Emergency and recovery preparedness: Lessons from past accidents and international recommendations

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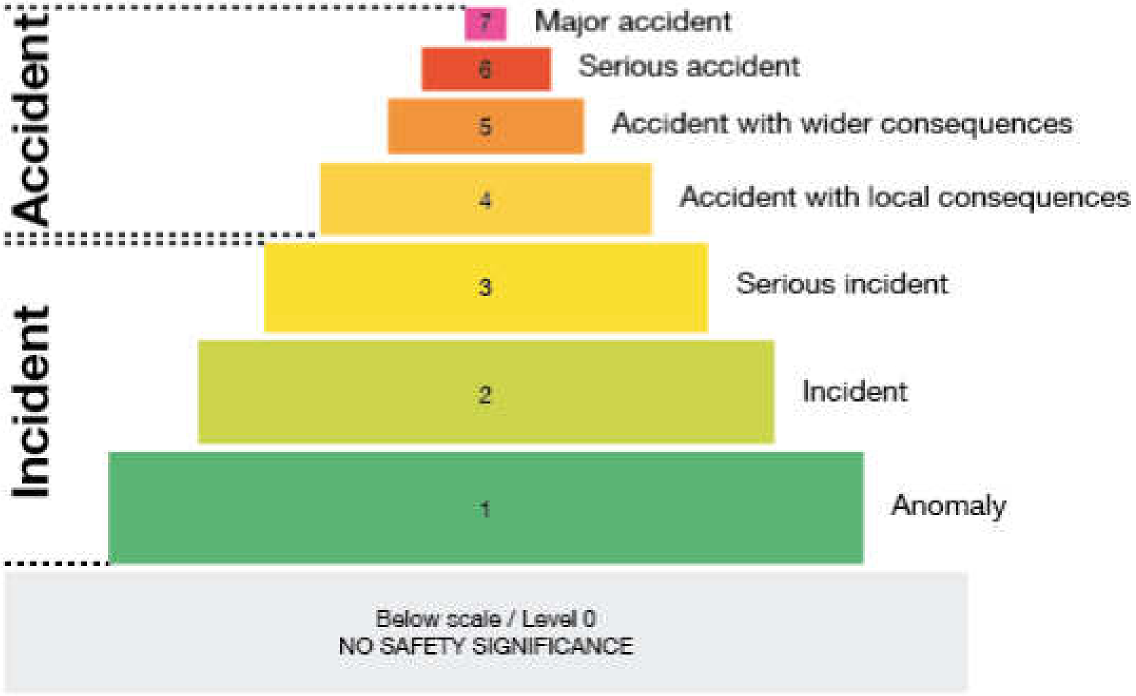
Introduction

- **Chernobyl and Fukushima experience has demonstrated a nuclear accident causes a breakdown in society affecting all aspects of individual and community life**
- **In this context, radiological protection has to address a double challenge:**
  - Protecting people and the environment
  - Maintaining and supporting the dynamic of socio-economic activities
- **The aim of this presentation is:**
  - To highlight what is at stake in emergency and recovery after a nuclear accident
  - To discuss the implementation of the radiological protection in the different phases of an accident
  - To emphasize the key challenges for preparedness

GENERAL CONSIDERATIONS

Past major accidents

- **Level 7**
  - 1986 Chernobyl
  - 2011 Fukushima
- **Level 6**
  - 1957 Kyshtym
- **Level 5**
  - 1953 Chalk River
  - 1957 Windscale
  - 1979 Three Mile Island
  - 1987 Goiânia
- **Level 4**
  - 1999 Tokaimura
  - etc.



(IAEA. 2012. LESSONS LEARNED FROM THE RESPONSE TO RADIATION EMERGENCIES (1945–2010). EPR-LESSONS LEARNED 2012, Vienna, IAEA)

Timeline for managing a nuclear accident

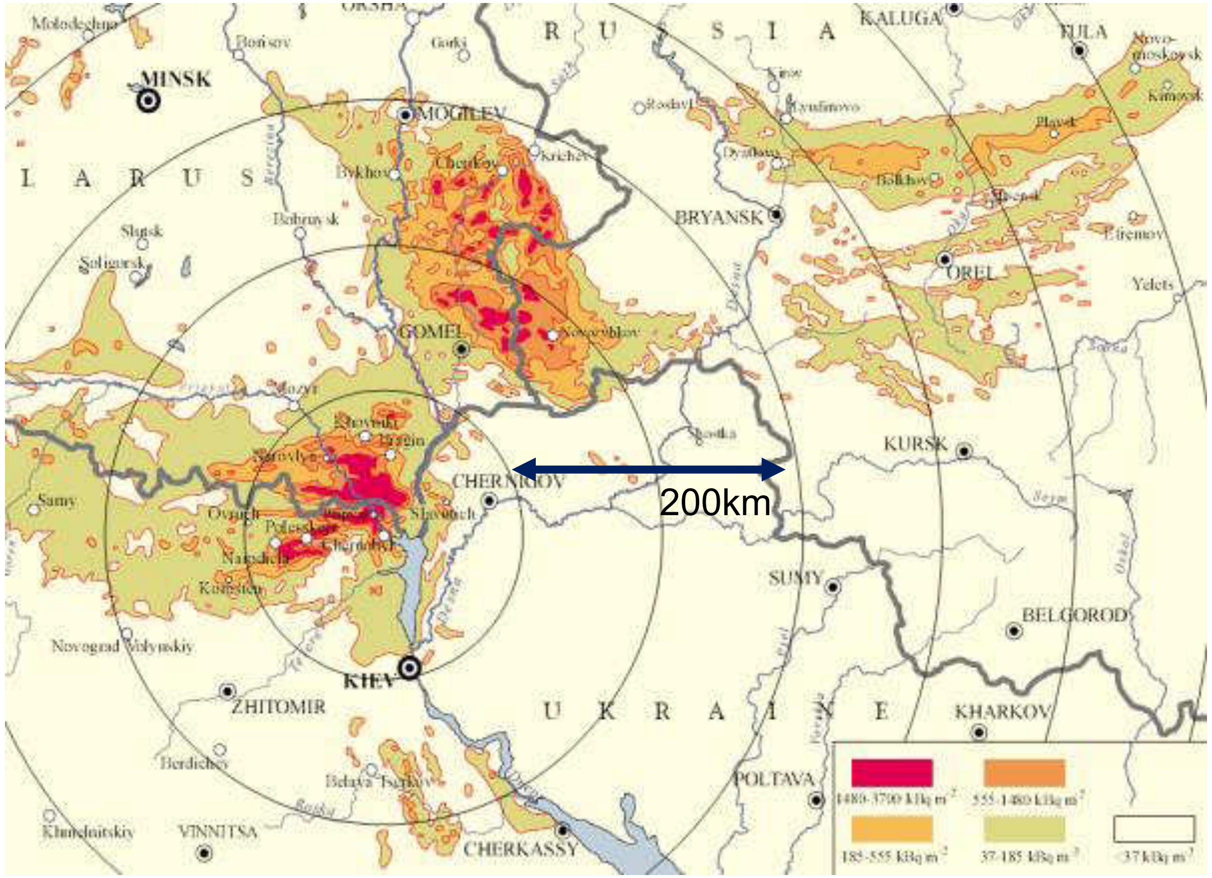
- **For implementation of the system of radiological protection, ICRP considers the early and the intermediate phases as an emergency exposure situation and the long-term phase as an existing exposure situation**

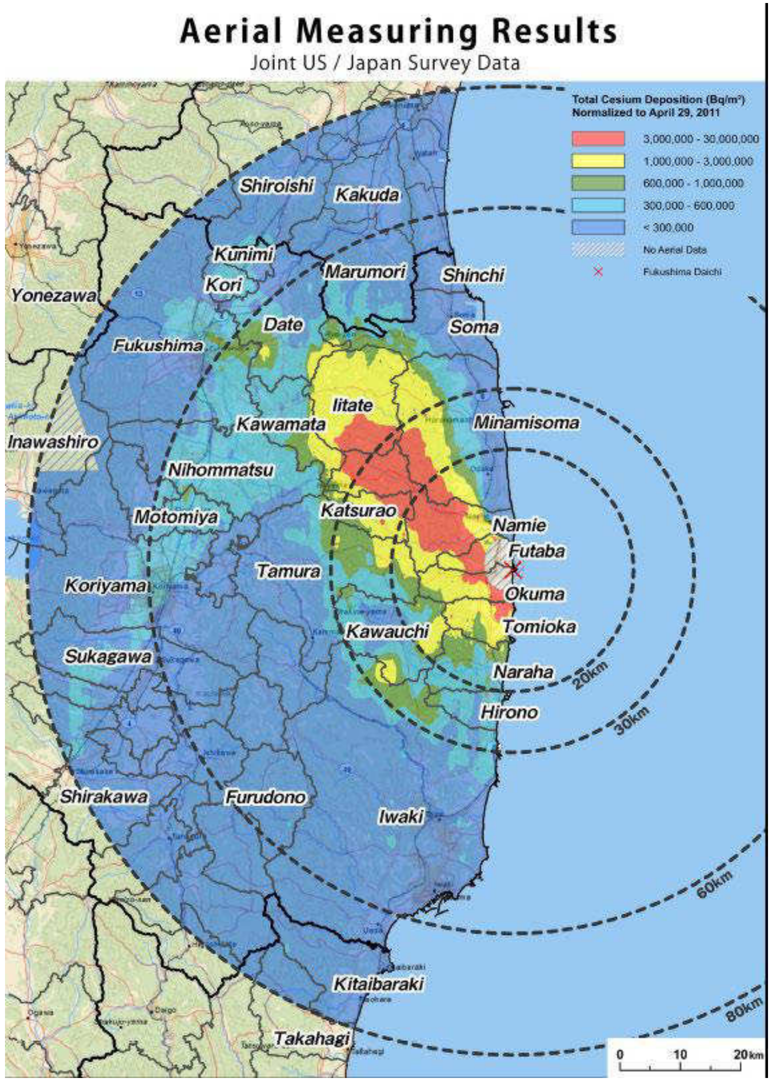
Preparedness	Emergency Response		Recovery
	Early phase	Intermediate phase	Long-term phase

Emergency exposure situation → Existing exposure situation

- The long-term phase begins:
  - on site when the source is considered secured enough, and
  - off site when the radiological conditions in the affected areas are **sufficiently characterised**.

Cs-137 deposition at Fukushima and Chernobyl





- Area in deposition density > 37 kBq/m²
  Chernobyl: 146,300 (km²)

Fukushima: 89,00 (km²)

Consequences of large nuclear accidents (1/3)

- **Radiation induced-health effects**
  - Tissue reactions (also called deterministic effects)
    - Possible effects mainly for emergency responders for high level of exposure (i.e. above 0.5 Gy)
    - Possible increase of circulatory diseases also for doses above several hundreds of mGy to the heart
  - Cancer and heritable diseases (also called stochastic effects)
    - Assume LNT relationship
    - Focus on thyroid mainly for children with observations following the Chernobyl accident
    - No significant observation in population for hereditary effects
- **The past experience showed non-radiological consequences may become more important than the radiological consequences.**

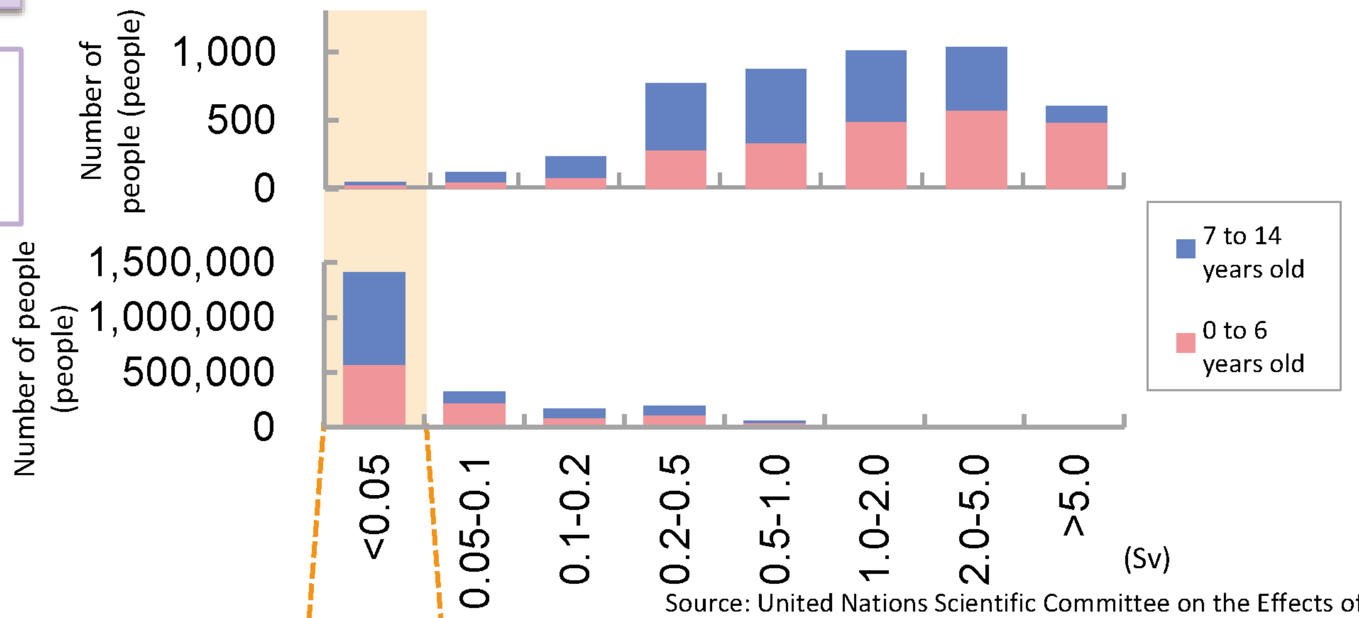
Comparison between the Chernobyl NPS Accident and the TEPCO's Fukushima Daiichi NPS Accident (Thyroid Doses)

Children's thyroid exposure doses

Chernobyl NPS Accident

A group of people who evacuated in Belarus in 1986

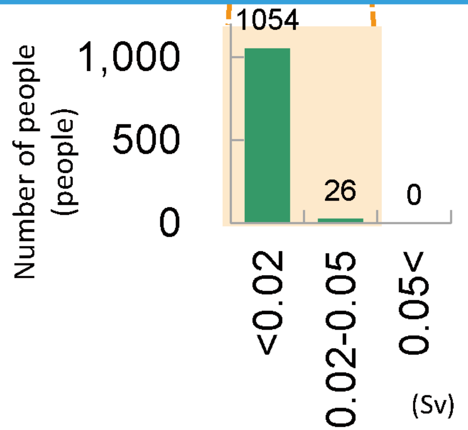
All people in Belarus (excluding evacuees)



Source: United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2008 Report

Accident at Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi NPS

* This data is based on a survey targeting a limited group of residents and does not reflect the overall circumstances.



Calculation method
For comparison, the "Results of the Simple Thyroid Screening for Children" contained in the "Outline of Children's Simple Measurement Test Results" (August 17, 2011; Team in Charge of Assisting the Lives of Disaster Victims (Medical Team)) is rearranged using "screening level of 0.2 μSv/h (equivalent to 100 mSv of thyroid dose equivalent for 1-year-old children)" (May 12, 2011; Nuclear Safety Commission of Japan) (Gy = Sv)
Source: "Safety of Fukushima-produced Foods," Nuclear Disaster Expert Group
Judging from the measurement method and ambient dose rates at the relevant locations, the detection limit is set at around 0.02 Sv.

Fukushima Health Management Survey

(borrowed to Pr. Yamashita – April 2021)

Thyroid Ultrasound Examination – Results

As of Mar.31,2020

		Preliminary Baseline (1st Exam)	Full-Scale Survey (2nd Exam)	Full-Scale Survey (3rd Exam)	Full-Scale Survey (4th Exam)	Survey of Age 25
Fiscal Year		2011-2013	2014-2015	2016-2017	2018-2019	2017-
Number of target population		367,637	381,244	336,670	294,240	66,637
Participation rate of primary exam		81.7%	71.0%	64.7%	61.5%	8.4%
Target population of confirmatory exam		2,293	2,227	1,501	1,362	244
Participation rate of confirmatory exam		92.9%	84.1%	73.4%	60.1%	68.9%
Malignant or suspicious for malignancy(FNAC)		**116**	**71**	**31**	**27**	**7**
Number who received surgery		**102**	**54**	**27**	**16**	**4**
Patho-logical diagnosis	Papillary cancer	100	53	27	16	3
	Undifferentiated cancer	1				
	Others	1	1			1

Consequences of large nuclear accidents (2/3)

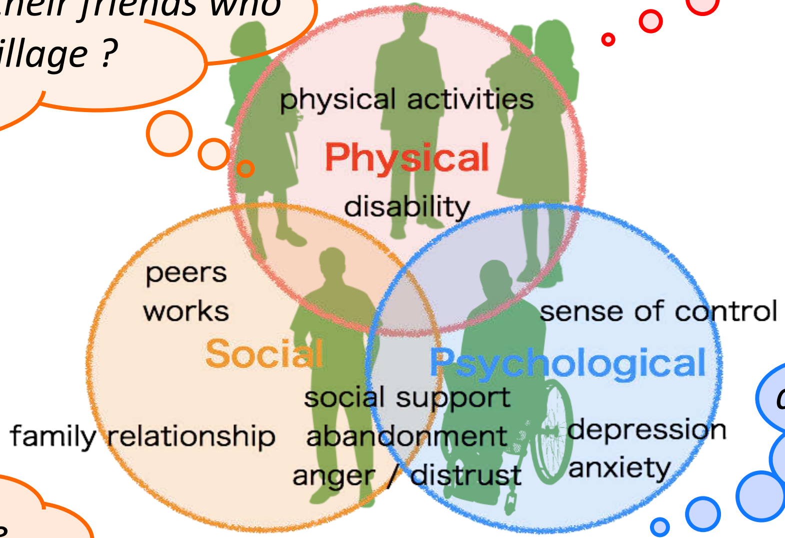
- **Societal consequences**
  - Impacts on the daily lives of individuals, family relationships and their local communities
  - Threat to people's autonomy and dignity
- **Economic impacts**
  - Radiological contamination likely to directly affect critical infrastructure impacting the local economy and key public services
- **Psychological effects**
  - The lack of control over their individual living conditions induces a high level of psychological distress
  - The psychological impact causes unspecific health problems, such as generalized fear and concerns about overall health status
- **Health impacts of changes in lifestyle associated with protective actions**
  - Increase in mortality and morbidity for vulnerable populations linked to evacuation, relocation, change in daily-life environment and health care infrastructure

Expectations and worries

Water and rice are safe?

Is it safe or dangerous to let my children play outside?

Why do our children have higher contamination levels than their friends who live in the same village ?



I have few friends or acquaintances nearby, and there is no one to talk with

When I see you here, I'm reminded we have a Bq problem

Iitate village case study
Y. Kuroda (FMU)

Consequences of large nuclear accidents (3/3)

- **Consequences on fauna and flora**
  - Potential direct radiation exposure detrimental to non-human biota in the immediate area surrounding the damaged installation
    - Ex. after Chernobyl:
      - Death of forests
      - Reduction of soil invertebrates
      - Genetic changes in some species
  - In most of the cases, for large areas with deposition of radionuclides:
    - Limited observation of direct effects
    - Major concern of local populations for daily life
  - In addition, need to consider the impact on the environment of the necessary countermeasures to be implemented:
    - Restriction of access and use of rural/natural areas
    - Impact of decontamination (removal of top soils…) and remediation actions (chemical ameliorants…)

Principles for protection of people and environment

- The objective is **to prevent severe tissue/organ damage, to reduce cancer and heritable diseases** to the extent reasonably achievable, and **to prevent or reduce** the frequency of deleterious radiation **effects on biota**
- This objective should be pursued considering to the extent possible, the **health and well-being** of all affected individuals, decent **working conditions** for responders onsite and off-site, the **quality of life** of affected communities off-site, and the **biological diversity** in affected areas
- The fundamental protection principles to guide action are:
  - ✓ The **justification** of decisions
  - ✓ The **optimisation** of protection
- The **principle of individual dose limitation** is not appropriate because the sources of exposures on-site and off-site are **no longer under control**.

The justification of protective decisions

- The principle of justification states that **any decision altering a radiation exposure situation should do more good than harm**

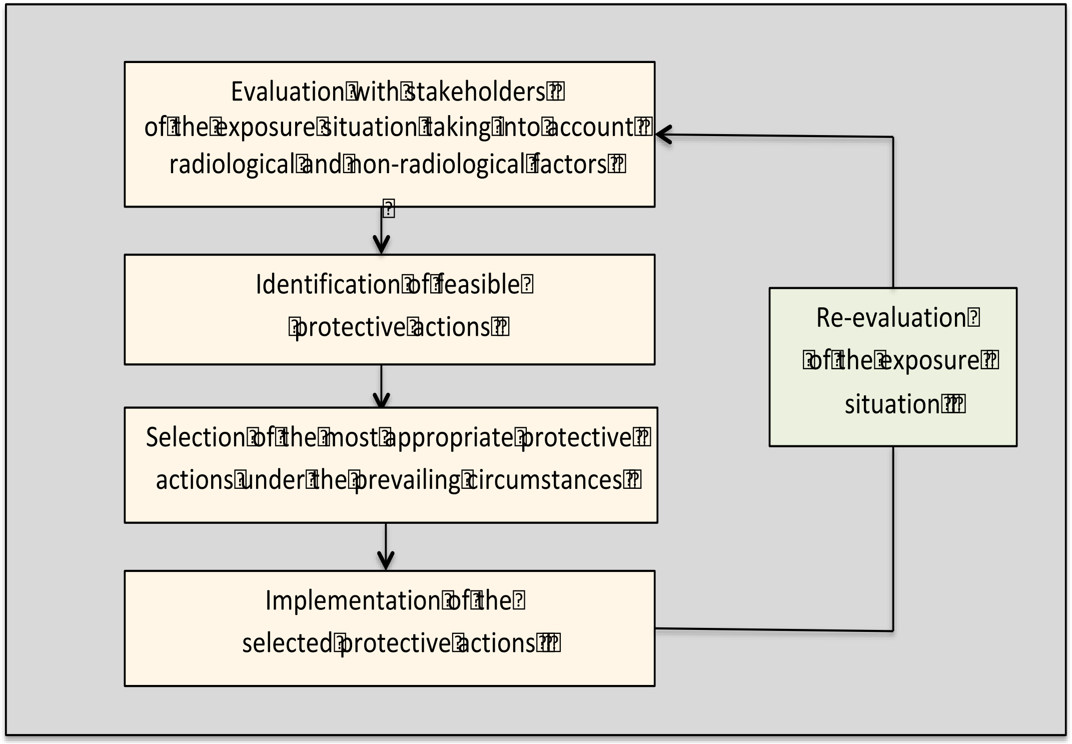
- In emergency and existing exposure situations, this principle is applied when deciding whether to take action **to avoid or reduce potential or actual exposures**

- All decisions that aim to reduce the impacts of exposure in the event of a nuclear accident **introduce additional constraints**, which have greater or lesser negative effects on the individuals and communities concerned

- Responsibility for making decisions on the justification of protection is usually the role of **authorities and responsible organisations**

The optimisation of the protection

- All individual exposures should be kept **as low as reasonably achievable**, taking into account **societal, environmental and economic** factors
- To be done with the objective to avoid unnecessary exposure (**prudence**), fair distribution of exposure among exposed individuals (**justice**), and treating people with respect (**dignity**)
- Optimisation should consider the radiological and environmental characteristics of the exposure situation, as reflected by the **views and concerns of stakeholders**, and the **ethical values** that govern radiological protection

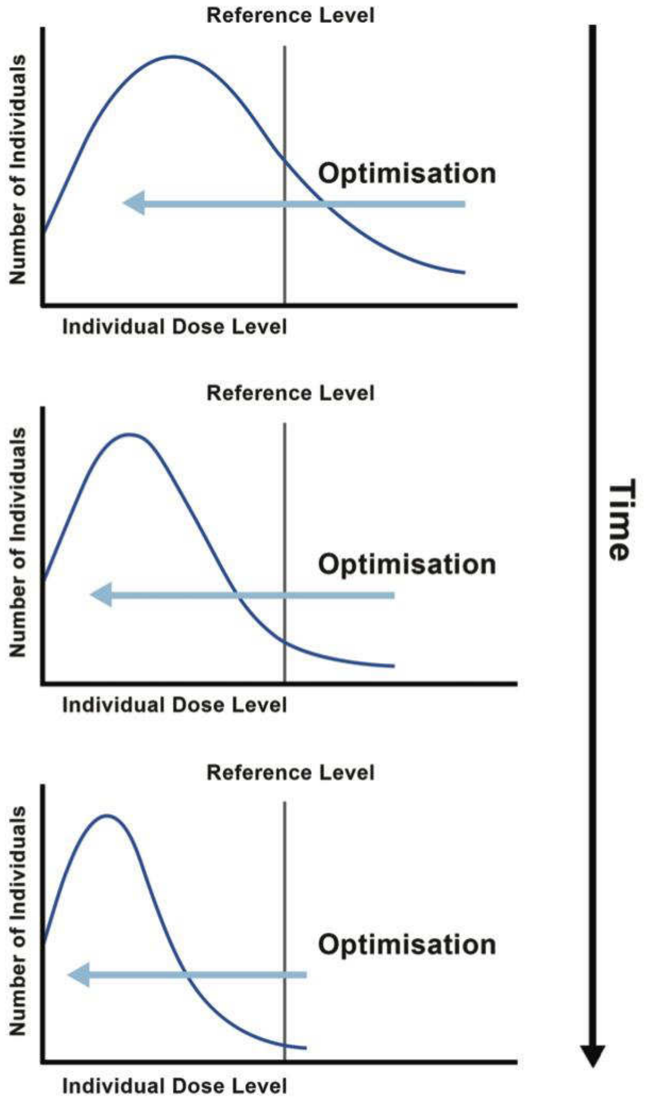


Optimisation and the use of reference levels

- ICRP recommends using **reference levels** to **restrain inequity** in the distribution of exposures and to **guide** optimisation

- Reference levels are generally expressed in terms of **annual individual effective dose (mSv/year)** and they reflect the level of exposure above which it is considered inappropriate for exposure to occur

- Reference levels are not **prescriptive regulatory limits** that should not be exceeded



THE EARLY PHASE

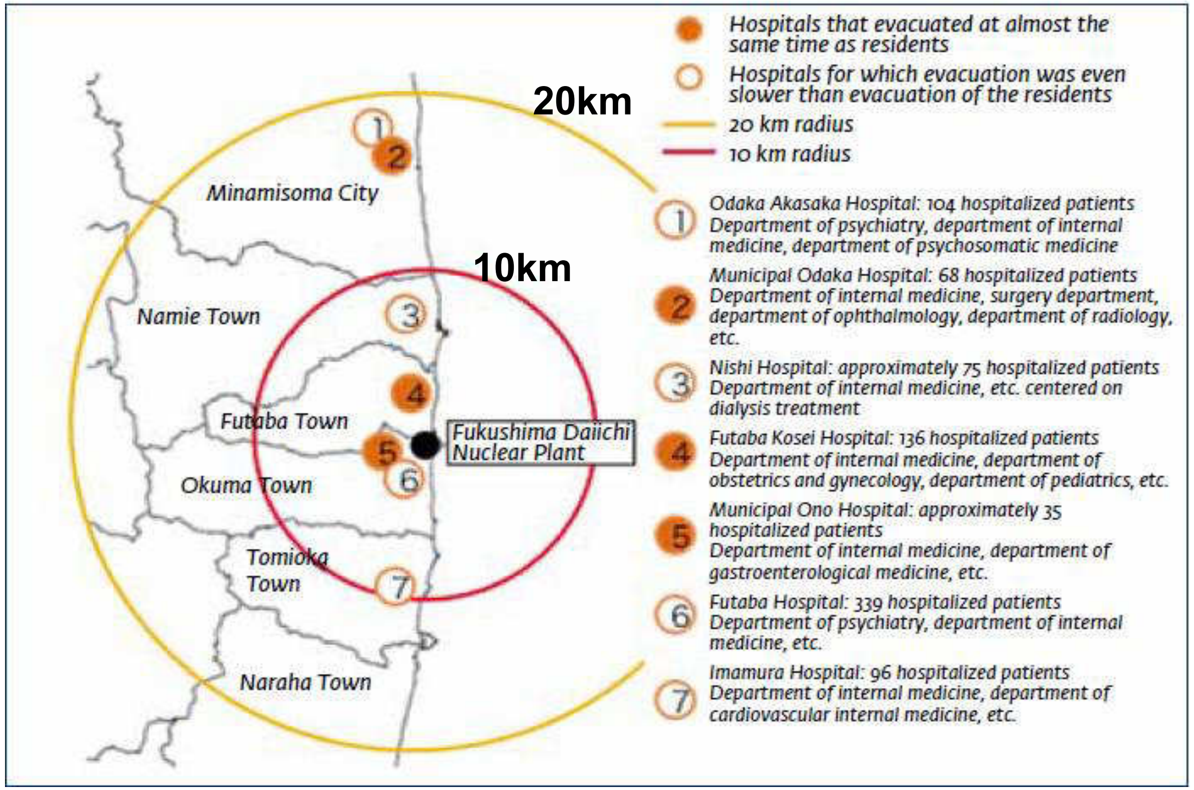
Characteristics of the early phase and protective actions

- During the early phase, it is necessary **to act promptly and timely** to avoid or reduce undesirable exposure, and regain control of the source
- The main **urgent protective actions in the early phase** are **evacuation**, **sheltering**, **iodine thyroid blocking, restrictions on local food and water supply**, and **protection of pets and livestock.**
- ICRP recommendation for the protection of the public: **Optimisation of protection using a reference level** of **100 mSv or below** for the entire duration of both the early and the intermediate phases
- Radiological situation is generally not known:
  - Need to estimate the situation on-site and off-site
  - Need to anticipate the possible impacts and evolution of the situation

Evacuation of hospital patients

- Approximately 2200 patients and elderly people stayed in 7 hospitals and 17 nursing homes within 20 km evacuation zone.

- No medical support was provided during evacuation or at shelters, resulting in the deterioration of the physical condition of many patients.
- More than 50 patients died either during or soon after evacuation in March 2011.



(Tanigawa, K. et al. Lancet, 2012)

(The National Diet Report, Chapter 4)

Protection of responders

- Diversity of responders: **emergency teams** (e.g. firefighters, police officers, medical personnel), **workers** (occupationally exposed or not), **professionals and authorities, military personnel, and citizens who volunteer to help**
- Responders' exposure should be managed **as closely as possible** to that of exposed workers in normal operation taking into account that the source of exposure is no longer under control and that the working conditions are unusual
- Given the unpredictability of the situation, this approach should be **sufficiently flexible, while remaining cautious**
- ICRP recommends applying the principle of **optimisation of protection using reference levels**
  - Total exposure of responders should be guided by a reference level of 100 mSv for the duration of the early and intermediate phases
- For life saving or to regain control of the installations, a very **limited number** of responders may receive exposures above 100 mSv
- Due to **stressful conditions**, need to ensure **decent working and housing conditions**

THE INTERMEDIATE PHASE

The intermediate phase

- During the intermediate phase **environmental and individual monitoring** should be undertaken in order to **characterize** the radiological situation
- The objective is to know **where, when, and how** people are exposed and will be exposed in the future in order to take actions
- Justification applies to decisions on implementing further protective actions with the perspective that these actions **combined together** constitute a coherent **protection strategy**
    - **Temporary relocation**
    - **Foodstuff management (introduction of radiological criteria)**
    - **Decontamination of the environment**
    - **Management of business activities**
- **Involving key stakeholders** in public consultation and co-expertise processes is crucial

Reference levels for responders and the public

	Early Phase	Intermediate Phase	Long-Term Phase
Responders on-site	100 mSv or below* Could be exceeded in exceptional circumstances†	100 mSv or below* May evolve with circumstances*†‡	20 mSv per year or below
Responders off-site	100 mSv or below* Could be exceeded in exceptional circumstances†	20 mSv per year or below‡ May evolve with circumstances	20 mSv per year or below in restricted areas not open to the public Lower half of the 1 to 20 mSv per year band in all other areas¶
Public	100 mSv or below for the entire duration of both the early and intermediate phases§		Lower half of the 1 to 20 mSv per year band with the objective to progressively reduce exposure to levels towards the lower end of the band, or below if possible¶

Emergency exposure situation

The co-expertise process (1/2)

Establishing dialogues to share experience and knowledge

↓

Engaging affected people in measurements and sharing results

↓

Identifying self-help protective actions and organizing collective vigilance

↓

Implementing local projects with the support of experts

Combining:

Two-way communication

Trust building

Citizen participation/ empowerment

Technical expertise

Dialogue, measurements and local projects are the three pillars of the co-expertise process

The co-expertise process (2/2)

- **The role of dialogue:**
  - Allow affected people to ask questions, share their concerns, challenges and expectations and gradually **become familiar with the basic notions of radiological protection**.
  - Rely on the **plurality of points of view**
  - **Listening** and **empathy** are the required qualities of experts
- **The role of measurements:**
  - Making the invisible and the frightening visible and of giving everyone the keys to understand where, when and how he/she is exposed
  - Contribute to make informed decisions
  - Importance of sharing results to identify possible actions
- **The role of local projects:**
  - A means to find again the meaning of personal fulfilment stopped after the accident and to look again positively at the future
  - Require cooperation with the authorities, organizations, and experts
  - Need to establish appropriate mechanisms to ensure legitimacy, transparency and fairness of the decision-making process

Ethos project, Belarus

Ethos project, Belarus

Chernobyl

Suetsugi, Japan

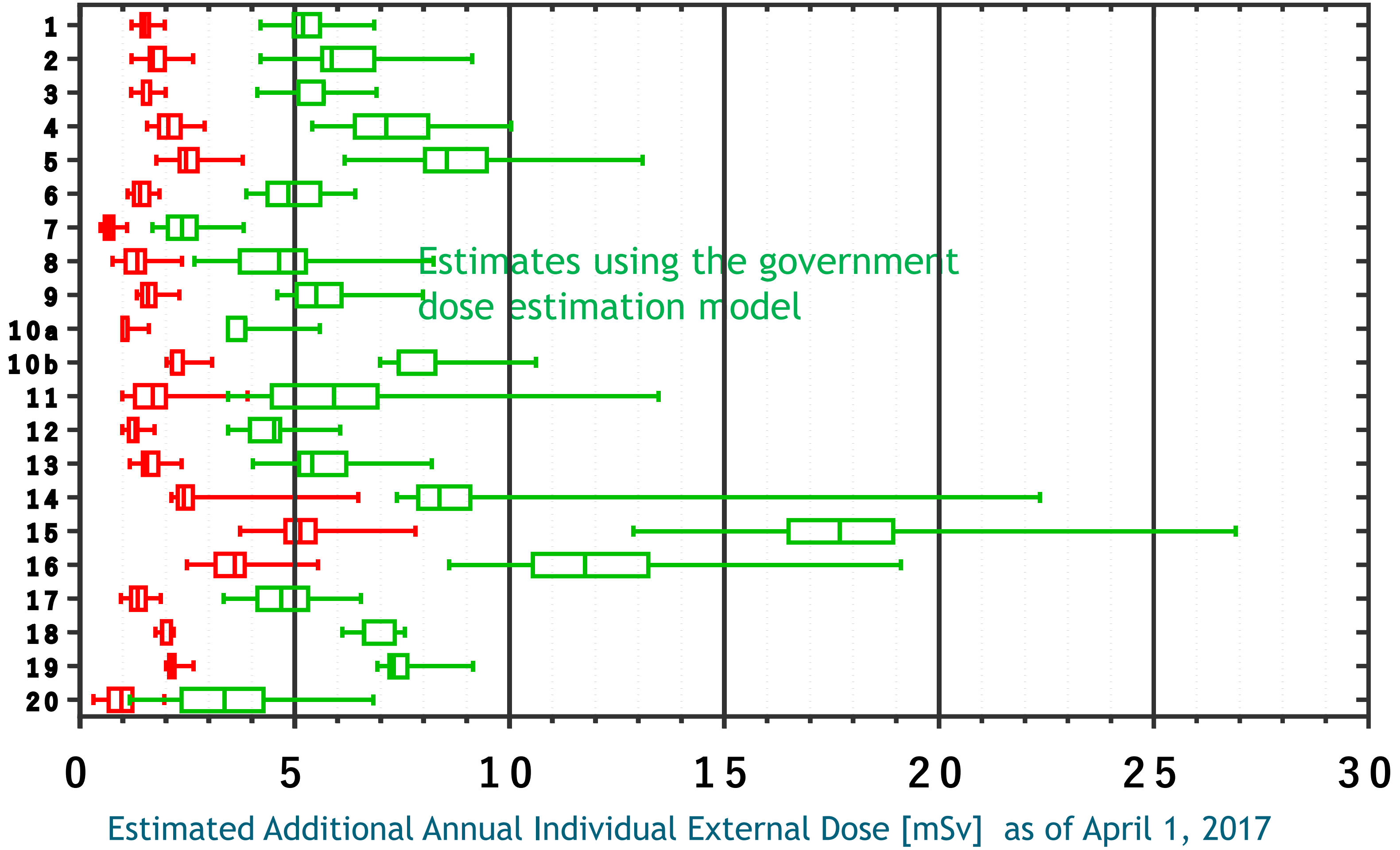
Suetsugi, Japan

Fukushima

Estimated individual dose in Iitate

From W. Naito et al., J. Radiol. Prot. 37 (2017) 606

The estimates of individual external doses based on the result from the study were about ¼ of the estimates calculated by the government dose estimation model.



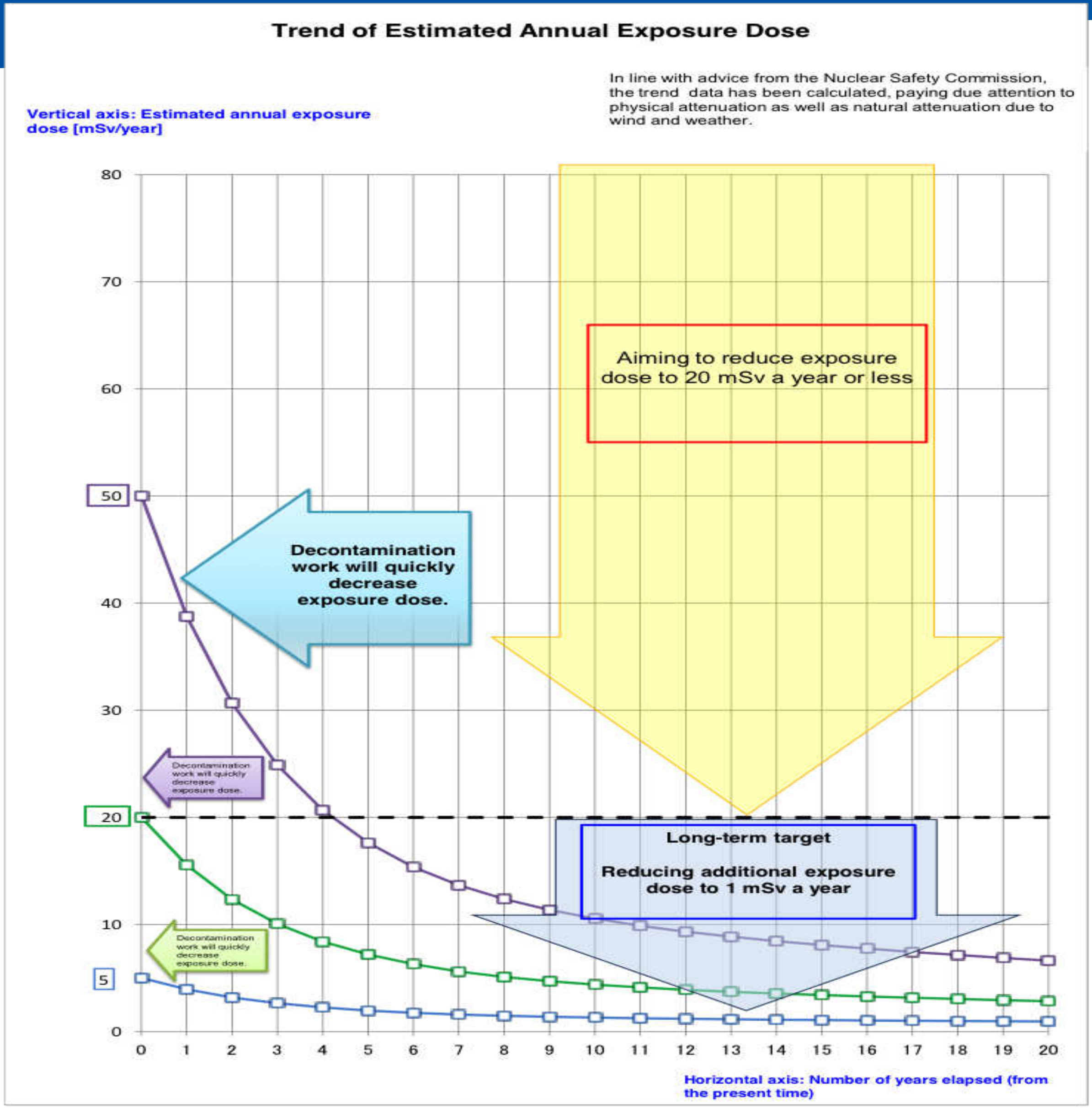
From an emergency to an existing exposure situation

Emergency

ICRP 103
ICRP 109
ICRP 111

TRANSITION

Existing



Source: METI (2011)

THE LONG-TERM PHASE

Characteristics of the long-term phase

- The level of exposures of people residing in affected areas is largely driven by their individual behaviours, depending on many factors including:
  - Location of home and work;
  - Profession or occupation;
  - Individual habits, significantly dependent on the socio-economic situation.
- Large differences in levels of exposure may exist between neighbouring communities; within families in the same community; or even within the same family.
- Skewed dose distribution where a few individuals receive a larger exposure than the average.
- Justification also applies to the fundamental decision of authorities concerning **the future of the affected areas**, and marks the beginning of the long-term phase
- Importance of **involving key stakeholders combining self-help and collective protective actions**

Reference levels for responders and the public

Existing exposure situation

	Early Phase	Intermediate Phase	Long-Term Phase
Responders on-site	100 mSv or below* Could be exceeded in exceptional circumstances†	100 mSv or below* May evolve with circumstances*†‡	20 mSv per year or below
Responders off-site	100 mSv or below* Could be exceeded in exceptional circumstances†	20 mSv per year or below‡ May evolve with circumstances	20 mSv per year or below in restricted areas not open to the public Lower half of the 1 to 20 mSv per year band in all other areas¶
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Lessons from experience

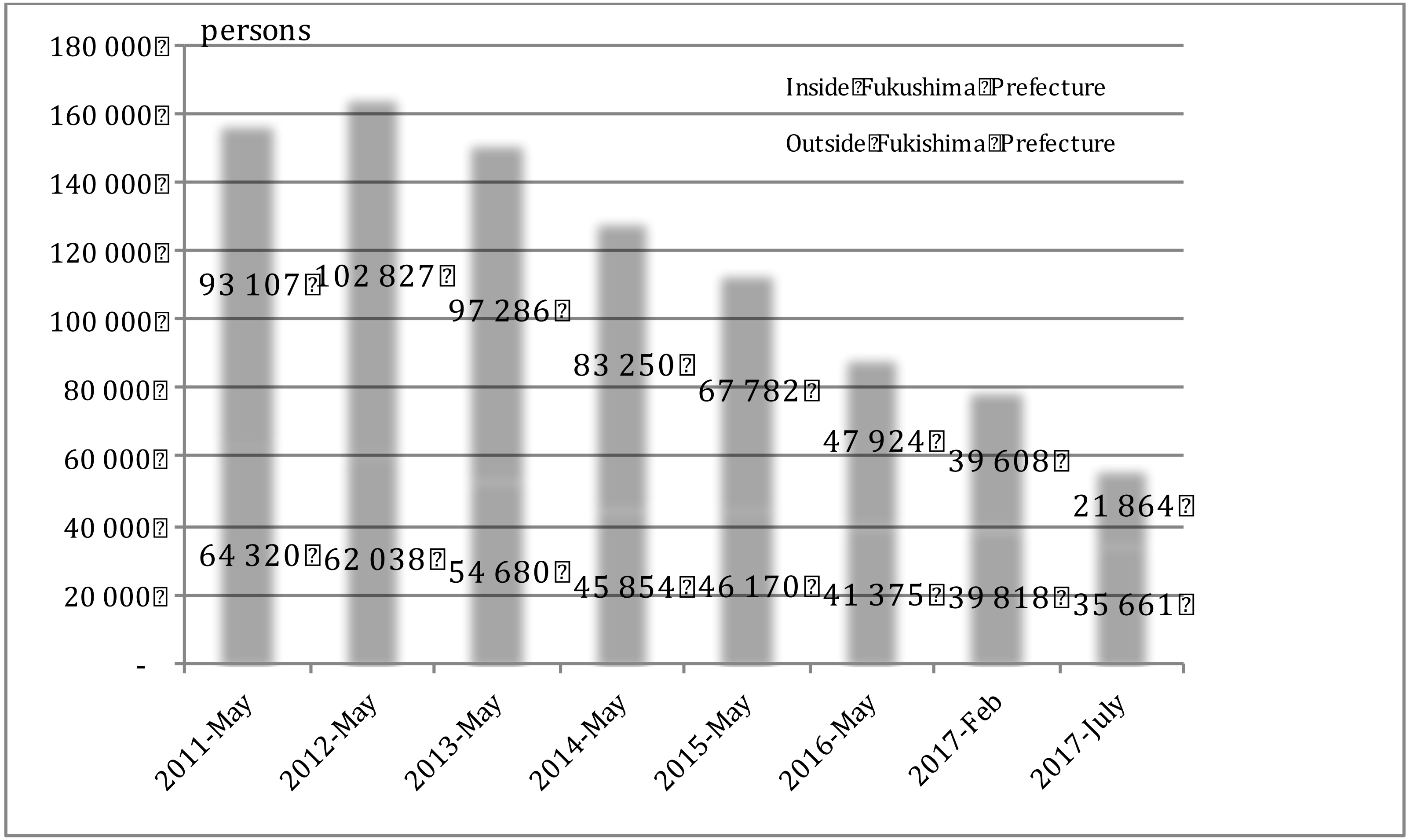
- After a nuclear accident people are lost, they no longer trust the authorities and experts, they gradually loose control of their daily life, there is a **threat on their dignity**

- The return to the ante situation is **not possible**:
  - ✓ Fully removing radioactivity is not achievable
  - ✓ Many human and societal consequences are irreversible (departures, etc.)
  - ✓ Disruption of communities induces **ruptures and complex dilemmas**

- The socio-economic dynamic is confronted to an **altered context** with **new constraints** (demography, image, environment...)

Complex waste management

Evolution of the number of evacuees

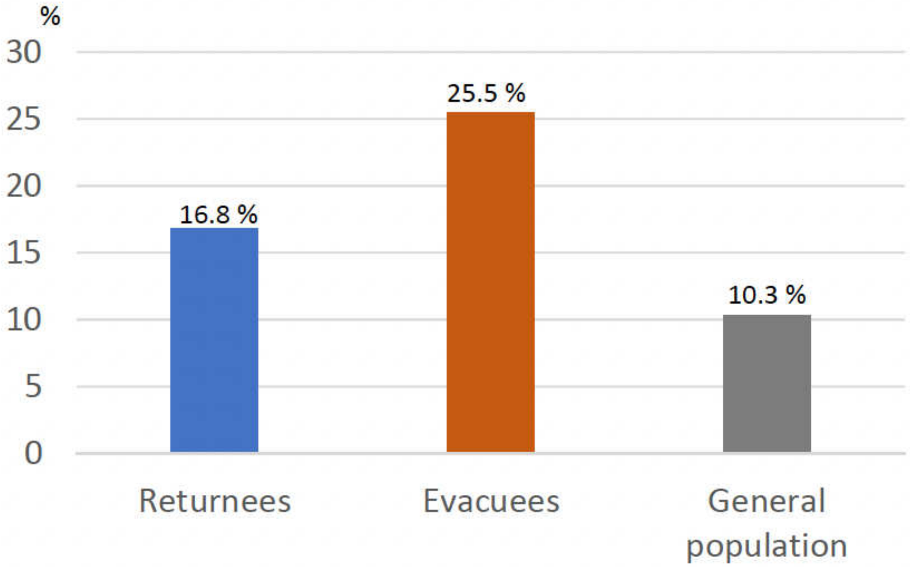


Source: Fukushima Prefecture

Fukushima: Predicted number of residents of each municipality *(borrowed to Pr. Takamura – Nov. 2022)*

	Katsurao	Namie	Futaba	Ohkuma	Tomioka	Kawauchi	Naraha	Hirono	Total
Population on March 2011	1,567	21,434	7,140	11,505	15,934	3,083	8,011	5,490	74,122
Population on January 2022	1,335	16,205	5,657	10,165	12,043	2,432	6,682	4,700	59,218 (-20%)
Returned	448	1,786	0	356	1,816	2,001	4,144	4,229	14,780 (25%)
Predicted Return (%)	46.1	16.7	10.8	12.5	15.1	80.9	54.3	83.3	29.4
Population in future	615	2,706	611	1,270	1,818	2,001	4,144	4,229	17,394

Fukushima: Psychological distress level in evacuees and returnees *(borrowed to Pr. Tanigawa – Nov. 2022)*



Prevalence of K6 ≥ 10

K6 ≥ 10 as an indicator of mood/anxiety disorders

Murakami M, et al. Lower psychological distress levels among returnees compared with evacuees after the Fukushima Nuclear Accident. The Tohoku Journal of Experimental Medicine 2019 Jan; 247(1):13-17.

Key lessons for addressing well-being (1)

Ethical considerations

- **Main objective: restoring decent living and working conditions for affected populations (resilience and sustainable development)**
- **Beneficence/Non-Maleficence:**
  - Provide good level of protection: *How to (and Who) assess the level of well-being?*
- **Prudence: Organise the vigilance on the long-term consequences of the accident (including co-expertise processes)**
- **Justice: Consider vulnerable populations and ensure equitable distribution of means and resources (notably key issues on compensation)**

Key lessons for addressing well-being (2)

Ethical considerations (cont.)

- **Respect dignity and autonomy of citizens**
  - Support citizen initiatives (co-expertise processes, self-help protective actions, local projects...)
  - Respect individual decisions
- **Establish appropriate mechanisms to ensure legitimacy, transparency and fairness of the decision-making process and ensure stakeholder participation**
- **Recovering trust is a key challenge for the authorities and the experts in post-accident situation: transparency, honesty, empathy are crucial in this perspective**

The governance of socio-economic activities

- **The rehabilitation of decent and sustainable living conditions must be based on a 'long term vision of the territory' co-negotiated between all the actors concerned**

- **The challenge is to articulate a sustainable framework:**
  - The restart of social and economic activities put in the aftermath of the accident
  - The emergence of new and innovative activities in line with the local context
  - The support for local projects led by individuals or communities

- It must also aim at the **constant improvement of the radiological situation**

Possible attractiveness

The lifting of protective actions

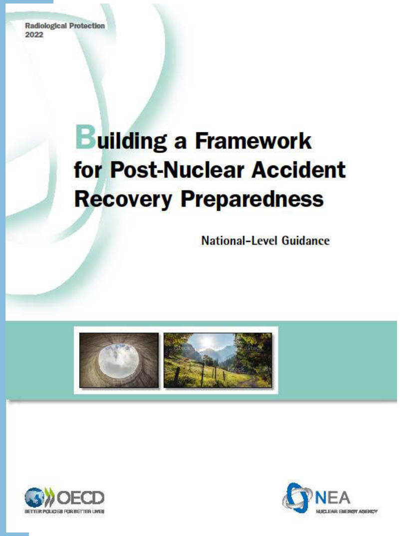
- A **difficult** decision
- Requires that actions no longer be considered necessary
- To be below the reference level is not the only criterion
- The assessment should be **shared**
- Often involves the implementation of **other actions** more suited to the situation
- For the long-term:
  - **Vigilance** is recommended
  - The transmission of the **memory** and the **practical radiological protection culture** should be organised

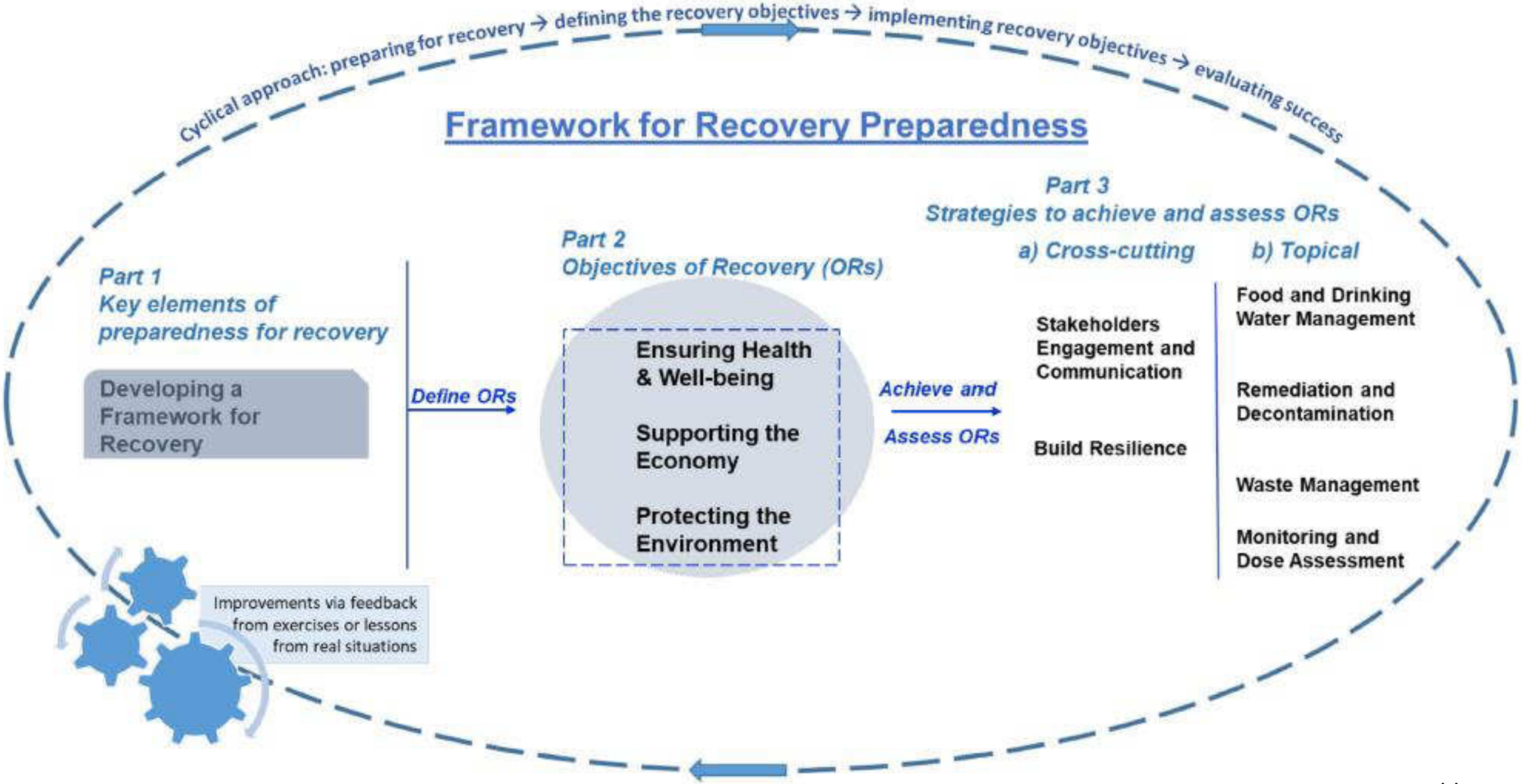
PREPAREDNESS PLANNING

Preparedness planning

- For the early phase:
  - Development of pre-planned protection strategies for postulated scenarios, based on hazard assessment
- For the long-term phase:
  - Identify the vulnerability of potentially affected areas,
  - Develop guidelines sufficiently flexible to cope with the real situation as appropriate
- A prerequisite: to preparedness is to
  - Acknowledge the possibility that a nuclear accident could occur
  - Need to develop awareness, if not among the general population, at least among organizations that will be involved in case of an accident
- **Key representative stakeholders** should participate in preparedness

The Recovery Framework for preparedness





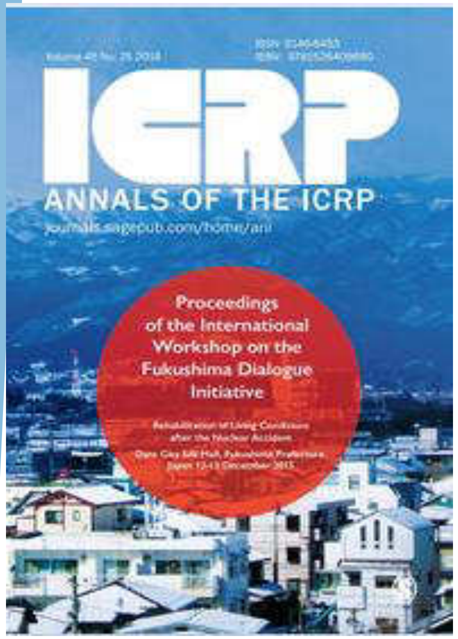
Concluding remarks

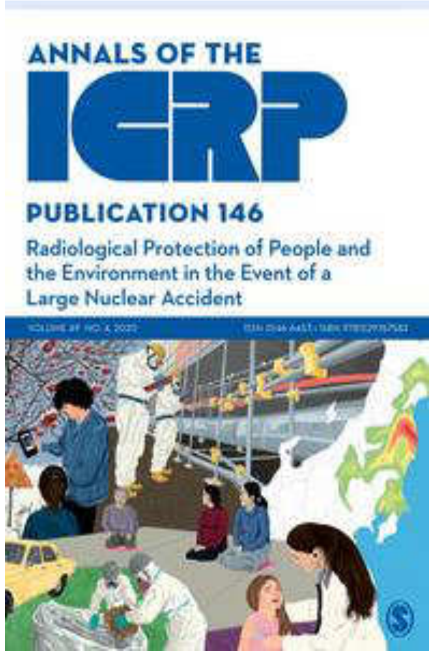
- A nuclear accident is an unexpected event that profoundly **destabilises** people and society, generates a complex situation, and requires mobilisation of considerable **human and financial resources**

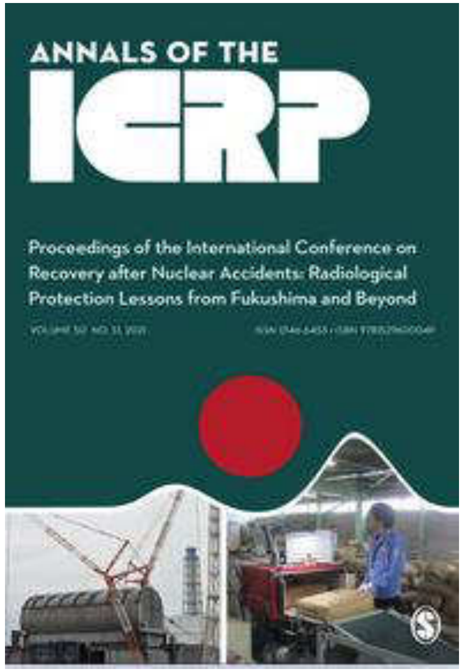
- Operationally, the main recommendation is to mitigate the potential effects of radiation on health and the environment using the **principle of optimisation with reference levels** to select and implement protective actions

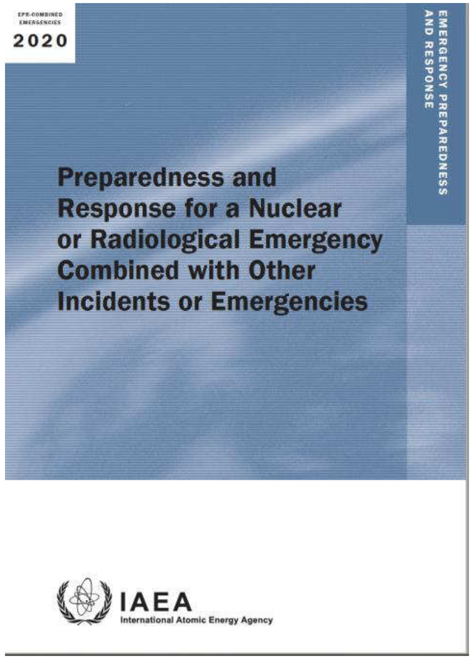
- To achieve this objective, it is crucial to **involve stakeholders and ensure the respect of ethical values**

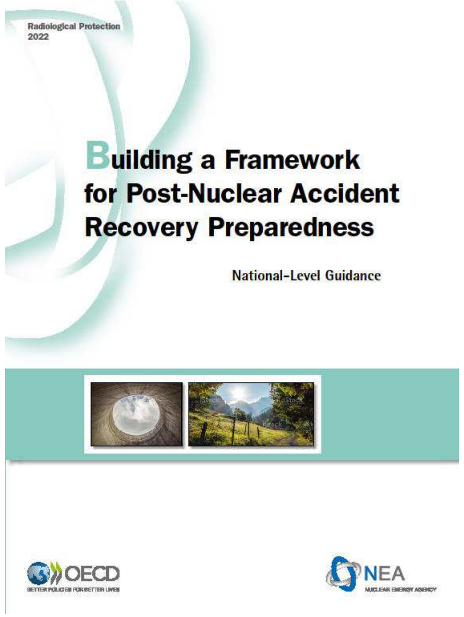
Some Publications on emergency and recovery issues











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