and recent developments	M.A. Lopez (CIEMAT, Spain)
14:50	Standardization in internal dosimetry – Recent developments in ISO Standards for Radiation Protection	D. Bingham (AWE, UK)
15:10	Research Needs in internal dosimetry– updating EURADOS SRA	Round Table

- Developments in Models and Approaches
- Standards and Guidelines

10th EURADOS Winter School

Time	Topic	Speaker
09:00	Opening: Welcome – Introduction	
09:05	How to assess doses from internal emitters in Radiation Protection and Medicine	B. Breustedt (KIT, Germany)
09:30	ICRP Perspective on internal dosimetry – OIR and Radiopharmaceuticals	D. Nosske (BfS, Germany - retired)
10:00	Internal Dosimetry in occupational radiation protection – The TECHREC project	G. Etherington (PHE, UK)
10:30	Coffee Break	
11:00	Internal dosimetry in nuclear medicine – Status, Challenges and Perspectives	M. Lassmann (U. Würzburg, Germany)
11:30	The use of alpha-emitting radionuclides in medicine: status, challenges and perspectives	M. Bardies (CRCT, France)
12:00	Computational phantoms used in internal dosimetry for radiation protection and medicine	M. Zankl (HMGU, Germany)
12:20	Micro- and nanodosimetry for internal emitters– changing the scale	W. Li (HMGU, Germany)
12:40	Lunch	
13:50	Uncertainties and internal dosimetry	A. Giusssani (BfS, Germany)
14:10	Dosimetry for the Epidemiology of internal emitters – risk assessment vs. operational radiation protection	E. Davesne (IRSN, France)
14:30	Internal dosimetry in emergency situations – challenges and recent developments	M.A. Lopez (CIEMAT, Spain)
14:50	Standardization in internal dosimetry – Recent developments in ISO Standards for Radiation Protection	D. Bingham (AWE, UK)
15:10	Research Needs in internal dosimetry– updating EURADOS SRA	Round Table

- Developments in Models and Approaches
- Standards and Guidelines
- Special Applications
  - Epidemiology
  - Emergency Situations

10th EURADOS Winter School

Time	Topic	Speaker
09:00	Opening: Welcome – Introduction	
09:05	How to assess doses from internal emitters in Radiation Protection and Medicine	B. Breustedt (KIT, Germany)
09:30	ICRP Perspective on internal dosimetry – OIR and Radiopharmaceuticals	D. Nosske (BfS, Germany - retired)
10:00	Internal Dosimetry in occupational radiation protection – The TECHREC project	G. Etherington (PHE, UK)
10:30	Coffee Break	
11:00	Internal dosimetry in nuclear medicine – Status, Challenges and Perspectives	M. Lassmann (U. Würzburg, Germany)
11:30	The use of alpha-emitting radionuclides in medicine: status, challenges and perspectives	M. Bardies (CRCT, France)
12:00	Computational phantoms used in internal dosimetry for radiation protection and medicine	M. Zankl (HMGU, Germany)
12:20	Micro- and nanodosimetry for internal emitters– changing the scale	W. Li (HMGU, Germany)
12:40	Lunch	
13:50	Uncertainties and internal dosimetry	A. Giusssani (BfS, Germany)
14:10	Dosimetry for the Epidemiology of internal emitters – risk assessment vs. operational radiation protection	E. Davesne (IRSN, France)
14:30	Internal dosimetry in emergency situations – challenges and recent developments	M.A. Lopez (CIEMAT, Spain)
14:50	Standardization in internal dosimetry – Recent developments in ISO Standards for Radiation Protection	D. Bingham (AWE, UK)
15:10	Research Needs in internal dosimetry– updating EURADOS SRA	Round Table

- Developments in Models and Approaches
- Standards and Guidelines
- Special Applications
  - Epidemiology
  - Emergency Situations
- Uncertainties

10th EURADOS Winter School

Time	Topic	Speaker
09:00	Opening: Welcome – Introduction	
09:05	How to assess doses from internal emitters in Radiation Protection and Medicine	B. Breustedt (KIT, Germany)
09:30	ICRP Perspective on internal dosimetry – OIR and Radiopharmaceuticals	D. Nosske (BfS, Germany - retired)
10:00	Internal Dosimetry in occupational radiation protection – The TECHREC project	G. Etherington (PHE, UK)
10:30	Coffee Break	
11:00	Internal dosimetry in nuclear medicine – Status, Challenges and Perspectives	M. Lassmann (U. Würzburg, Germany)
11:30	The use of alpha-emitting radionuclides in medicine: status, challenges and perspectives	M. Bardies (CRCT, France)
12:00	Computational phantoms used in internal dosimetry for radiation protection and medicine	M. Zankl (HMGU, Germany)
12:20	Micro- and nanodosimetry for internal emitters – changing the scale	W. Li (HMGU, Germany)
12:40	Lunch	
13:50	Uncertainties and internal dosimetry	A. Giusssani (BfS, Germany)
14:10	Dosimetry for the Epidemiology of internal emitters – risk assessment vs. operational radiation protection	E. Davesne (IRSN, France)
14:30	Internal dosimetry in emergency situations – challenges and recent developments	M.A. Lopez (CIEMAT, Spain)
14:50	Standardization in internal dosimetry – Recent developments in ISO Standards for Radiation Protection	D. Bingham (AWE, UK)
15:10	Research Needs in internal dosimetry– updating EURADOS SRA	Round Table

- Developments in Models and Approaches
- Standards and Guidelines
- Special Applications
  - Epidemiology
  - Emergency Situations
- Uncertainties
- New Issues
  - Alpha Emitters in Medicine
  - Micro-/Nano Dosimetry