MONITORING AND ASSESSMENT OF EXPOSURE FROM UNPLANNED RELEASES TO THE ENVIRONMENT:
INTERNATIONAL REQUIREMENTS, GUIDANCE DOCUMENTS AND THE EXPERIENCE OF UKRAINE

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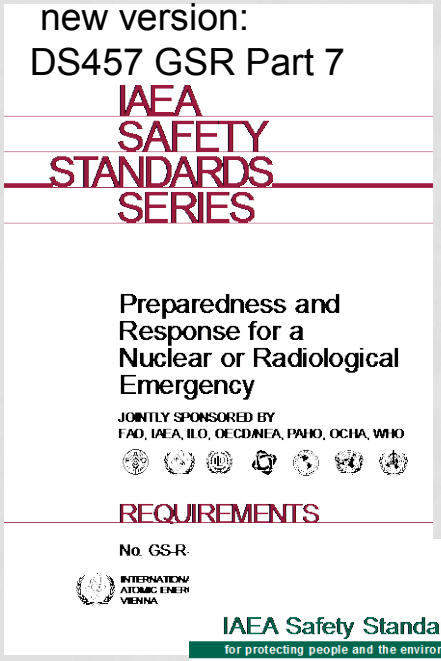
RPI

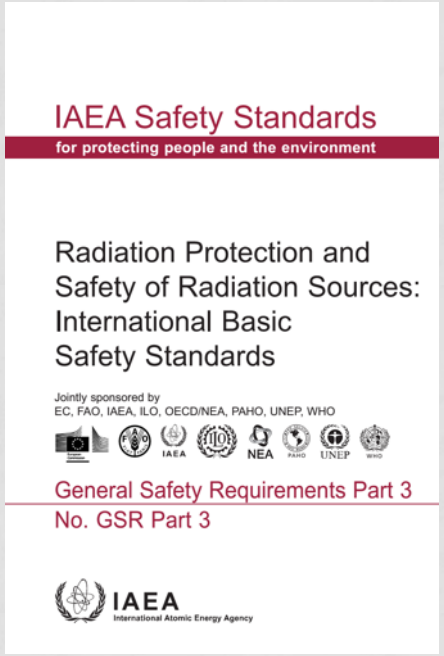
IAEA DOCUMENTS

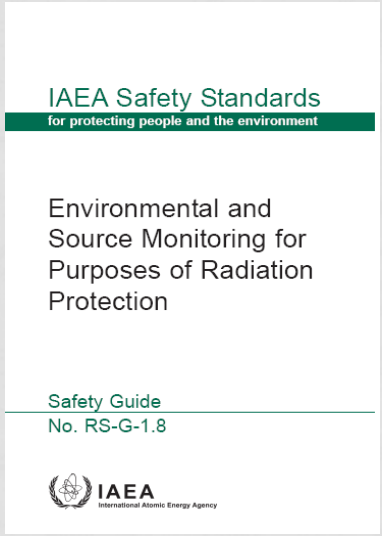
REQUIREMENTS AND GUIDANCE DOCUMENTS

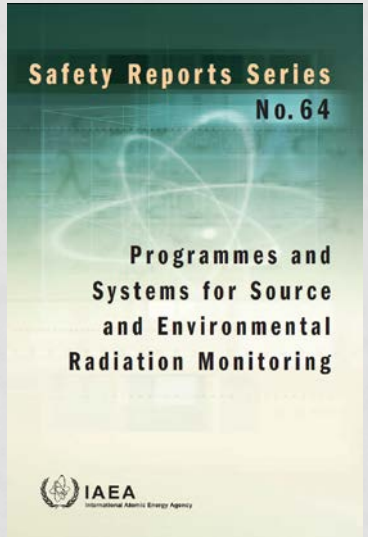
IMPORTANT IAEA SAFETY STANDARDS AND SUPPORTING DOCUMENTS

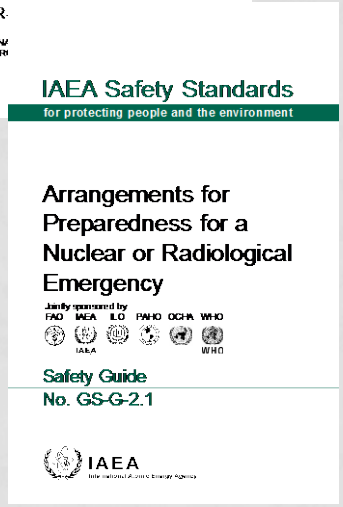
new version:
DS457 GSR Part 7

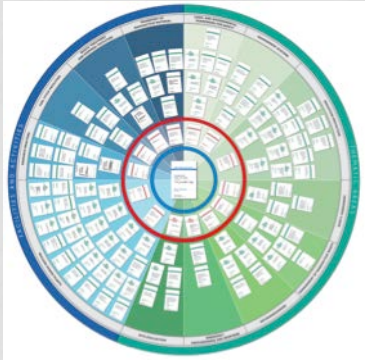


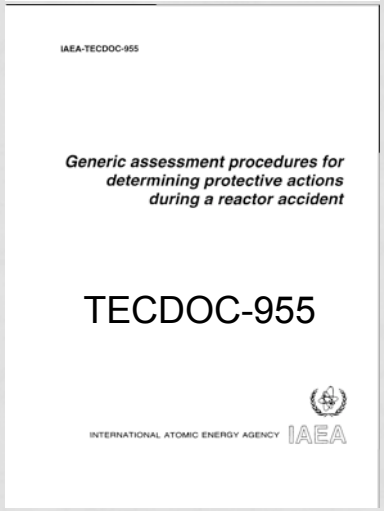


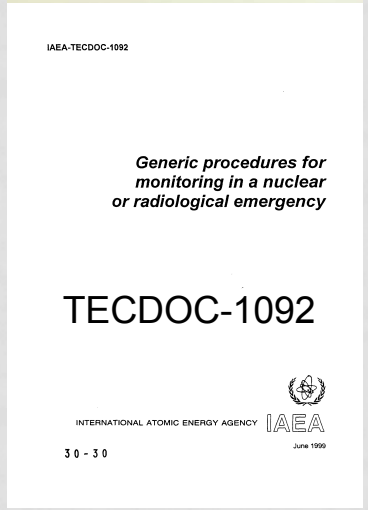












GS-R-2: PRECAUTIONARY URGENT PROTECTIVE ACTION

3.17. In a threat assessment, facilities, sources, practices, on-site areas, off-site areas and locations shall be identified for which a nuclear or radiological emergency could warrant:

- (a) **Precautionary**[7] urgent protective action to prevent severe deterministic health effects by keeping doses below those for which intervention would be expected to be undertaken under any circumstances;

Prospective assessments: monitoring data are not available. Pre-established operational criteria are required.

[7] Taken on the basis of conditions at the facility or the scene before environmental monitoring is carried out.

NEW BSS: GSR PART 3

4.11. The government shall ensure that the response in an emergency exposure situation is undertaken by the timely implementation of arrangements for emergency response, including but not limited to:

- (a) Promptly taking protective **actions** and other response actions **to avert severe deterministic effects on the basis of observed conditions** and, **if possible, before any exposure occurs**. Dose levels required to be used as generic criteria for preventing severe deterministic effects are given in Table IV.1 of Schedule IV;
- (b) **Assessing the effectiveness** of the protective actions and other response actions taken and modifying them as appropriate;
- (c) **Comparing residual doses with the applicable reference level**, giving priority to those groups for whom residual doses exceed the reference level;
- (d) Implementing **further protection strategies** as necessary, **on the basis** of prevailing conditions and **available information**.

Prospective assessments, but monitoring data should be required for individual follow-up

Retrospective assessments based on the monitoring data

GSR PART 3: ACTIONS ARE EXPECTED TO BE UNDERTAKEN UNDER ANY CIRCUMSTANCES TO AVOID OR TO MINIMIZE SEVERE DETERMINISTIC EFFECTS: ACUTE INTERNAL EXPOSURE DUE TO AN INTAKE (Δ = 30 D)

$AD(\Delta)_{red\ marrow}$	0.2 Gy for radionuclides with atomic number $Z \geq 90$[e] 2 Gy for radionuclides with an atomic number $Z \leq 89$[e]
$AD(\Delta)_{thyroid}$	2 Gy
$AD(\Delta)_{lung}$[g]	30 Gy
$AD(\Delta)_{colon}$	30 Gy
$AD(\Delta')_{fetus}$	0.1 Gy

If the dose has been received:

— Perform immediate medical examination, consultation and indicated medical treatment

— Carry out contamination control

— Carry out immediate decorporation[f] (if applicable)

— Carry out regular follow-up medical follow-up

— Provide comprehensive psychological counselling

Further guidance documents of the ICRP and IAEA are needed.

E.g. the corresponding activity intakes AND bioassay data will be helpful

These actions are expected to be undertaken under any circumstances if criteria exceeded.

IMPORTANT: listed actions can be justified for lower doses

[d] AD(Δ) is the RBE weighted absorbed dose delivered over a period of time Δ by the intake (I_{05}) that will result in a severe deterministic effect in 5% of exposed individuals. This dose is calculated as described in appendix I of Ref. [29].

[e] Different generic criteria are used to take account of the significant difference in RBE weighted absorbed dose from exposure at the intake threshold values specific for these two groups of radionuclides.

[g] For the purposes of these generic criteria, 'lung' means the alveolar-interstitial region of the respiratory tract.

[h] For this particular case, 'Δ′' means the period of in utero development of the embryo and fetus.

DS-457 (DRAFT GSR PART 7)

- Consideration shall be given on actions to be taken to avoid or to minimize severe deterministic effects and to reduce the risk of stochastic effects.
- Deterministic effects shall be evaluated on the basis of relative biological effectiveness (**RBE**)-**weighted absorbed dose to an organ or tissue**.
- Stochastic effects in an organ or tissue shall be evaluated on the basis of **equivalent dose to the organ or tissue**.
- The detriment associated with the occurrence of stochastic effects in an exposed population shall be evaluated on the basis of the **effective dose**.

For internal exposure: short-term (30 d) committed RBE-weighted dose in an organ or tissue

For internal exposure: committed RBE-weighted dose in an organ or tissue.
Workers/Adult: integration over 50 y,
Non-adult: integration to age 70 y

THE COMMITTED RBE-WEIGHTED DOSE IN AN ORGAN OR TISSUE

The committed absorbed dose in the organ or tissue T

$$D_T^R(\Delta) = \int_{t_0}^{t_0+\Delta} \dot{D}_T^R(t)dt$$

The committed RBE-weighted dose in the organ or tissue T

$$AD_T = \sum_R D_T^R \times RBE_T^R$$

TECHNICAL STANDARDS AND TOOLS

- **IRIX** is the IAEA standard for exchange information among emergency response organizations at national and international levels during a nuclear or radiological emergency (XML –based format).
- IAEA's International Radiation Monitoring Information System (**IRMIS**) will routinely and reliably enable the exchange of radiation monitoring data.

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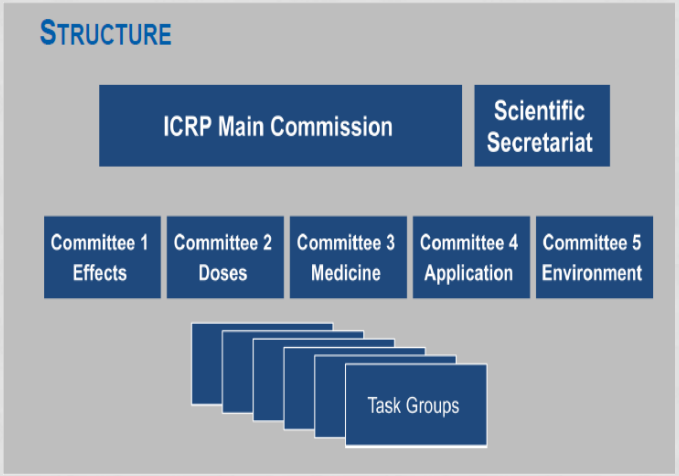


ICRP DATA FOR RADIOLOGICAL ASSESSMENTS

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION (ICRP)

ICRP METHODOLOGY IN RADIOLOGICAL ASSESSMENTS

- The ICRP has established:
  - **Principles** of radiation protection in emergency exposure situations
  - Radiation **protection quantities** to be used in assessments of exposure to ionising radiation
  - **Methodology** for dose assessments
  - Authoritative **set of reference dosimetric data, such as dose coefficients**.
- The ICRP publications are broadly used for planning of the environmental monitoring, modelling and assessment of the effectiveness of protective actions

PUBLISHED ICRP DATA FOR RADIOLOGICAL ASSESSMENTS

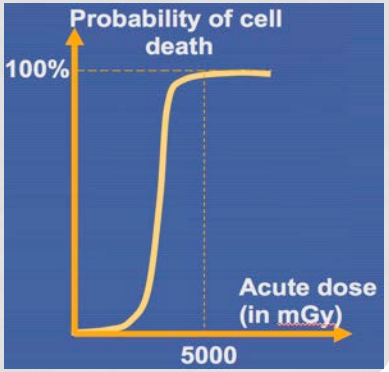
- Dose coefficients "committed effective [equivalent] **doses** to the ICRP reference person [organs/tissues] **per intake**" (Sv per Bq intake):
  - more than 700 radionuclides
  - inhalation and ingestion
  - **various age groups**, incl. embryo, foetus and breastfed infant
  - **various chemical forms and aerosol sizes.**
- These ICRP dose coefficients are based on ICRP Publication 60 and are partially reproduced in GSR Part 3.
- There is incompatibility of these dose coefficients with new w_R and w_T values defined in ICRP Publication 103 and reproduced in GSR Part 3 Glossary.

CHALLENGES

- The lack of resources has limited the scope of the fundamental dosimetric data published so far by the ICRP for emergency exposure situations
- There is a lack of:
  - **Environmental dose coefficients:** doses to the reference person per activity concentration in environmental media
  - **Dose coefficients** for assessments in case of application of thyroid blockade or decorporation agents
  - **Dose coefficients and bioassay data** for prospective and retrospective **assessments of tissue reactions**
- The available ICRP dose assessment methodology is intended to be used in low dose range. Do we need an additional conservatism for assessments of doses above 100 mSv or 1 Gy?

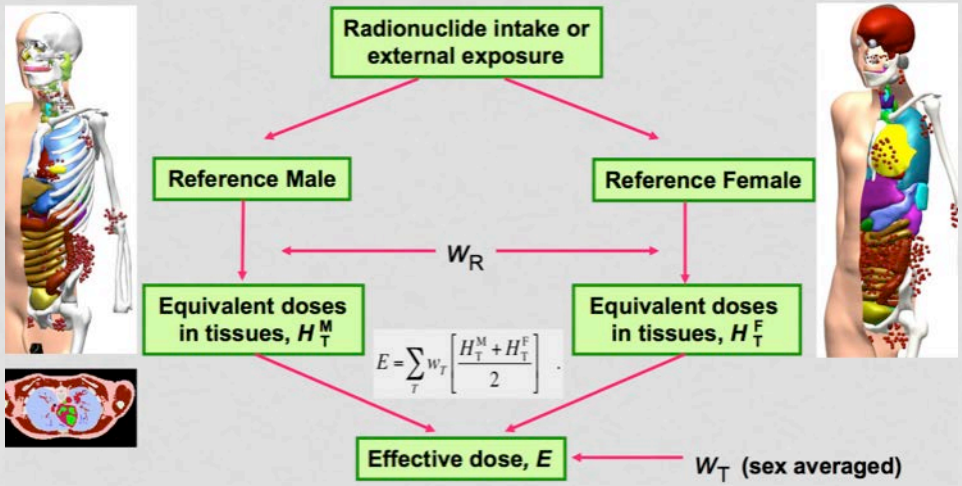
CHALLENGES IN ASSESSMENTS OF TISSUE REACTIONS

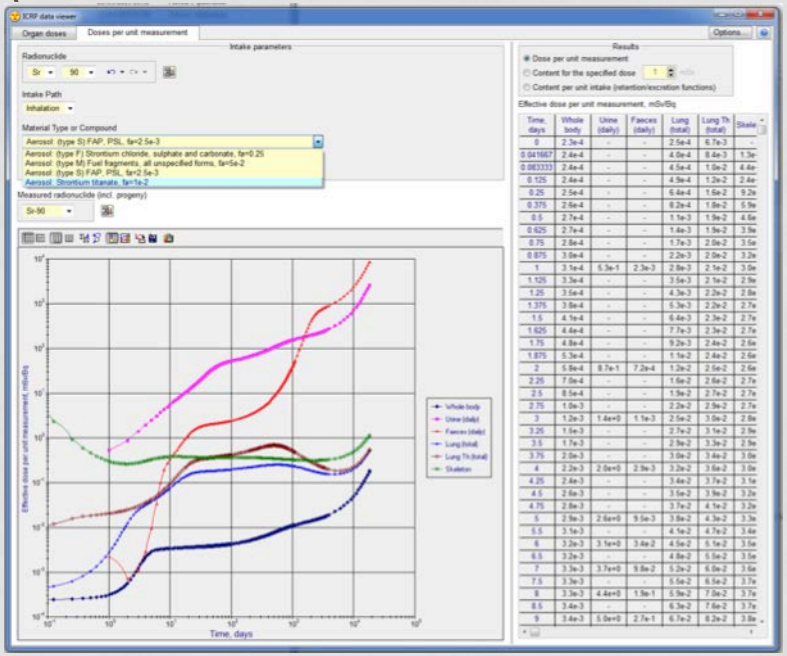
- The available ICRP coefficients are not appropriate for assessments of quantities, listed as a criteria for protective actions to be undertaken under any circumstances to avoid or to minimize severe deterministic effects
  - **Prospective assessments:** The data provided by the ICRP are the [Committed] equivalent doses to organs/tissues → a potential overestimation in orders of magnitude
  - **Retrospective assessments:** There are no ICRP reference data for dose assessments based on bioassay measurements
  - High demands to the **reliability** of dose estimates



RECENT ICRP METHODOLOGICAL INNOVATIONS

- **New** nuclear **decay data** (ICRP P107)
- **New adult reference computational phantoms** (ICRP P110)
- **New** series of **biokinetic and dosimetric models** for prospective and retrospective assessments, and (draft ICRP OIR series)
- **New** set of dose coefficients "**Dose per intake" and the "Dose per measured quantity**" functions (draft ICRP OIR series and online data set)





ICRP OIR data viewer developed by the RPI:

PROSPECTIVE ASSESSMENTS OF INDIVIDUAL DOSES VS. ASSESSMENTS BASED ON INDIVIDUAL MONITORING DATA

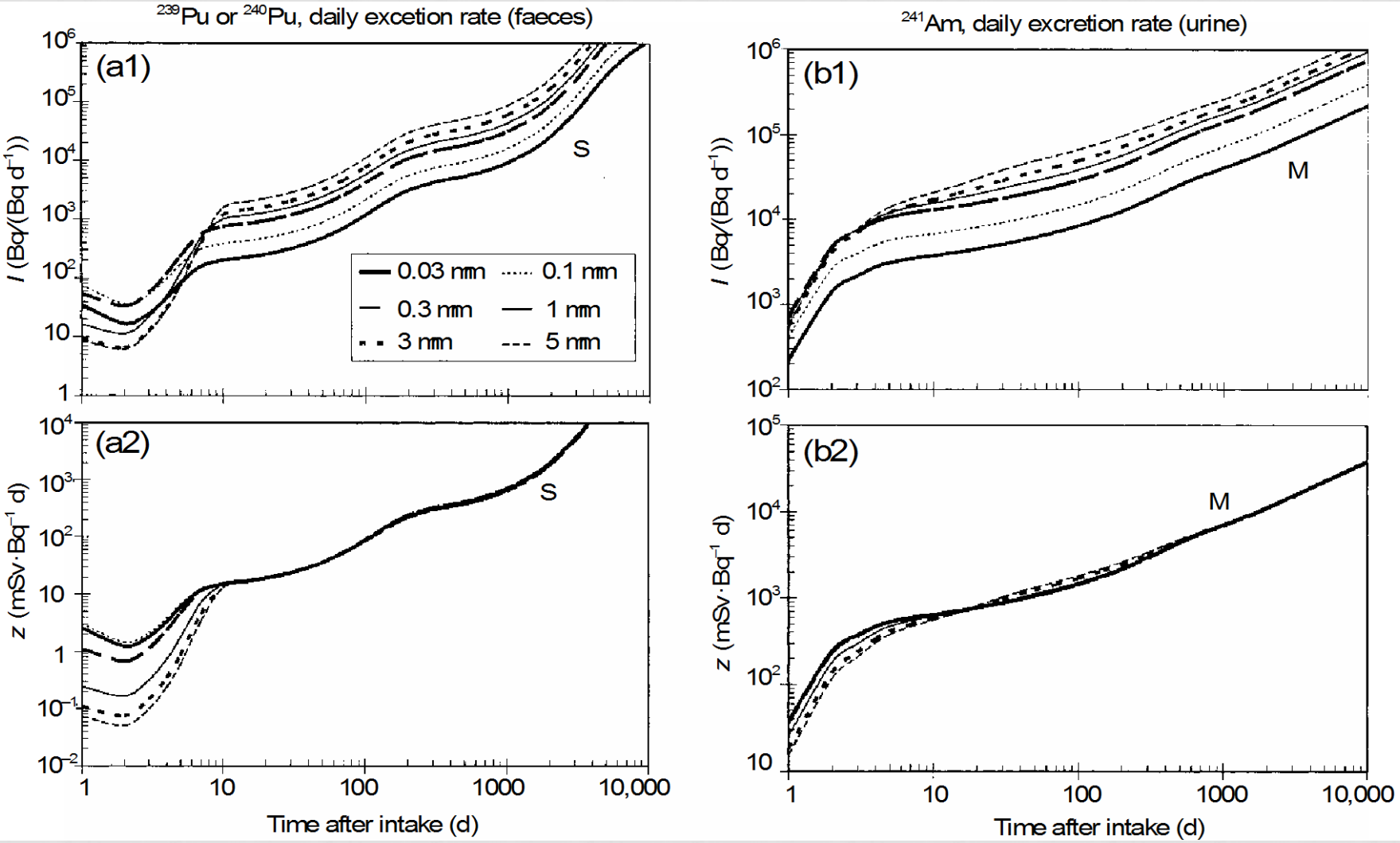
- In the **prospective assessments**, the **intake** of the radionuclide is the main input information for dose assessments
  - '**Dose per intake**' coefficients (denoted as **e**) are the natural instrument in such problems.
- **When exposure occurred**, assessments can/should use **individual monitoring** and the primary input information is the **bioassay** data.
  - In the case of inhalation, **e** is substantially depend on the **activity median aerodynamic/thermodynamic diameter (AMAD/AMTD)** and the **Type of material (TM)**, which describe the solubility of aerosols in lungs.

DOSE PER MEASURED QUANTITY

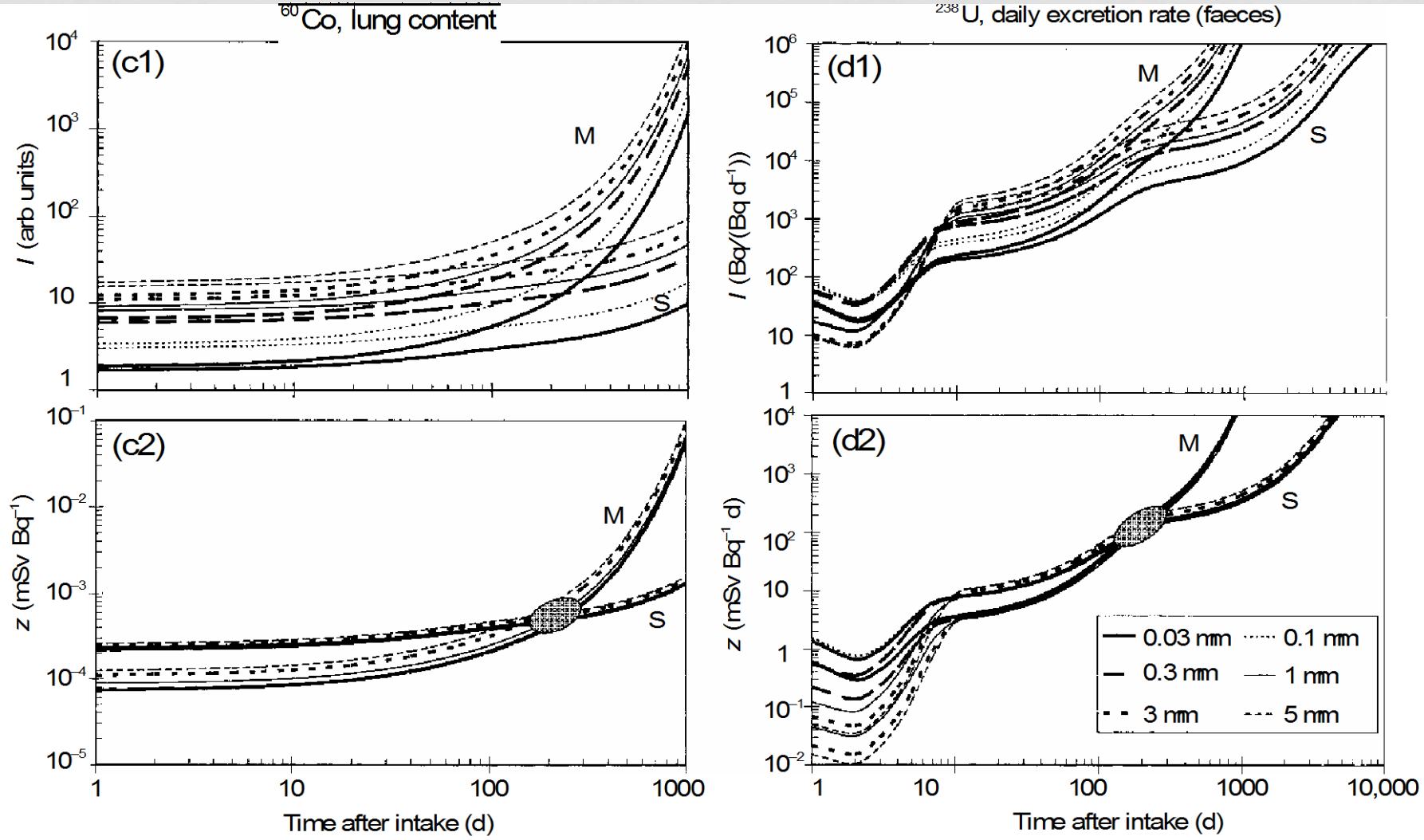
- The **assessment of the activity intake after inhalation from the bioassay data** can be difficult due to the lack of information about the time of intake, chemical form and AMAD of the aerosols.
- Aggregated functions '**dose per measured quantity**' ***z(t, AMAD, Type of Material)***, -- e.g. 'dose per daily excretion rate' -- have been proposed as a convenient and reliable tool for bioassay.
- The analysis of the variation of **z** with changes of AMAD has demonstrated the areas of the relative invariance, which permits the application of a single reference **z-function** in the wide range of AMAD.
- **The proposed approach has been used by the ICRP in the preparation of the new series of publications "Occupational Intakes of Radionuclides"**, which should replace ICRP Publications 30, 68 and 78.

- **Recommended reading**: "Dose per unit content" functions: a robust tool for the bioassay. Berkovski, V.; Bonchuk, Y.; and Ratia, G. Rad. Prot. Dosim. 105 (1-4) 2003.

THE VARIATION OF FUNCTIONS *I(T)* (*ACTIVITY INTAKE PER EXCRETION RATE*) AND *Z(T)* (*COMMITTED EFFECTIVE DOSE PER EXCRETION RATE*) WITH AMAD/AMTD AND TYPE OF MATERIAL



THE VARIATION OF FUNCTIONS *I*(*T*) AND *Z*(*T*) WITH AMAD/AMTD AND TYPE OF MATERIAL



ICRU REPORTS

INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS (ICRU)

KEY ICRU REPORTS (1)

- **Fundamental Quantities and Units for Ionizing Radiation** (ICRU Report 85a-Revised)
  - Definitions of fundamental quantities, and their units, for ionizing radiation
- **Measurement Quality Assurance for Ionizing Radiation Dosimetry** (ICRU Report 76)
  - Calibrations and measurements. Absorbed dose, air kerma, fluence, and dose equivalent
- **Sampling of Radionuclides in the Environment** (ICRU Report 75)
  - A conceptual guide for designing statistically based sampling approaches for the analysis of radionuclides in environmental media such as soil, sediment, water, plants, aquatic organisms and animals

KEY ICRU REPORTS (2)

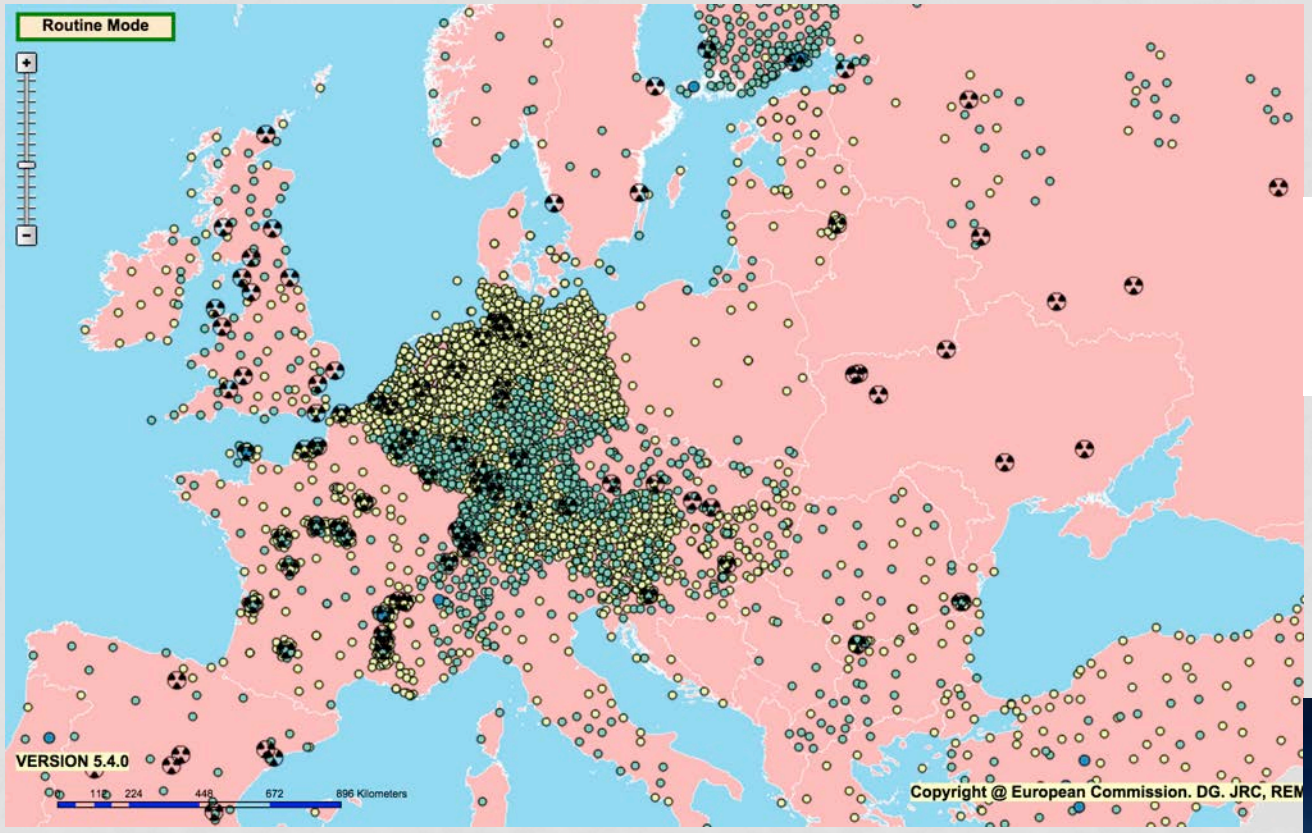
- **Direct Determination of the Body Content of Radionuclides** (Report 69)
  - Guidance on the overall process of the direct measurement of radionuclides in the human body
- **Quantities, Units and Terms in Radioecology** (Report 65)
  - Comprehensive and authoritative set of definitions for quantities, units and terms used in the highly interdisciplinary field of radioecology
- **Gamma-Ray Spectrometry in the Environment** (Report 53)
  - Addresses the sensitivity and uncertainties involved in gamma-ray spectrometry, stressing new developments for in-situ determination of attenuation due to the surface roughness of the ground

REPORT COMMITTEE 28 OF THE ICRU

HTTP://WWW.ICRU.ORG/CONTENT/UNCATEGORISED/REPORT-COMMITTEE-28

- Despite of a substantial volume of important ICRU reports, a number of topics related to monitoring in emergency and existing exposure situations need further development. For example:
  - **Recommended monitoring equipment for various emergency and existing exposure situations**
  - **Detection capabilities and dynamic ranges of instruments**
  - **Design of the national and regional monitoring systems and programmes**
  - **Proportions between stationary and mobile components of the monitoring system**
  - **Calibration techniques for *in-situ* gamma-spectrometers to be used for the determination of the deposition density of typical "fresh" depositions**
  - **Monitoring and assessment of the effectiveness of protective measures**
- Recognising these outstanding issues, the ICRU, in collaboration with the IAEA and national expert organizations, has established the **ICRU Report Committee 28** for the development of a new **report on monitoring**.

BALANCE BETWEEN STATIONARY AND MOBILE MONITORING SUBSYSTEMS



European Radiological Data Exchange Platform: EURDEP

AND

Mobile Laboratory

Smartphone Radiation Monitor

Airborne Radiation Monitoring

ICRU RC28 DRAFT

- Working title **Radiation monitoring for protection of the public after major radioactive releases to the environment**
  - **The objective** of the report is to provide detailed practical information on radiation monitoring for protection of the public and the environment in **emergency and existing exposure situations**
  - This report deals with the **design and operation of monitoring programmes and systems** relating to the accidental release of radioactive material to the environment from nuclear installations
  - Specifically, **the report is focused on the emergency and existing exposure situations caused by accidents at nuclear power plants**. The report may also be useful for other facilities and events

ICRU REPORT ON RADIATION MONITORING FOR PROTECTION OF THE PUBLIC AFTER MAJOR RADIOACTIVE RELEASES TO THE ENVIRONMENT

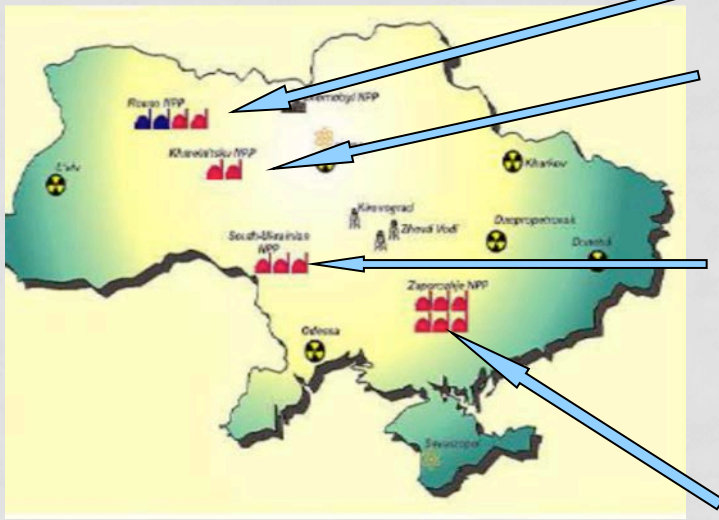
TENTATIVE STRUCTURE

- Introduction
- Quantities used in radiation protection
- Major releases of radionuclides to the environment
- Monitoring programmes
- Monitoring systems
- Conclusions and recommendations
- Technical Annexes
  - Source term
  - Radiological Monitoring after the Accident at the Chernobyl NPP
  - Radiological Monitoring after the Accident at the Fukushima Daiichi NPP
  - Dynamic range of and minimum detectable concentrations with typical radiation survey instruments, organize by instrument class
  - Detection capability: terminology and approaches
  - Individual monitoring

UKRAINIAN EXPERIENCE

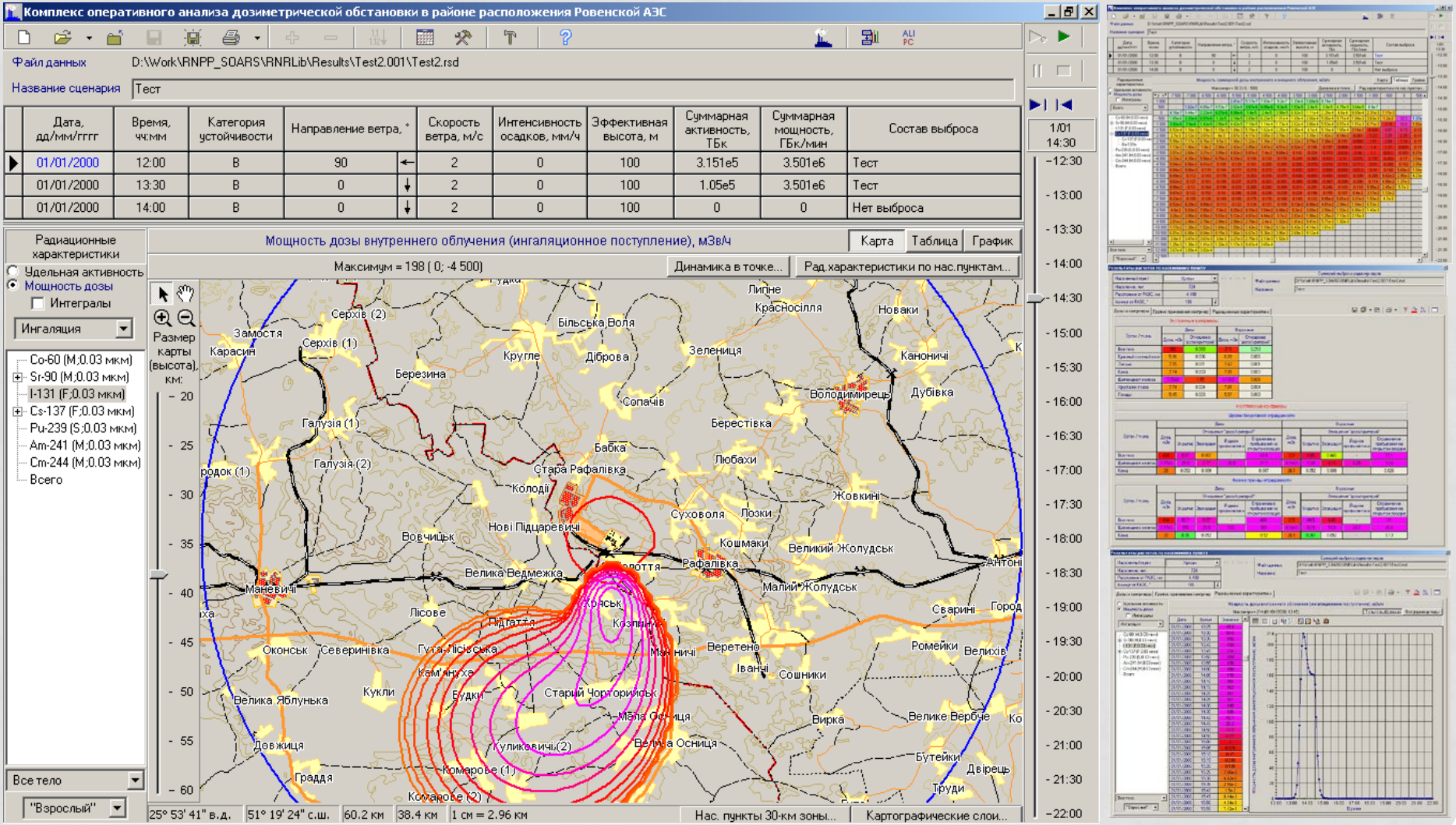
RADIATION PROTECTION INSTITUTE (RPI), KYIV

UKRAINIAN NUCLEAR POWER PLANTS



NPP	Unit	Type	Capa-city (MWe)	Commiss-ioned
Rivne NPP	1	WWER-440/ V-213	420	Dec 1980
	2		415	Dec 1981
	3	WWER-1000/ V-320	1000	Dec 1986
	4			Oct 2004
Khmelnitsky NPP	1	WWER-1000/ V-320	1000	Dec 1987
	2			Aug 2004
South-Ukrainian NPP	1	WWER-1000/ V-302	1000	Dec 1982
	2	WWER-1000/ V-338		Jan 1985
	3	WWER-1000/ V-320		Sep 1989
Zaporizh-zhya NPP	1	WWER-1000/ V-320	1000	Dec 1984
	2			July 1985
	3			Dec 1986
	4			Dec 1987
	5			Aug 1989
	6			Oct 1995
TOTAL	15		13825	

SOARS
DECISION SUPPORT SYSTEM [© RPI]



DISCUSSION

- The available set of requirements and guidance documents of the IAEA, ICRP and ICRU constitutes a **good basis for the elaboration** of comprehensive **technical recommendations** on monitoring and assessment of exposure from unplanned releases to the environment.
- The **quality assurance** is essential in the development of the quantitative data to be used for monitoring and assessments of exposure in emergency exposure situations. The ICRP, ICRU and many national institutes have a unique multi-decade experience in this field, but lack appropriate resources for such a work.
- The emergency preparedness and response would benefit from **reinforcement** of the existing **coordination and collaboration between the IAEA, ICRP and ICRU**.