Remediation policy and remediation techniques following the accident in the Fukushima Daichii Nuclear Power Plant – International guidance and implementation

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International Symposium of the Society for Remediation of Radioactive Contamination in the Environment

Tokyo, 4 July 2018

Content

- IAEA Safety Standards
- Deposition of Cs-137 and γ-dose rates
- Radiation protection aspects
- Dose assessment
- Remediation techniques and success
- Interaction and dialogue with the public
- Conclusions

IAEA Safety Standards

IAEA Basic Safety Standards (IAEA GSR part 3)

- ***International consensus* on Radiation Protection**
  - Based on ICRP 103 (2007)
- **Defines responsibilities**
  - Government and regulatory body
  - Operator
- **Defines exposure situations**
  - Planned, existing, emergency situation
- **Radiation protection principles**
  - Justification, Optimization, Limitation
- **Radiological criteria**
  - Public in all exposure situations
  - Workers

IAEA Safety Standards

for protecting people and the environment

Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards

Jointly sponsored by
EC, FAO, IAEA, ILO, OECD/NEA, PAHO, UNEP, WHO

General Safety Requirements Part 3

No. GSR Part 3

IAEA

International Atomic Energy Agency

Remediation of Affected Areas

2007

(Currently being updated)

IAEA SAFETY STANDARDS

for protecting people and the environment

Revision of Safety Guide WS-G-3.1 on

Remediation Process for Areas Affected by Past Activities and Accidents

DRAFT SAFETY GUIDE

DS468

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IAEA Safety Standards

for protecting people and the environment

Remediation Process for Areas Affected by Past Activities and Accidents

Safety Guide

No. WS-G-3.1

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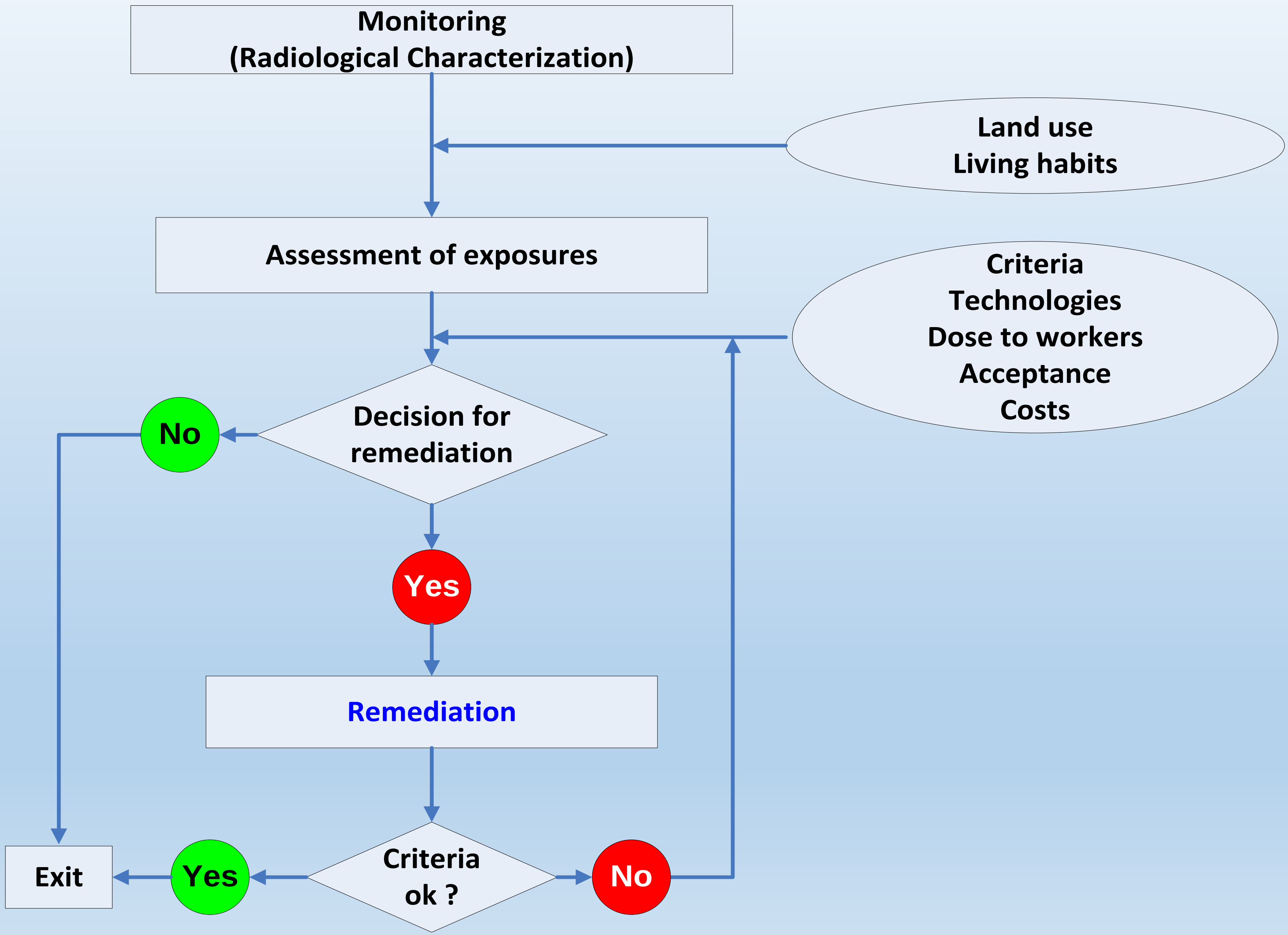
National Framework for Remediation

- **It should provide**
  - National remediation policy and corresponding strategy
  - Radiological criteria
  - Radioactive waste management
  - Mechanisms for interaction with the public
  - Mechanisms for interaction between national authorities and ministries

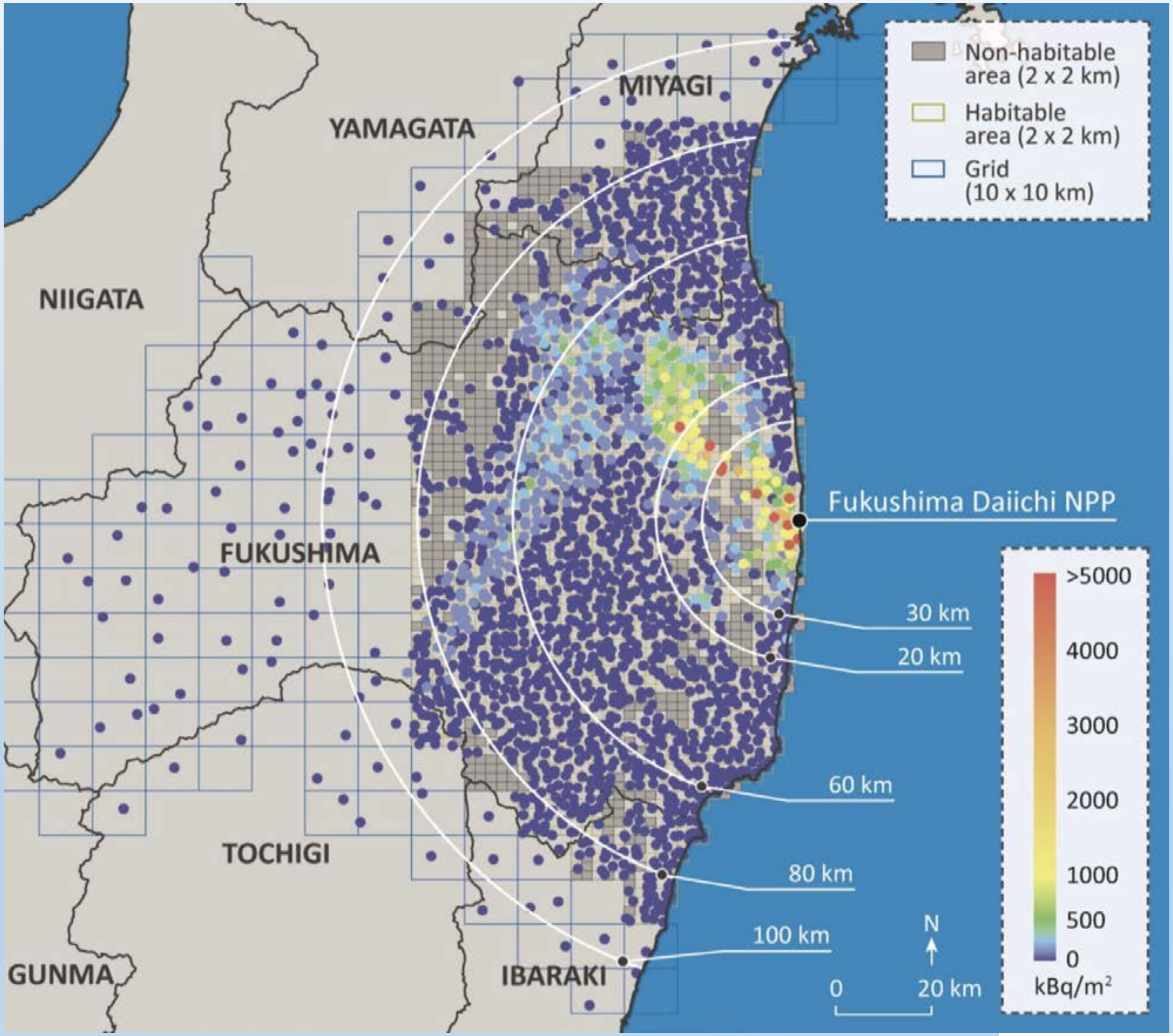
- **No pre-accident planning for post-accident recovery**
  - **June 2011:**
    Disposal Guideline for Disaster Waste in Fukushima Prefecture
  - **August 2011:**
    Act on Special Measures Concerning the Handling of Radioactive Pollution

Simplified scheme of a remediation process



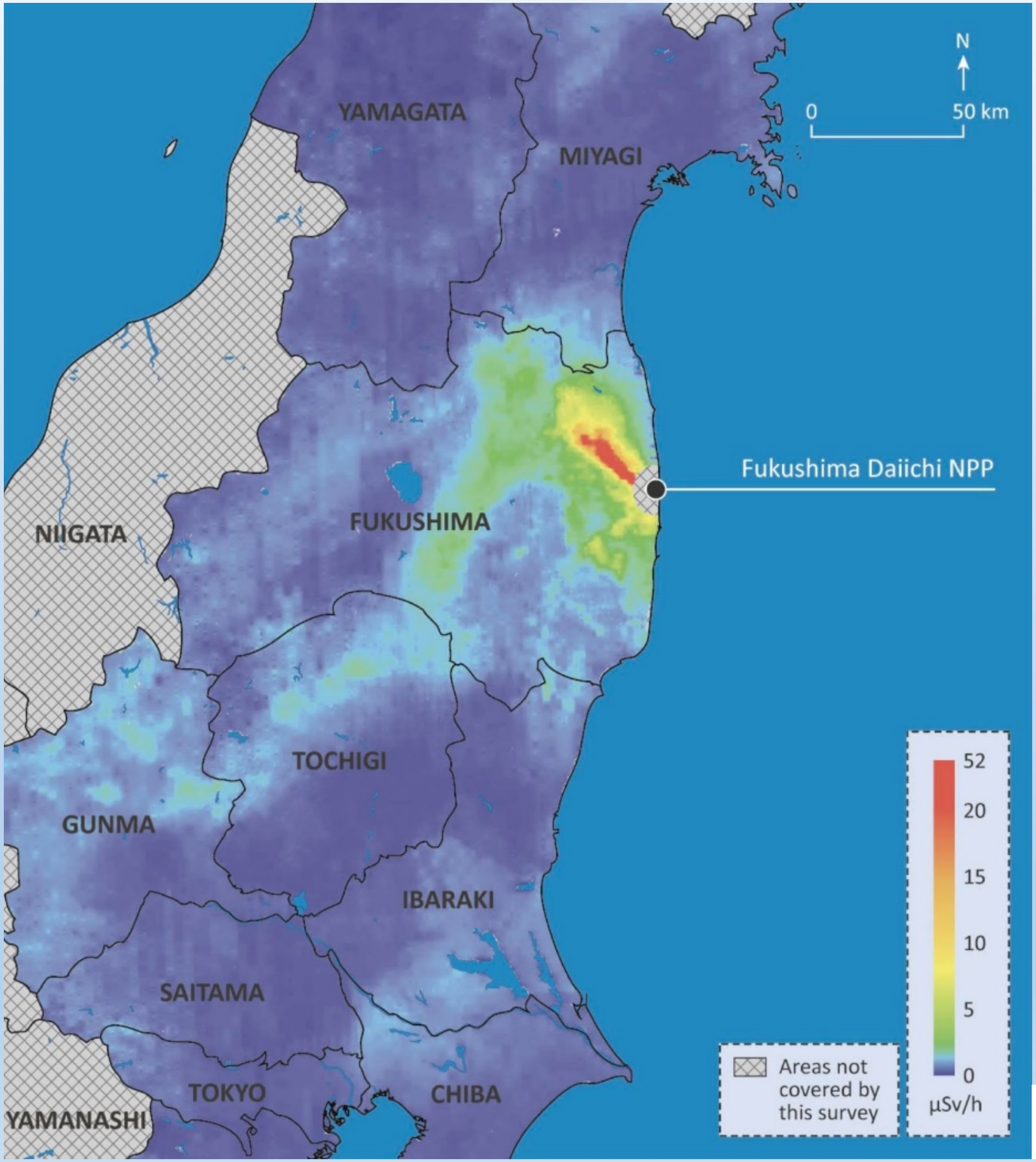
Deposition of Cs-137 and γ-dose rates

Cs-137-Deposition (corrected for 11 June 2011)



IAEA Fukushima Report 4, 2015

Ambient dose rates (µSv/h) at a height of 1 m

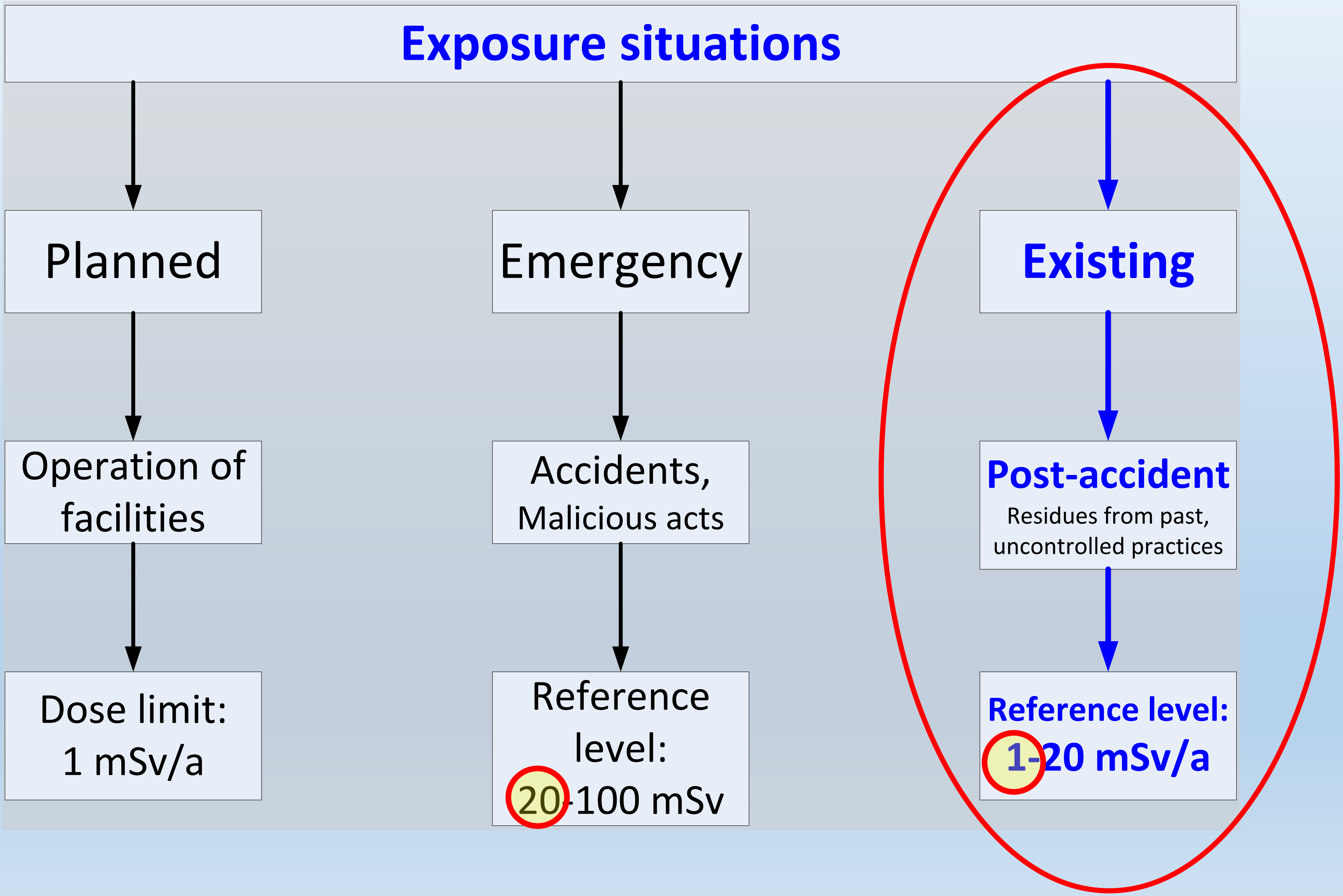


Air survey as of 18 September 2011

IAEA Fukushima Report 5, 2015

Radiation Protection Aspects

Limitation of exposures in the IAEA Safety Standards



Limitation of exposure by a reference level

- **According to IAEA Standards:**
  To be defined taking into account **"prevailing circumstances"**
  - Levels of exposure and people affected
  - Possibilities to reduce doses to people
    - Available countermeasures
    - Technical feasibility of countermeasures
    - Costs
  - Generation of waste
  - Acceptance by the population
  - Value of land
  - Any other implications

- **Range recommended by IAEA for the reference level**
  (in accordance with ICRP)
  - **To be selected within the range of 1-20 mSv/a**

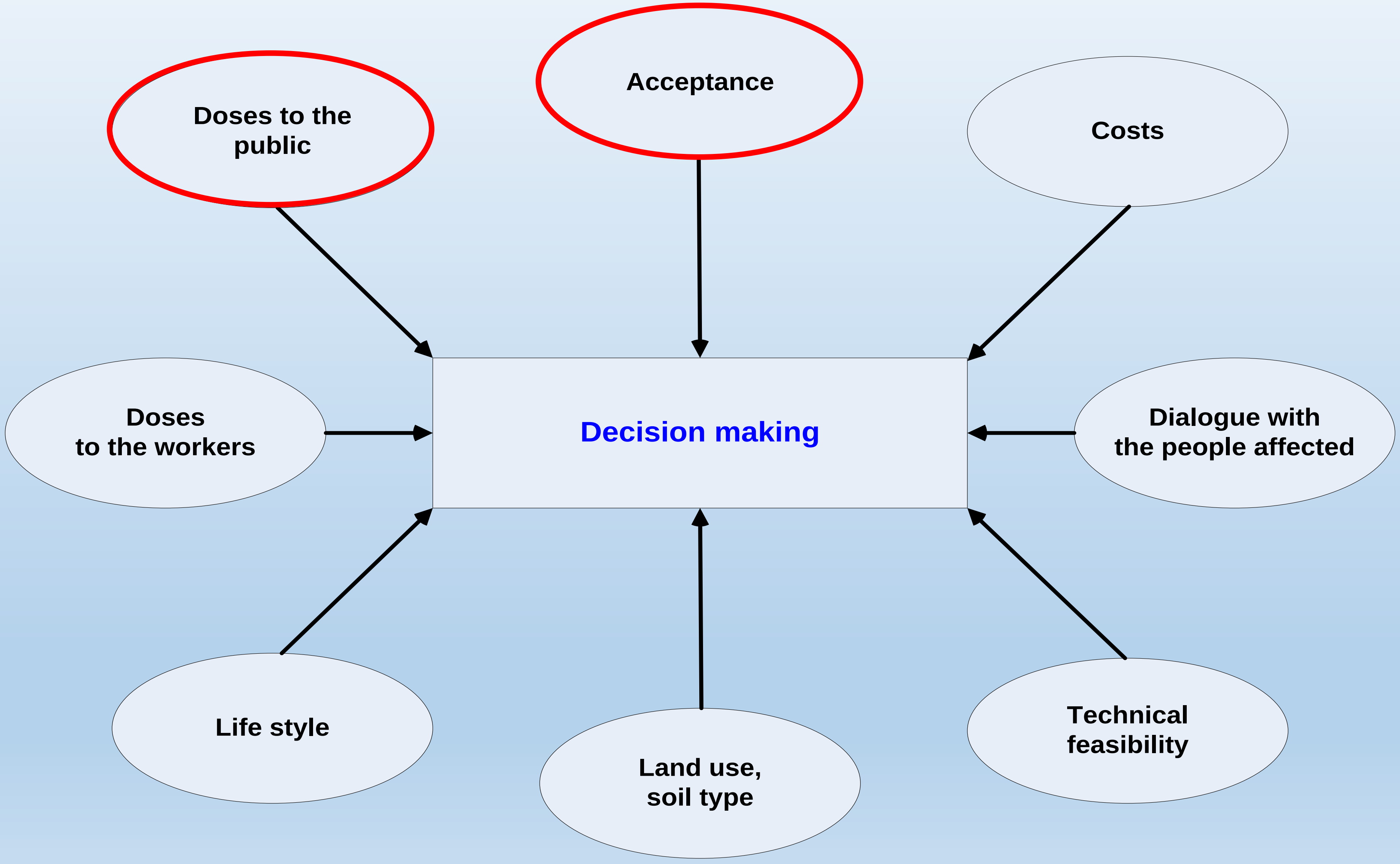
Setup of radiological criteria

- **Situation was classified** in accordance with IAEA Basic Safety Standards as an **existing exposure situation**

- **Japanese „Act of Special Measures …“**
  - For areas with additional doses < 20 mSv/a:
    - Reduce the additional doses to **1 mSv/a** or **lower over the long term**

- **Lowest level of the dose range of 1-20 mSv/a** was defined as final goal
  - Time until this goal can be achieved was not quantified
    - Years? Decades? Centuries?
  - Raising immediately high expectations

Inputs for decision making



Reference levels after historical environmental contaminations

Location		Reference level
Maralinga (Australia, 1955-1963)	Weapons testing	**- 5 mSv/a** (established **long time after testing**)
Semipalatinsk (USSR, 1949-1989)	Weapons testing	**- 1 mSv/a** (established in **1990**)
Kyshtym (USSR, 1957)	Accident	**- 1 mSv/a** (established in **1990**)
Chernobyl (USSR, 1986)	Accident	**USSR** **- 100 mSv** (26 April 86 to 26 April 87) **- 30 mSv** for 2nd year (87) **- 25 mSv** for 3rd and 4th year (88/89) **From 1991 (Belarus, Russia,Ukraine)** **- 1 mSv/a**
Goiânia (Brazil, 1987)	Dispersion of a Cs-137 source	**- 5 mSv** in the 1st year **- 1 mSv/a** lifetime average (70 years)

Dose assessment

Dose assessment in August 2011 as the basis for remediation

- **Based on the γ-dose rates in air**
  - 60 % indoors, 40% outdoors
  - Shielding factor indoors: 0.4
- **Ingestion not considered**
  - Strict monitoring
  - People avoid local foods
- **γ-dose-rate as operational quantity for remediation**
  - **1 mSv/a equivalent to 0.23 µSv/h**
- **Results for 2011 are also applied for the following year(s)**

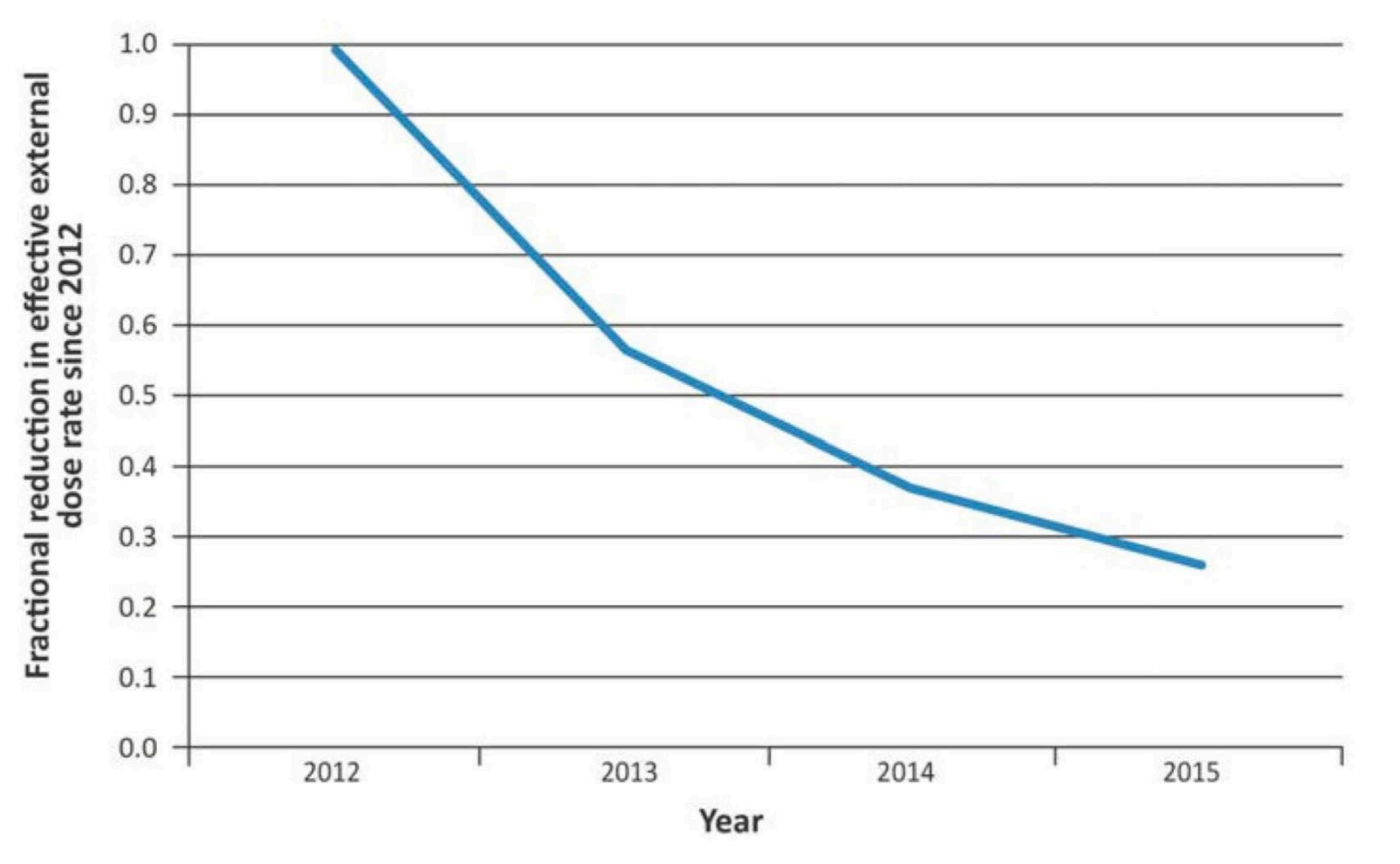
Time-dependence of the γ-dose rates

- **Physical decay is not appropriately taken into account**
  - Decision on remediation refer to the assessment performed in 2011

- **No natural attenuation due to**
  - Weathering
  - Wash-off
  - Migration

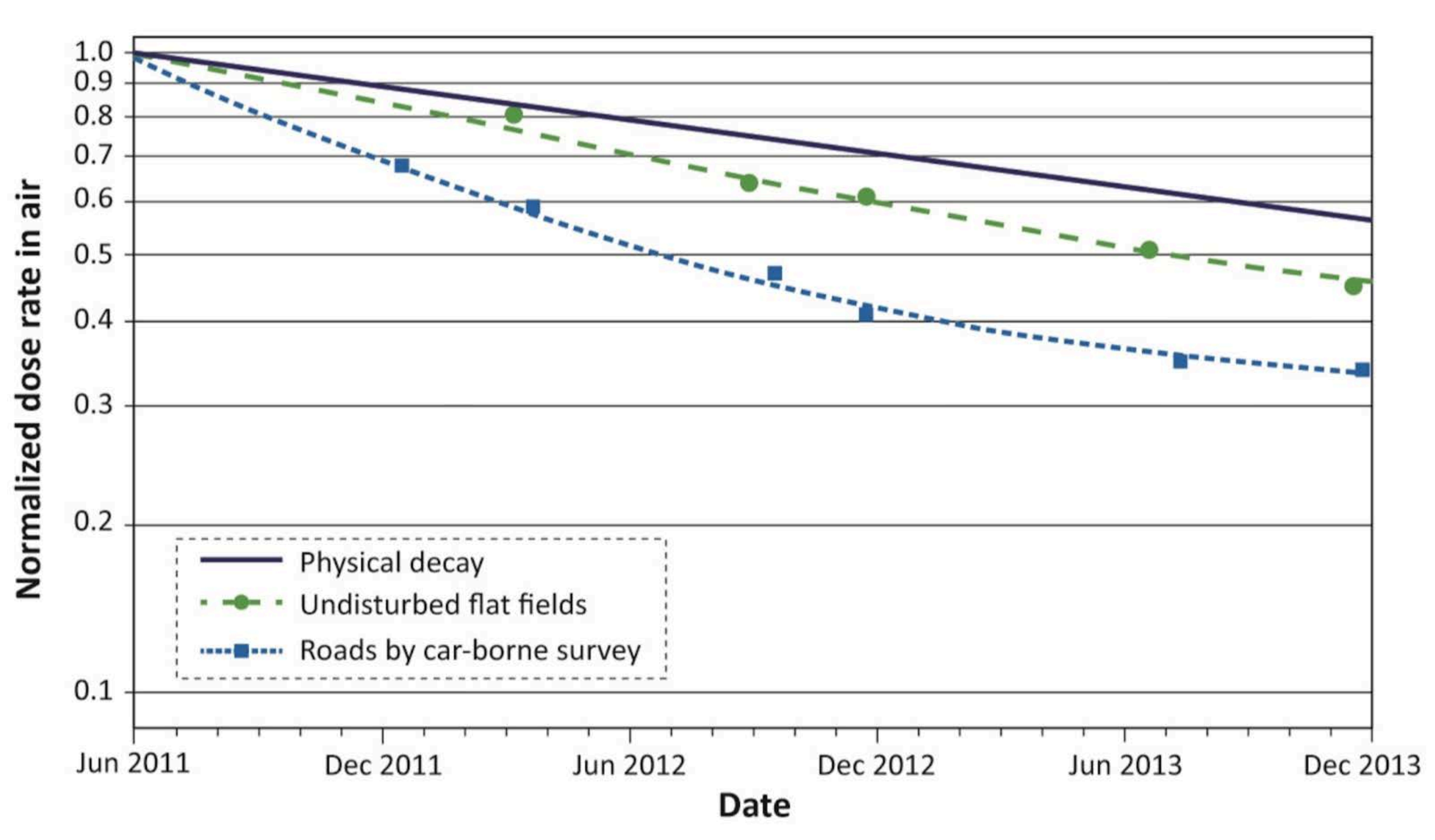
- **Increasing overestimations** of estimated in the coming years

Decline of effective external doses
(relative units)



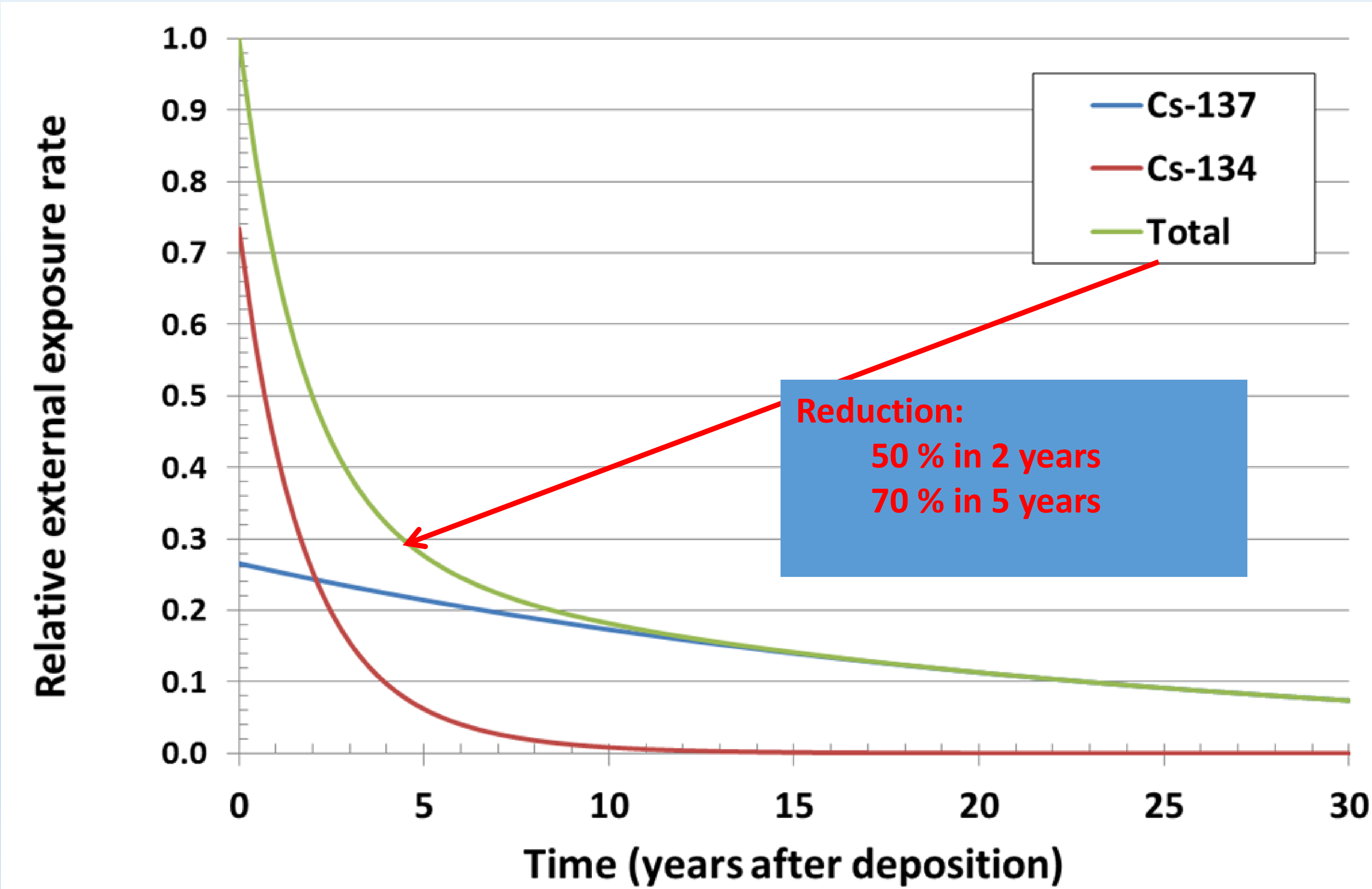
IAEA Fukushima Report, 2015 (p 21)

Decline of the γ-dose rate over different surfaces (relative units)



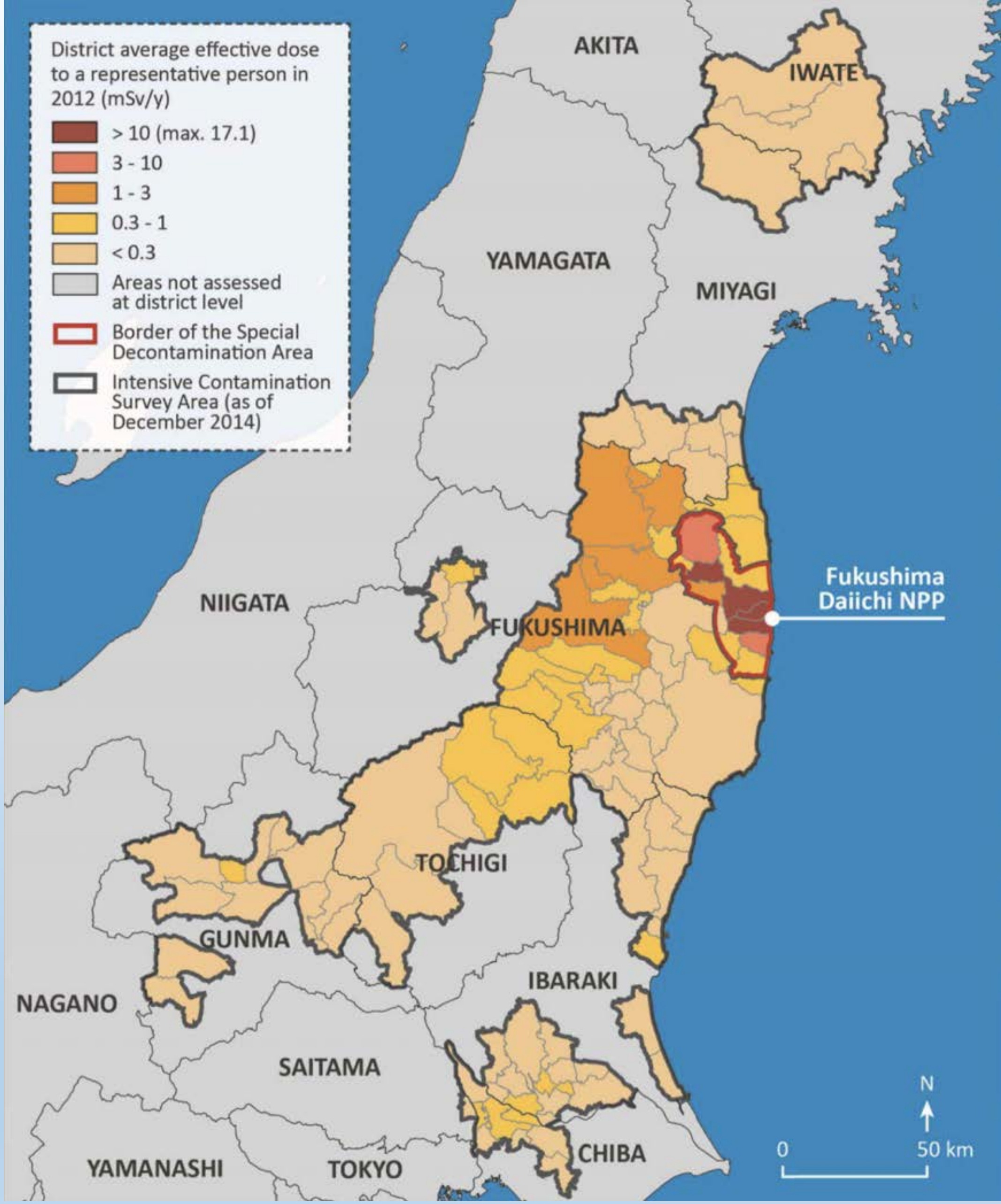
IAEA Fukushima Report, 2015 (p 12)

Decline of external exposure from Cs-134 and Cs-137 (ratio 1:1) due to radioactive decay and weathering



Doses in 2012

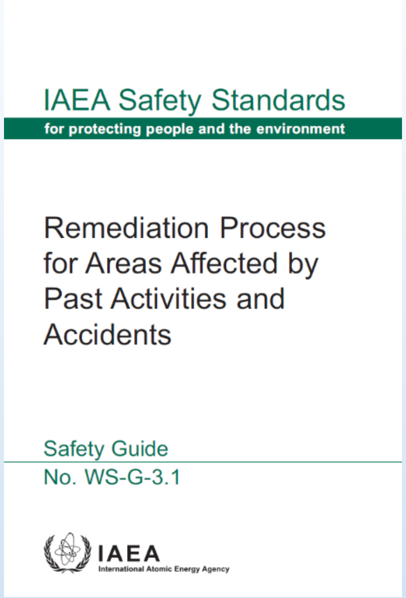
- District average effective doses estimated by **UNSCEAR**
- **Average doses in large parts** of Intensive Contamination Survey Area are **well below 1 mSv/a in 2012**



IAEA Fukushima Report, 2015 (p 22)

Guidance for dose assessment
(IAEA WS-G3.1, section 4.23)

- The calculation of projected doses requires modelling of the various exposure pathways from an environmental contaminant to people.
- The models adopted may be of differing complexity depending on the processes involved in this transfer.
- **In general, the models used should be as realistic as is appropriate for making dose projections.**
- **Incorporating excessive conservatism can result in operational quantities being impractical or impossible to measure, or in remediation that is <u>more costly than necessary</u>.**
- The models should readily be able to address all relevant exposure pathways.
- They should readily be able to use site specific data, and they should be tested or validated. Particular attention should be paid to matching the assumptions of the model to the circumstances under consideration.


IAEA Safety Standards
for protecting people and the environment

Remediation Process for Areas Affected by Past Activities and Accidents

Safety Guide
No. WS-G-3.1

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Remediation techniques and success

Remedial actions applied in agriculture: Observed reduction factors

Remedial option	Chernobyl accident	Fukushima Daiichi accident
Top soil removal[a]	—	4.0–5.0
Normal ploughing	2.5–3.0	1.5–2.5
Deep ploughing[b,c]	3.0–8.0	2–3
Reverse tilling of soils	10–16	—
Potassium application	1.5–3.0	1.5–3.0
Application of organic fertilizers	1.5–2.0	1.3–2.5
Application of sorbents	1.3–2.0	1.5–1.8

[a] Not applied to farmlands in areas affected by the Chernobyl accident.
[b] Deep ploughing to replace topsoil up to a depth of 5 cm with soils taken from a depth of 50 cm.
[c] Reduction of the external dose rate at the height of 1 m.

Howard et al., 2016

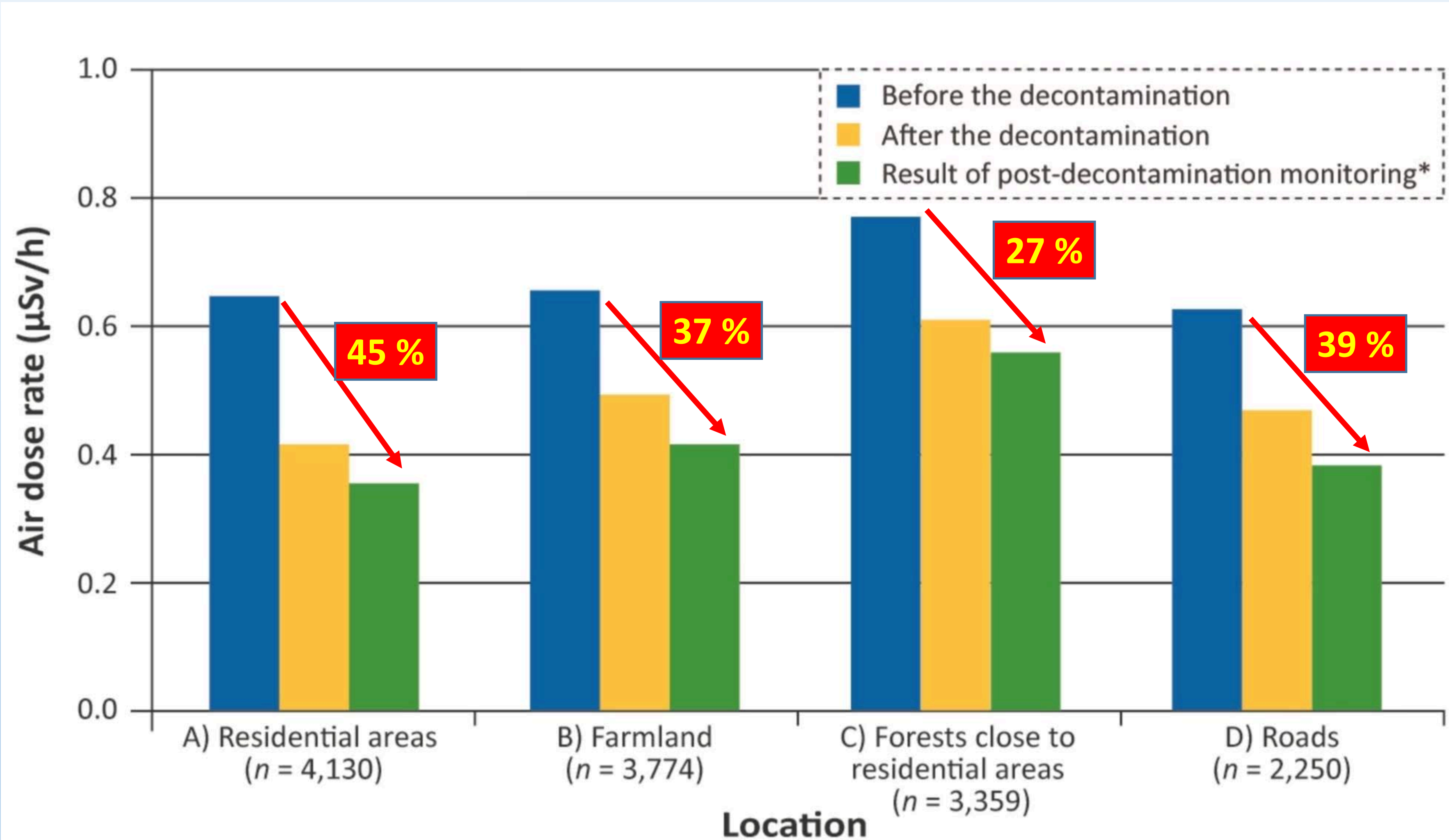
Remediation measures in residential areas

Remediation measure	Chernobyl	Fukushima Daiichi
Decontamination of residential areas		
High pressure water hosing	✓	✓
Removal of deposits from the roof, gutters etc	✓	✓
Wiping roofs and walls	✓	✓
Vacuum sanding		✓
Topsoil removal	✓	✓
Removal of plants	✓	✓
Removal of deposits in road ditches		✓
Decontamination of gardens/trees		
Topsoil removal		✓
Paring fruit trees		✓
High pressure water hosing		✓
Mowing		✓
Removing leaves	✓	✓

- **Reduction of γ-dose rate by a factor of 2-4**
- **Generation of large amounts of waste**

Howard et al., 2016

Reduction of γ-dose rate following remediation
(Tamura City)



IAEA Fukushima Report, 2015 (p 49)

Remarks to remediation

- **Operational quantities were driving remediation**
  - Remediation focused on the reduction of γ-dose rates and activity levels
  - No systematic assessment of the doses to people
- **IAEA Safety Standards recommend an integrated assessment of doses:**
  - Taking into account all relevant pathways
  - Realistic assessments
  - A systematic and situation-specific selection of remedial actions
- **Effectiveness of the measures**
  - Similar to those observed in studies outside Japan

Example:
Removal of bottom sediments from irrigation ponds

- Area: ca 11000 m²
- Supplies rice paddies: 5 ha
- Removal, dewatering and storage/disposal of sediments as waste
- Costs:
  - Per m²: 200-300 US-$
  - Total: ca 2-3 million US-$
  - Per ha rice paddy: ca 400 000 – 600 000 US-$
- Reduction of activity levels in rice: Unknown
- Reduction of individual doses: Unknown
- Reduction of collective dose: Unknown
- Additional waste needs to be managed

=> **Strong emphasis on reducing activity levels and dose rates**

Example:
Decontamination of river banks used for recreation, school routes etc.

- Dose rates: above 0.23 µSv/h, but less than 1 µSv/h
- Reduction of gamma dose rate: Factor 1.5-2
- Annual occupancy: 100-200 h
- Individual dose saved:
  - max 100 µSv/a
  - Typically less than 50 µSv/a

- **Strong public pressure**

For comparison:	Dose rate during long-distance flights: 4-8µ Sv/h Tokyo – Frankfurt and home again: ca. 100-200 µSv

Exposure from natural sources (UNSCEAR 2008)

Item	Annual effective dose (mSv/a)	
	Average	Range
Ingestion	**0.3**	**0.2 - 1**
^{40}K	0,17	
U- and Th-series	0,12	
Cosmogenic radionuclides	0,01	
Inhalation	**1.256**	**0.2 - 10**
U- and Th- series	0,006	
Radon ($^{222}Rn/^{220}Rn$ and decay products)	1,25	
External exposure	**0.87**	**0.6 - 2**
Cosmic radiation (at sea level	0,39	0,3 - 1
Natural radionuclides in soil	0,48	0,3 - 1
Total	**2.4**	**1 - 13**

Interaction and dialogue with the public

Interaction with the public

- **The problem**
  - World-wide aversion against **artificial environmental radiation**
  - Emotions drive reactions
  - Difficult to communicate radiation protection principles
  - Various sources of information with contradicting messages
  - Mistrust among the population
- **The measures**
  - Distribution of information
    - Newspapers, TV, Internet, social media, leaflets, Information Plaza in Fukushima City
    - Food monitoring
    - Interaction with international organizations (ICRP, UNSCEAR, IAEA, WHO)
  - Involvement of the local people in decision making
    - Local briefings
    - Self-help initiatives

Observations

- **To overcome mistrust is very difficult**
  - Well prepared information is “slower” and less credible than rumours
- **Promising activities**
  - Close cooperation with the local population
  - Support of self-help initiatives
  - Providing possibilities for food monitoring
  - Involvement of the people in decision processes
  - Face-to-face discussions and personal contacts
- **Carefully tailored strategy should address**
  - Anxieties
  - Life styles and habits
  - Cultural aspects
  - Economic aspects
  - The activities of other parties (media)

Conclusions

- **National framework for remediation**
  - Established in summer 2011

- **Very cautious reference level**
  - 1 mSv/a “on the long-term”
  - Raising high expectations
  - Historical contaminations: not higher than 5 mSv/a, in most cases 1 mSv/a

- **Conservative assessment of doses**
  - Natural attenuation processes are only rudimentarily considered
    => Remediation activities also in areas with low doses
    => Generation of large amounts of waste

Conclusions (cont.)

- **Focus of remediation and optimisation**
  - The reduction of γ–dose rates and activity levels in the environment are the key driver
  - No systematic optimisation process to balance dose reduction against costs, human resources, and generation of waste
  - High importance of social and cultural considerations
    - High value of a “clean” environment

- **Established remediation techniques applied**
  - Effectiveness consistent with global experience
  - Reduction in dose rates ca. 30-50%
    - Some projects implemented with little radiological impact
  - Cost-benefit analysis hardly applied
  - Generation of large amounts of waste

Conclusions (cont.)

- **Interaction with the public**
  - Key challenge in remediation
  - Emotions and anxieties are omnipresent
  - The co-existence of information and rumours from different sources are confusing
  - Tailored situation-specific approaches including personal and empathic elements seem to be most successful

- **By and large, the remediation programme followed the IAEA Safety Standards**
  - Very cautious approaches were implemented
  - Higher costs and enhanced efforts for management of waste are accepted

Thank you very much
for
your attention