

# **59th IAEA General Conference**

**IAEA Nuclear Safety and Security Programme**

## **The Fukushima Daiichi Accident**

**Vienna International Centre (VIC) 17 September 2015 – 9 a.m. to 2 p.m.**

# **The Radiological Consequences of the Fukushima Daiichi Accident**

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August 25th, 2015

# 'Radiological Consequences'

**Presence of radioactivity in the environment**  
(releases, dispersion, deposition, consumer products)



**Protection measures have to be undertaken**



**People are exposed to radiation**



**Health effects may occur**



**Impact on non-human biota**

# **The Team of Experts**

# The Co-Chairs



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# The Scientific Liaison



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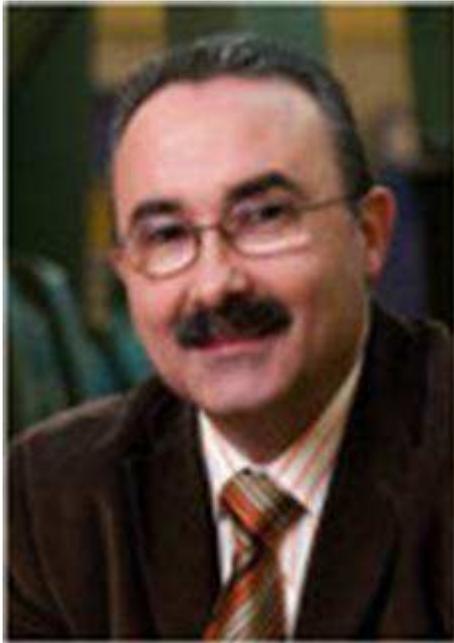
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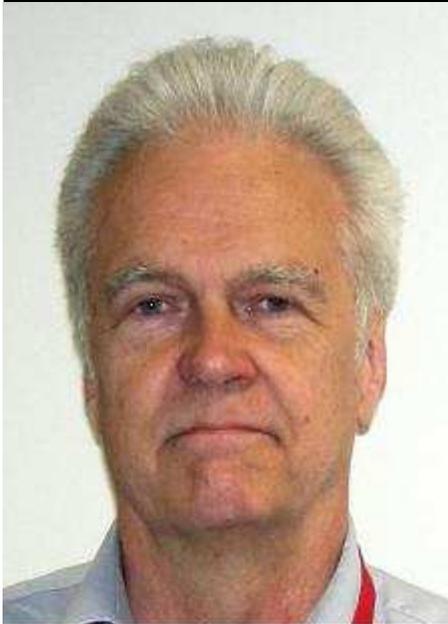
# The Leaders



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# The definitive architects



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**Silvia  
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**Louise  
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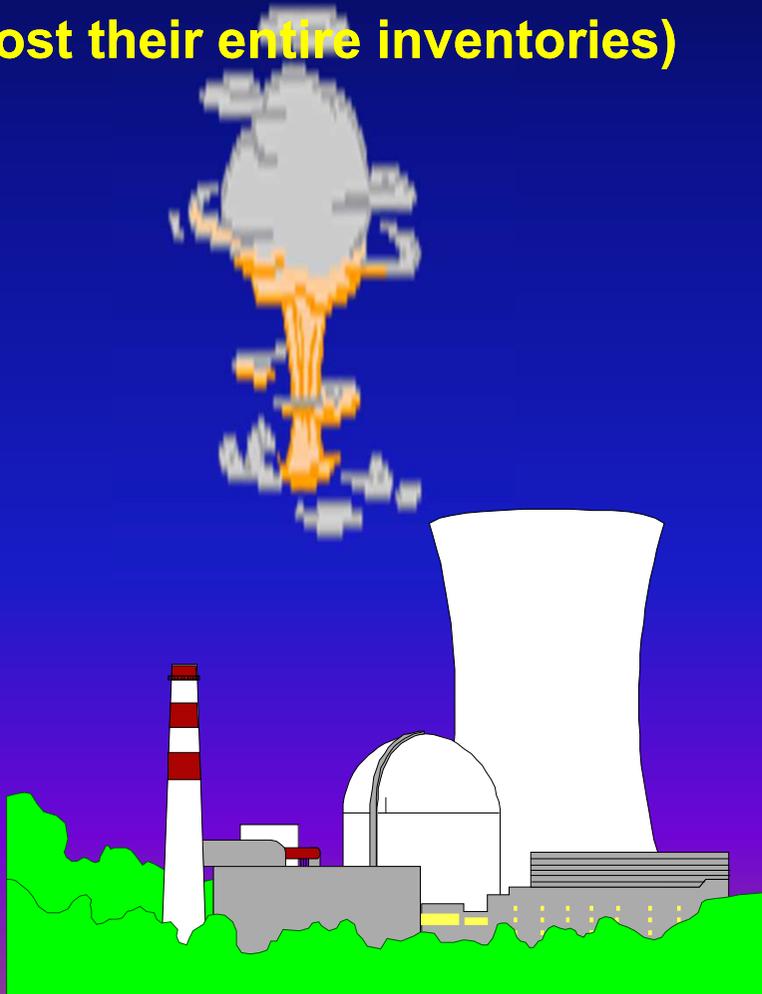


# **1. Radioactivity in the environment**

## Noble gases

**6.4 to 32.6 PBq of  $^{85}\text{Kr}$   
and up to  
11 000 PBq of  $^{133}\text{Xe}$   
(almost their entire inventories)**

**Global dispersion  
dilution**



140 to 200 PBq of  $^{131}\text{I}$   
12 to 16 PBq  $^{137}\text{Cs}$



“Contamination” of:

- Ocean,
- Land,
- Forests,
- Water,
- Foodstuff
- Consumer products

'Contamination' **means** presence,

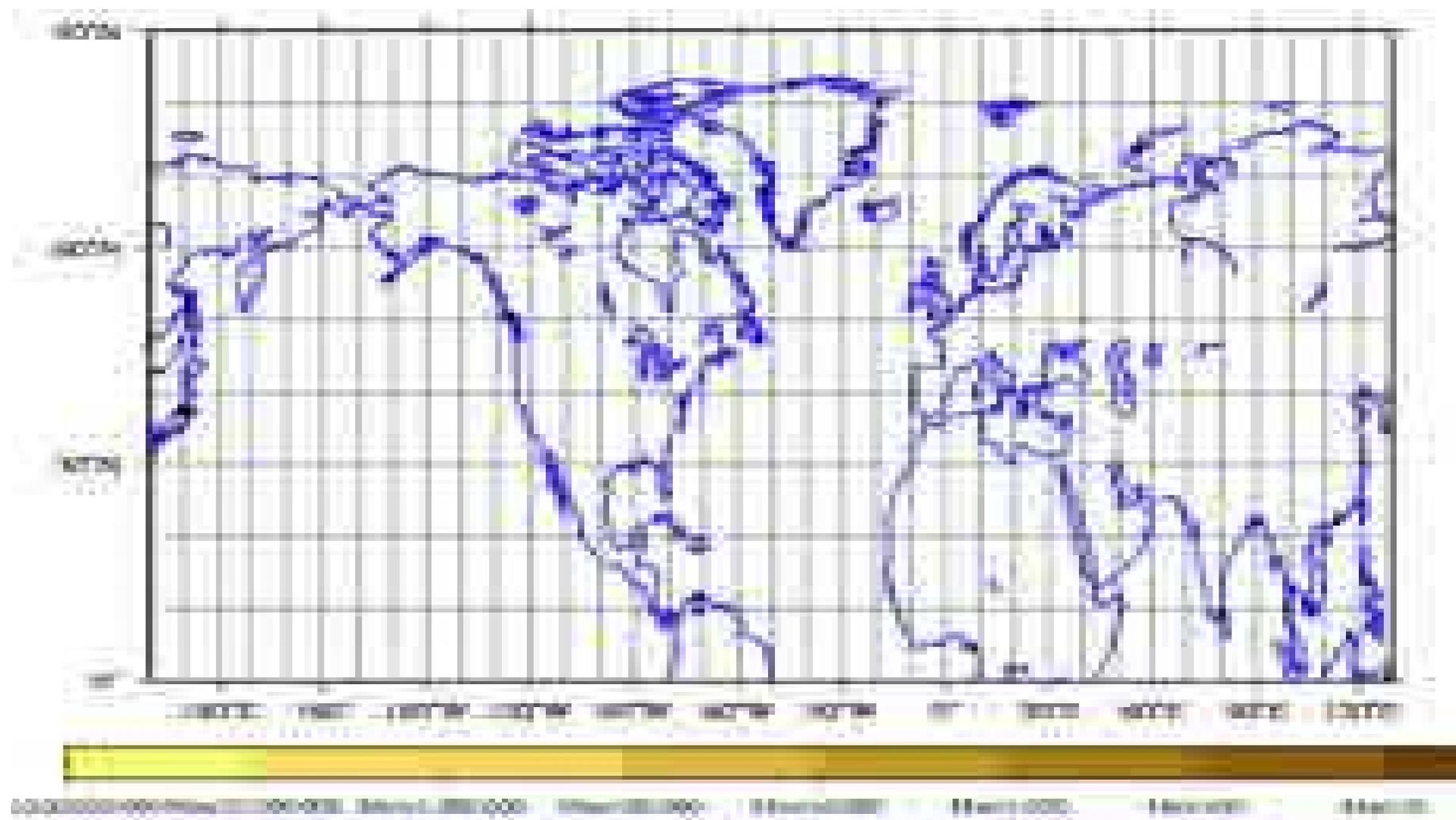
**but carries an unintended connotation of....**

impurity **and** danger!

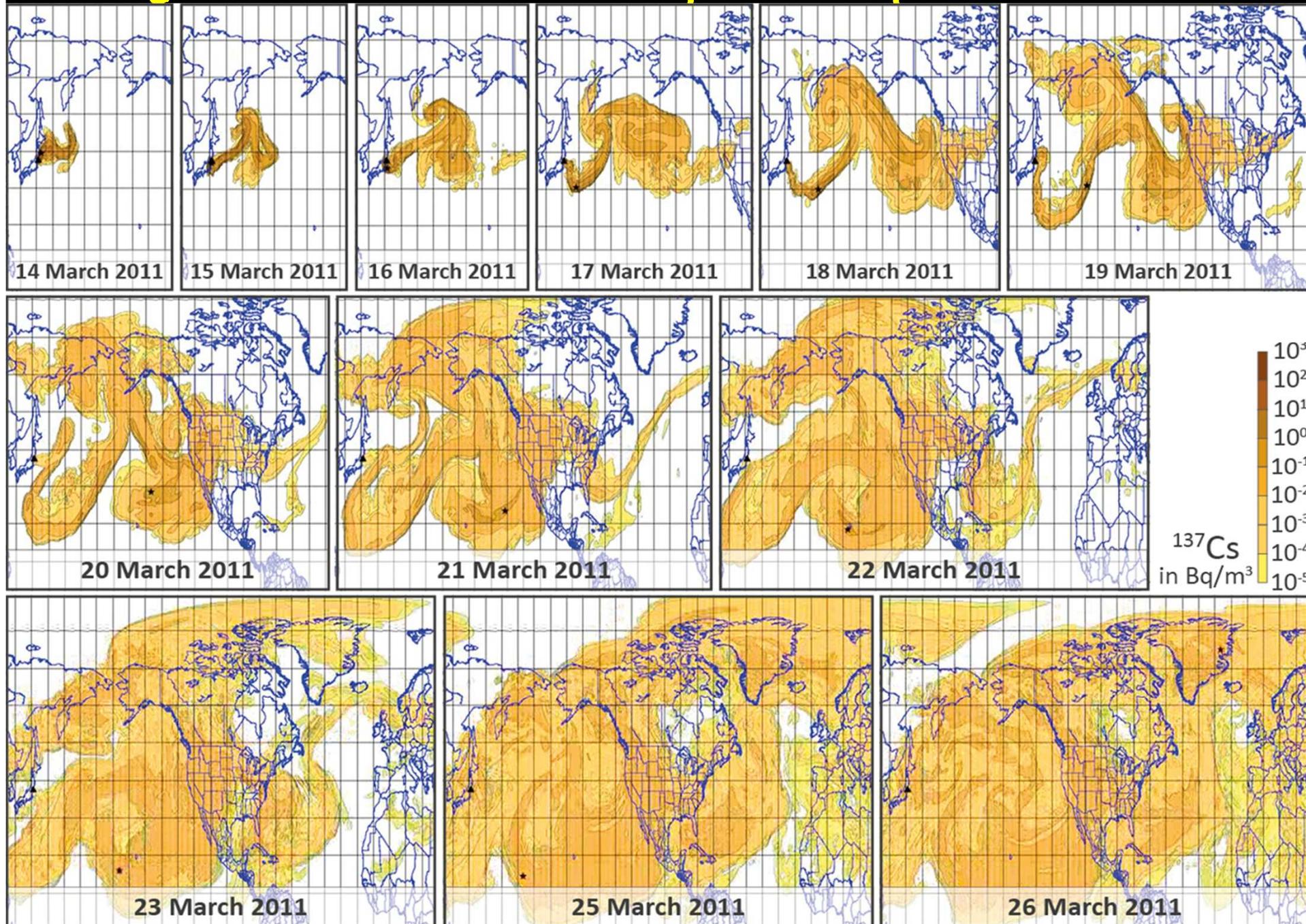
***'Contamination'* of the atmosphere**

# Accidenti di Fuochi d'Incendio (1955-2000) (1)

Comunicazione: maggio 2001 con la società: G&P (G&P) (1)



# A global model of the atmospheric dispersion of $^{137}\text{Cs}$

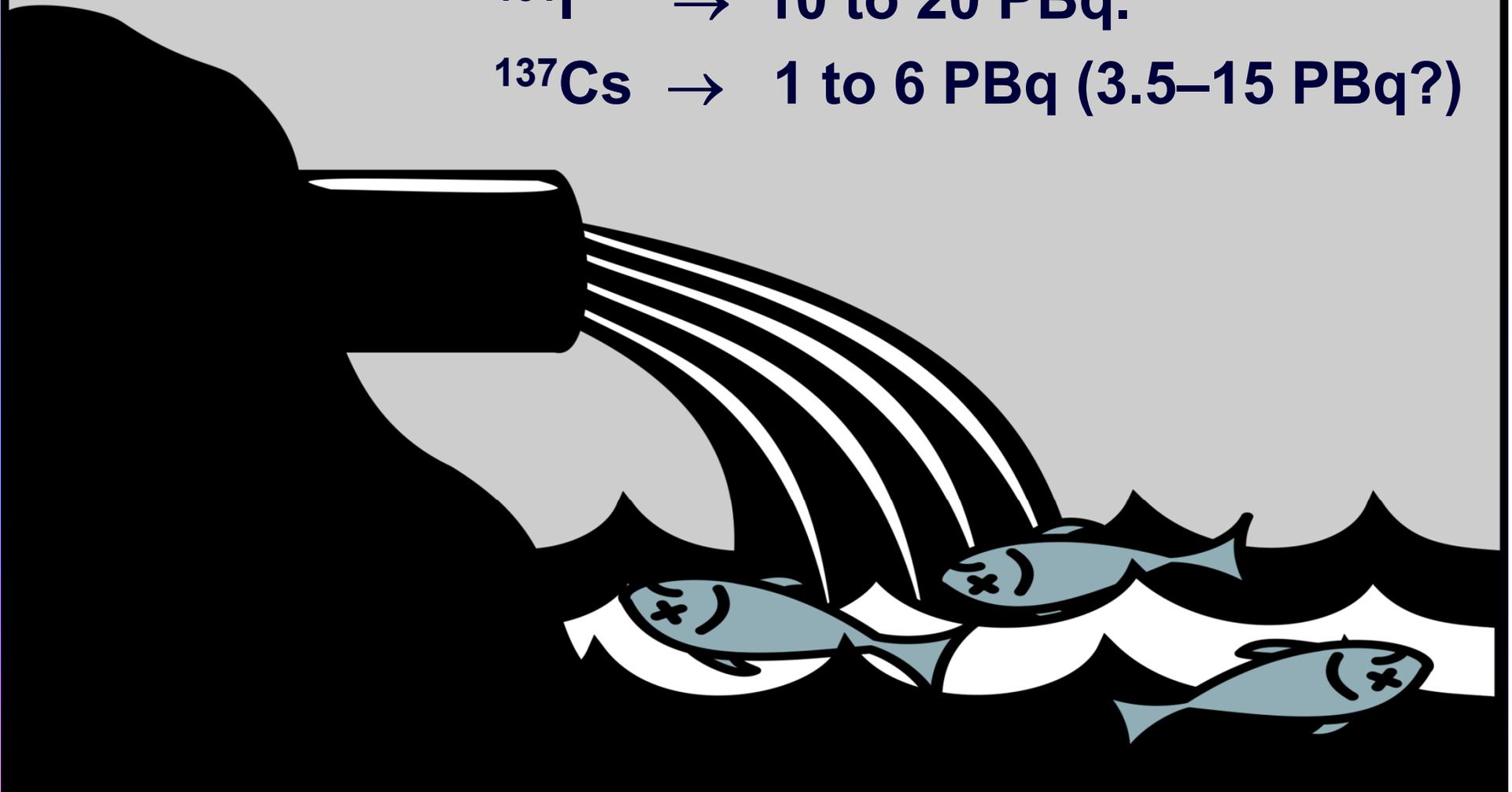


# ***'Contamination'* of the Sea**

# Discharges into the sea at the site

$^{131}\text{I}$  → 10 to 20 PBq.

$^{137}\text{Cs}$  → 1 to 6 PBq (3.5–15 PBq?)

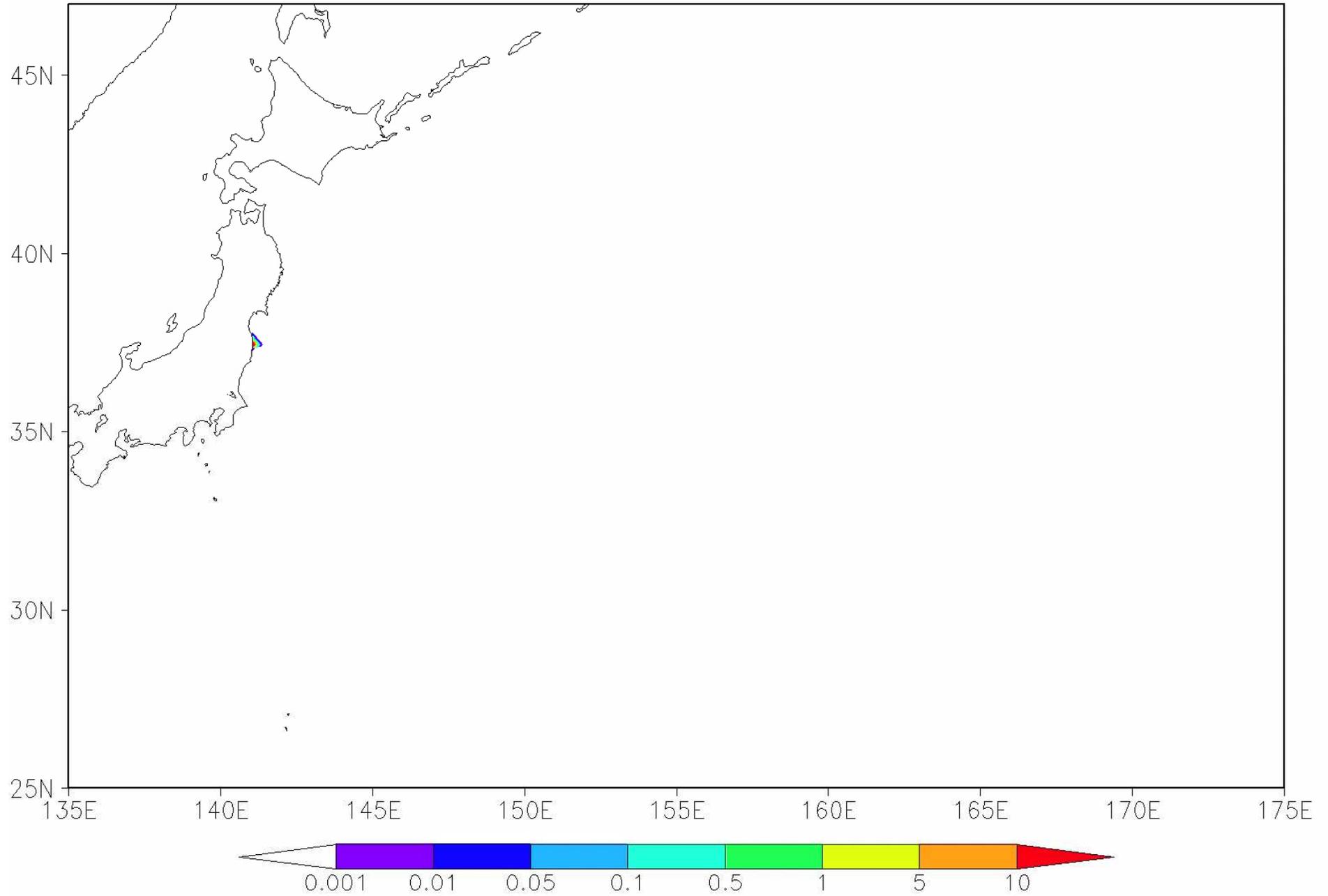


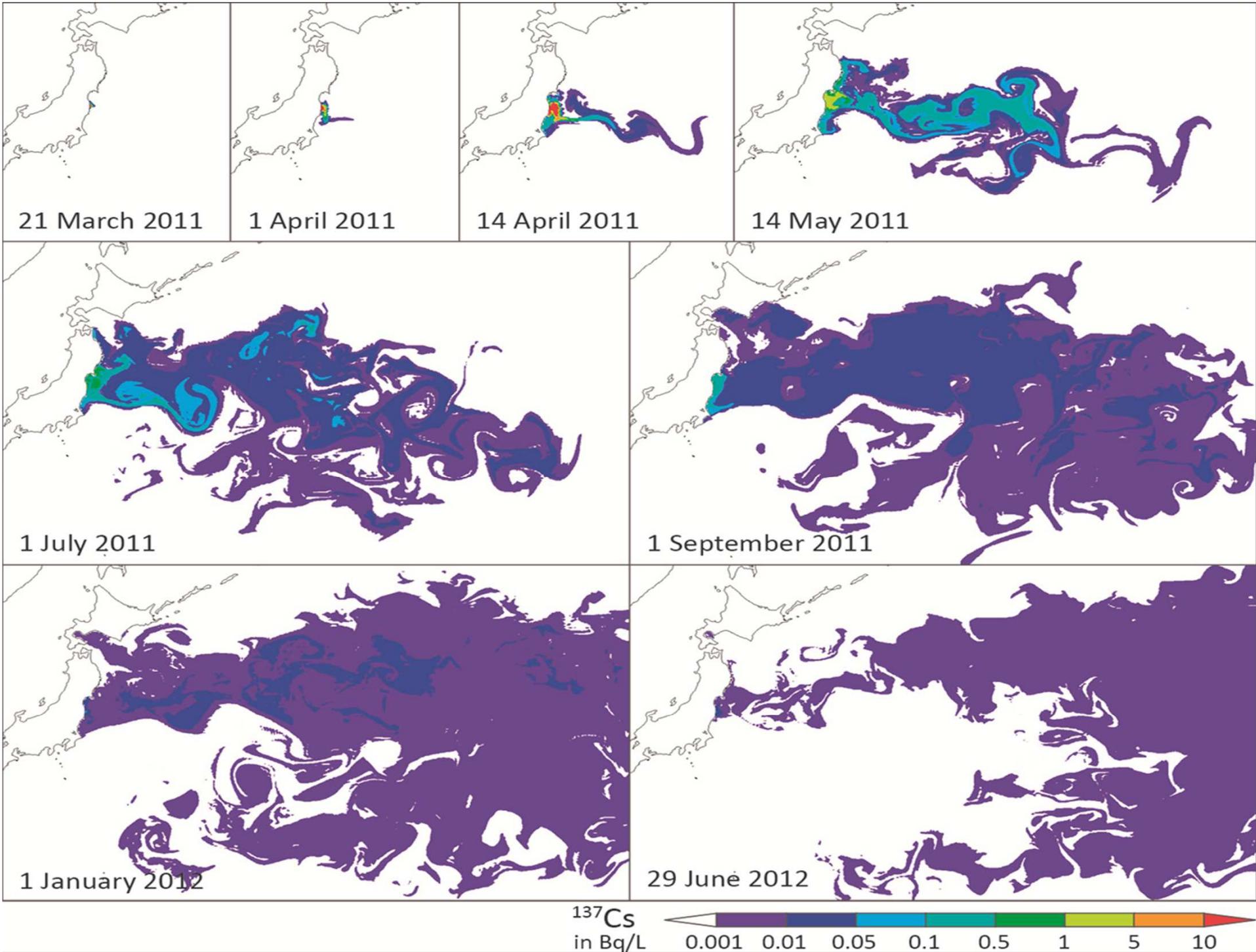
# Oceanic dispersion



- Moved eastward with the *Kuroshio current*.
- Transported over large distances via the *N. Pacific Ocean gyre*.
- Highly diluted in the seawater

# Cs-137 (2011 MAR 21)

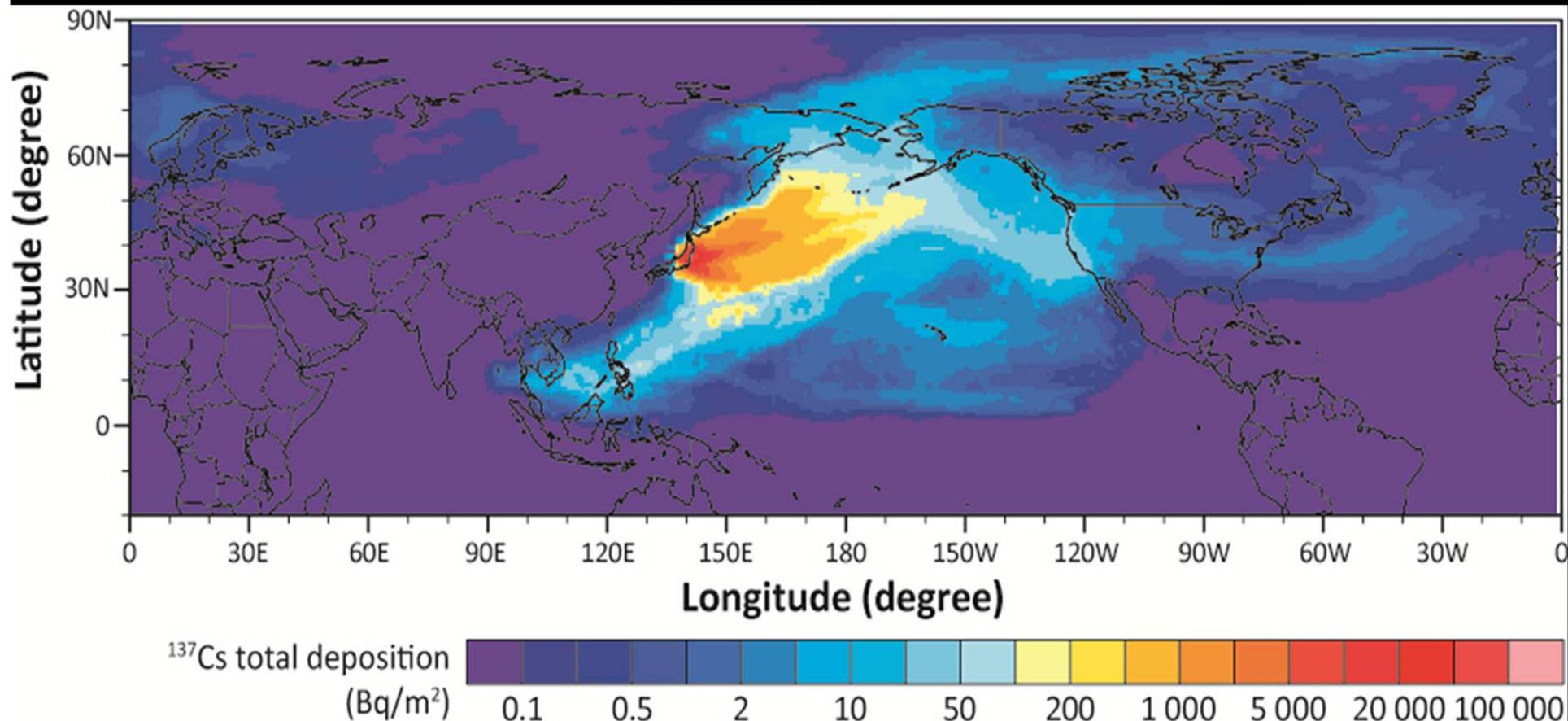




# Deposition

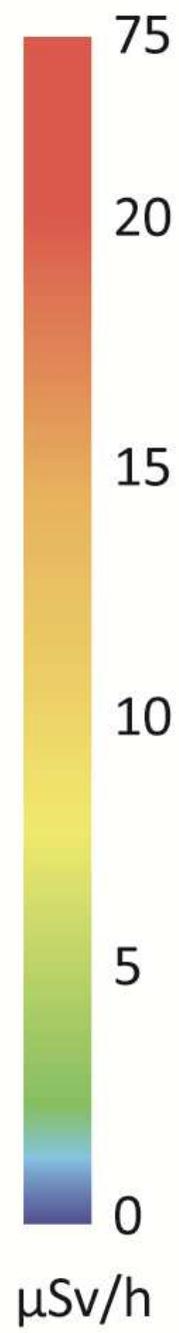
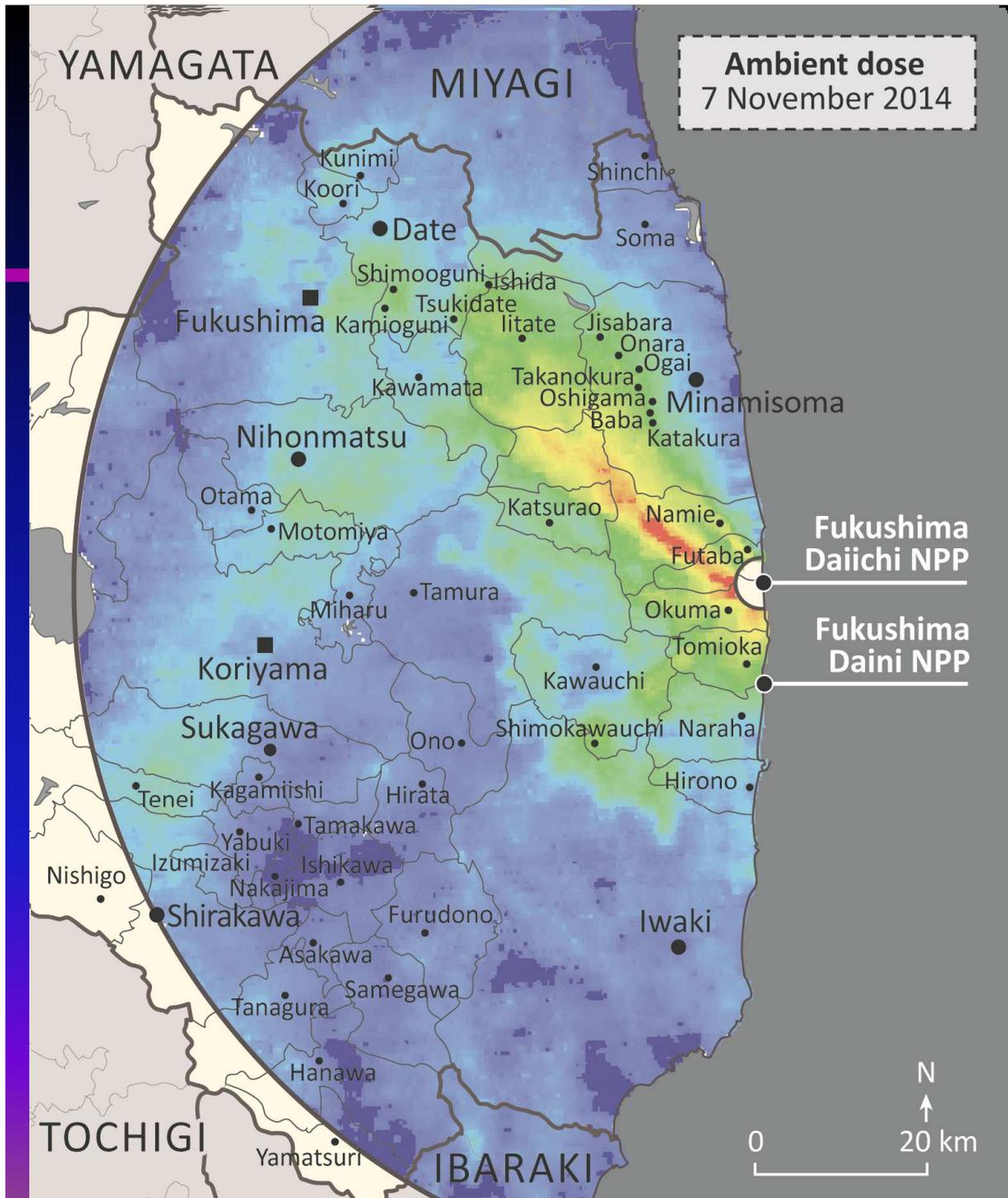
# The oceanic deposition

# Modeling the Oceanic deposition



# The terrestrial deposition

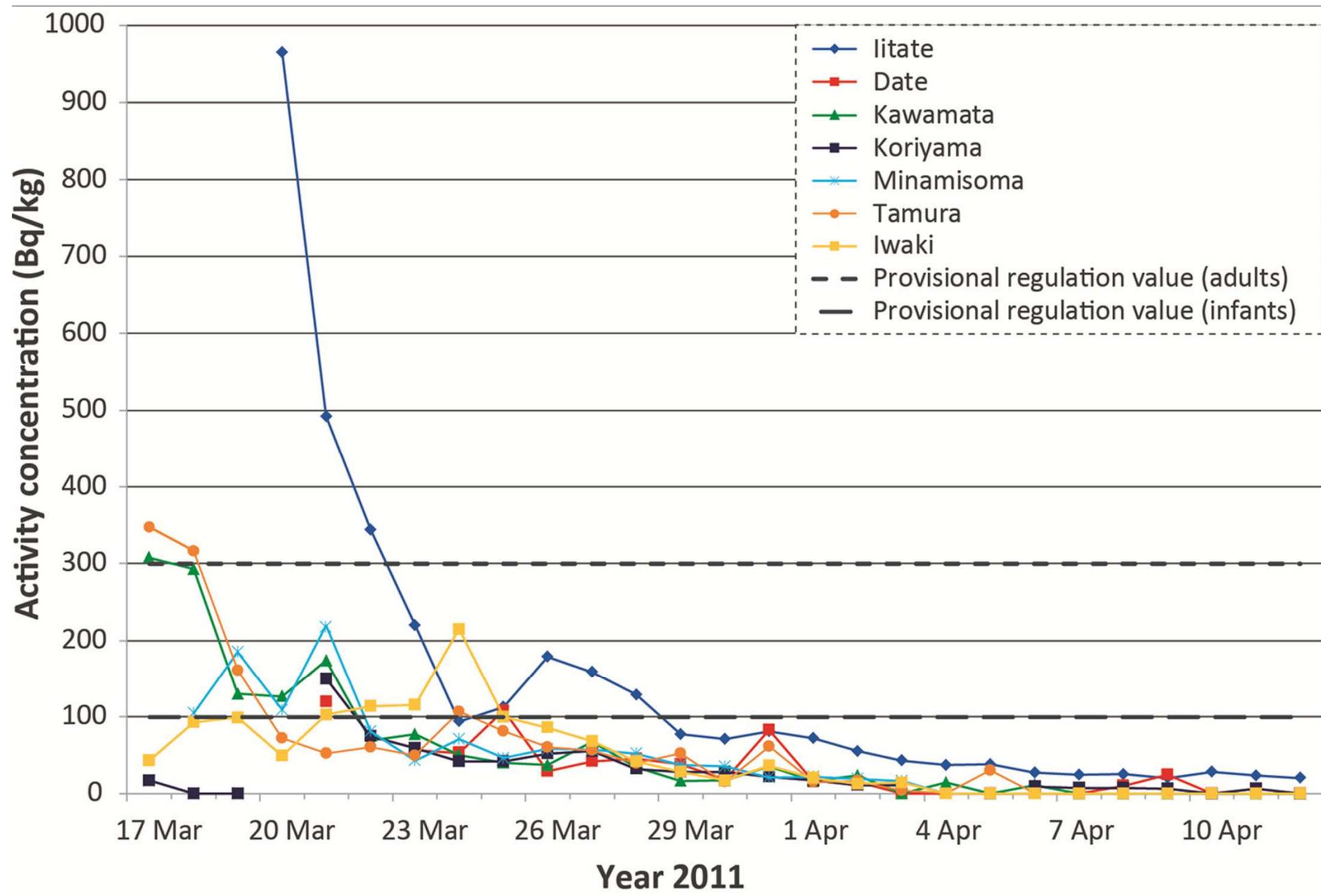
(“*Contamination*” of land)



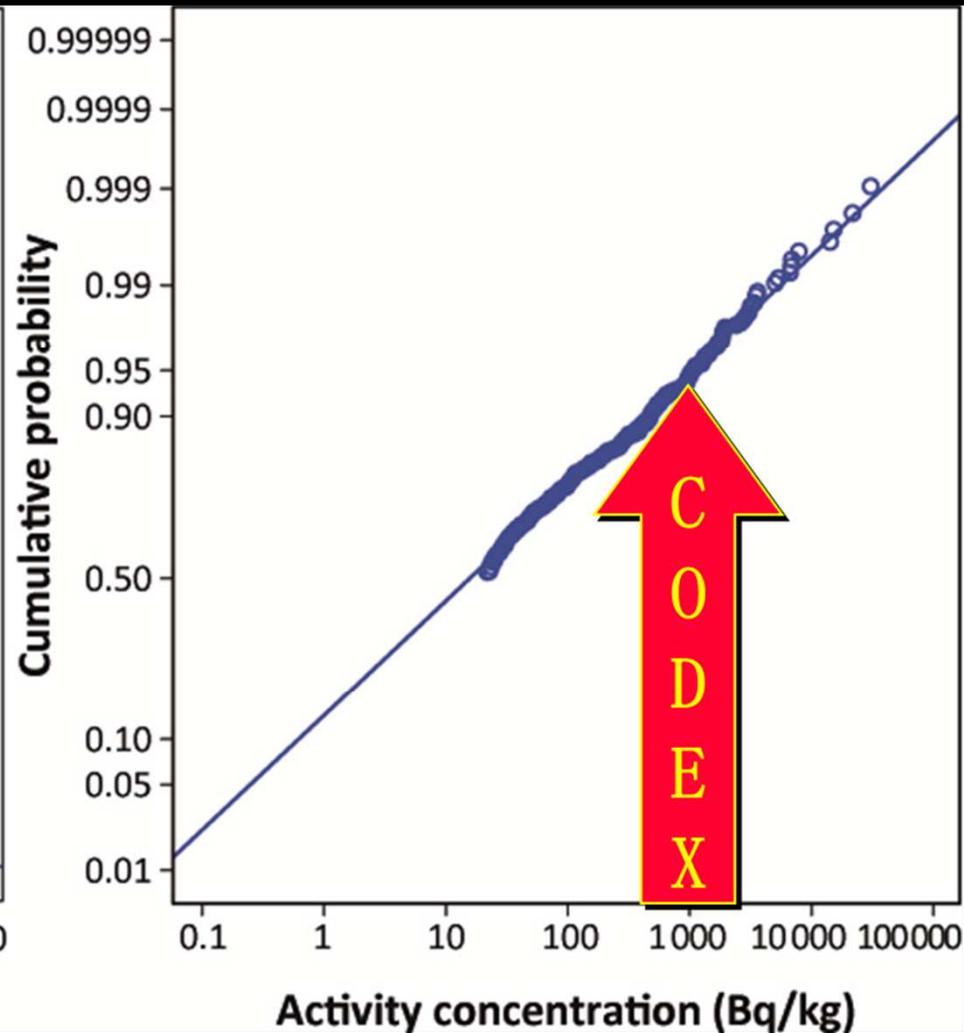
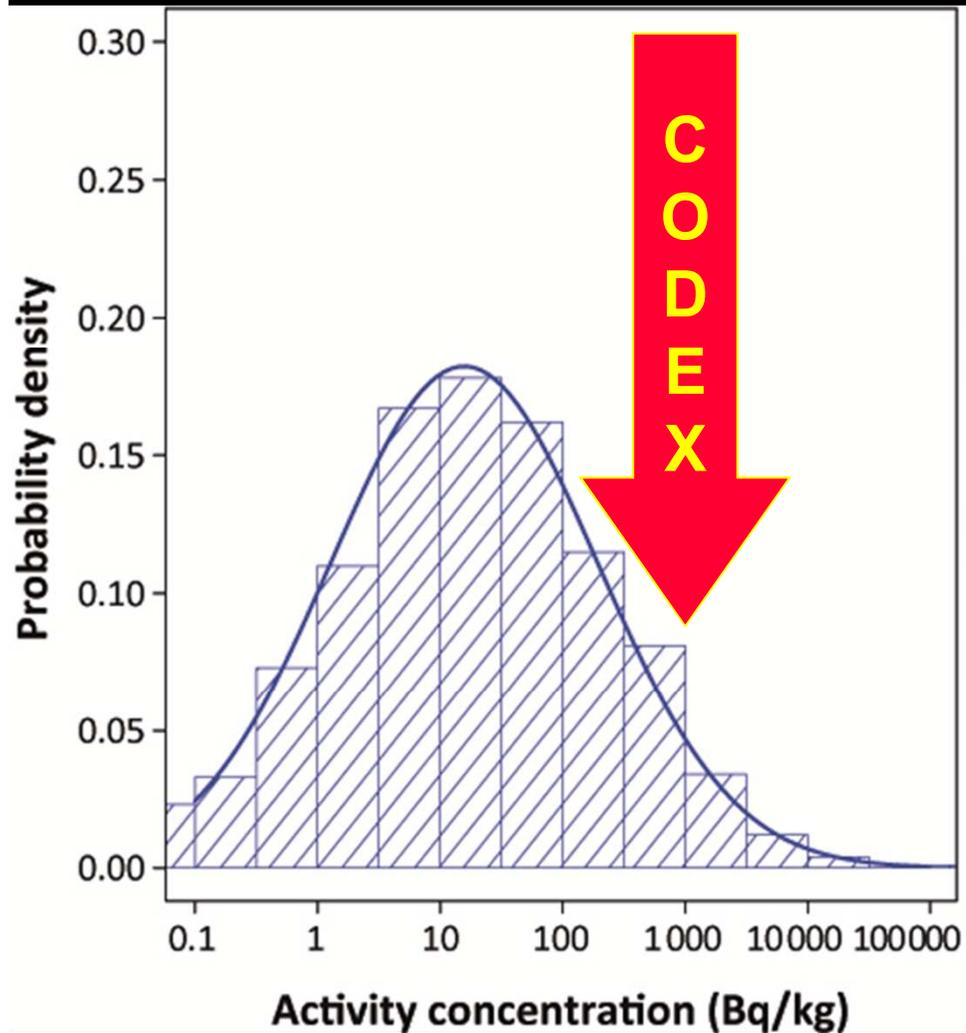
**Global  
Backgr.**



**'Contamination'**  
**of**  
**consumer products**



**Activity concentration of  $^{131}\text{I}$  in drinking water supplies**



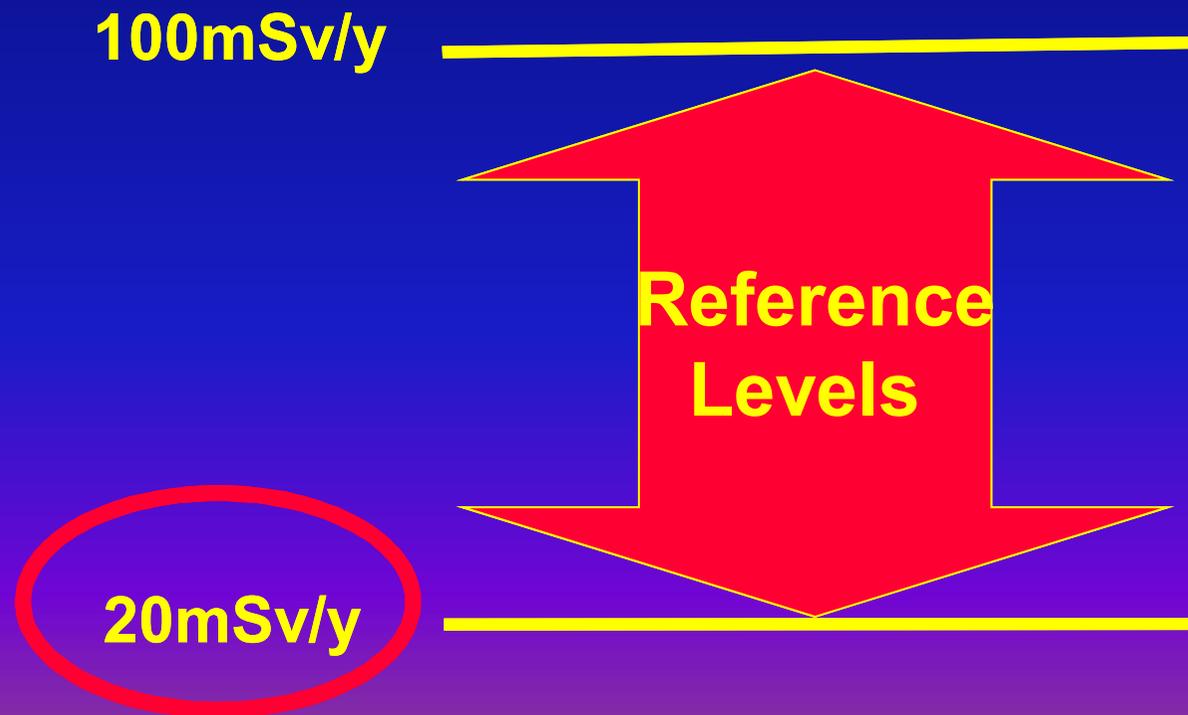
**Lognormal probability distribution of  $^{134+137}\text{Cs}$  in mushrooms**

## **2. Radiation Protection**

**Public**

# Basic policy

- The Japanese authorities applied conservative reference levels of dose recommended by ICRP



Typical question from the public

*Why doses of 20 to 100 mSv/year are allowed after the accident,  
when doses greater than 1 mSv/y were unacceptable before the accident?*

The Japanese expression for the **1mSv/y dose limit**, is unequivocal:

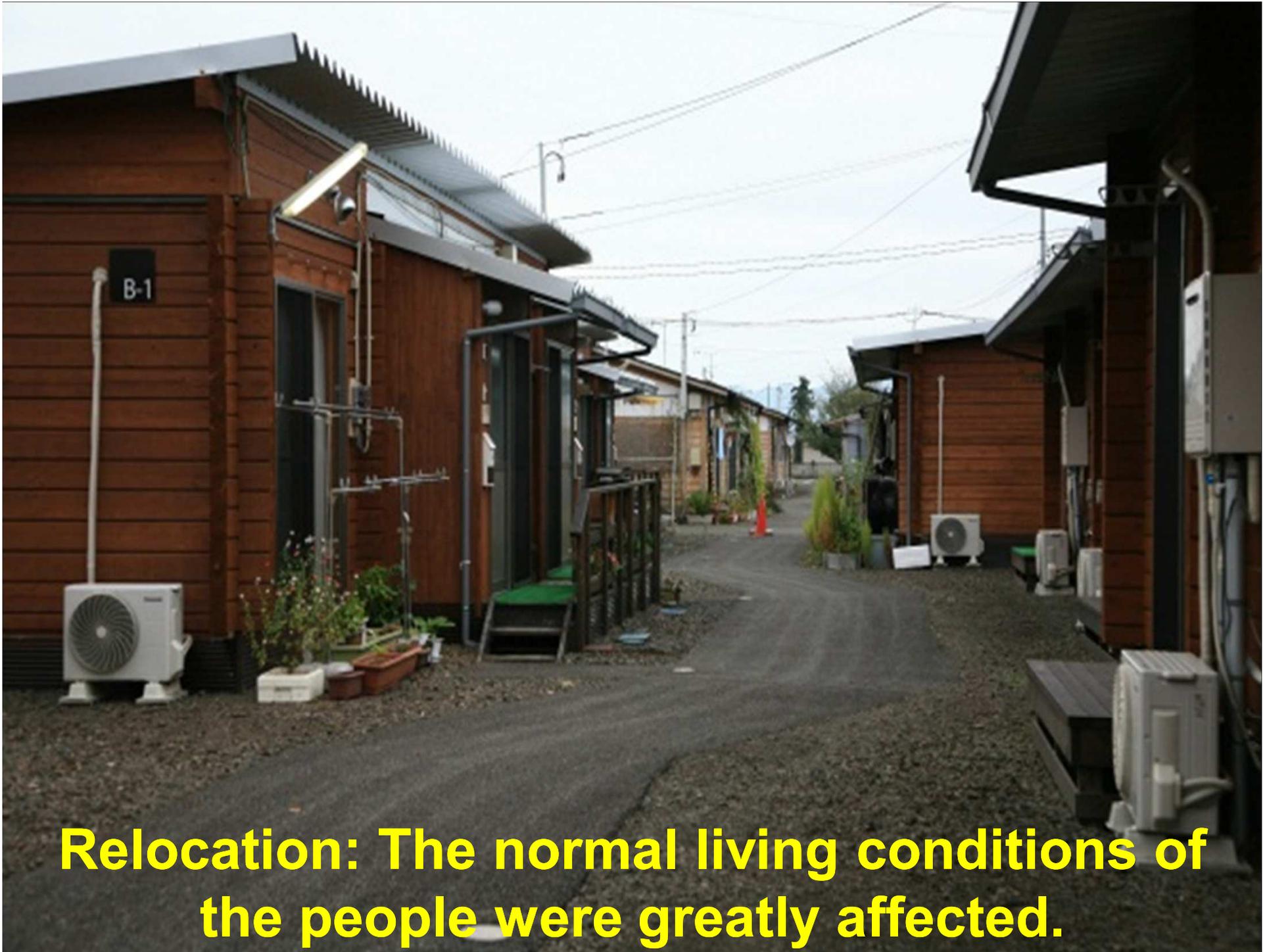
**線量限度**, [線= radiation, 量= amount, 限=border, 度=time]

**'amount of radiation dose that shall not be exceeded in the time'.**

**Impact of measures and  
actions taken to protect the  
public**



**Sheltering: The initial evacuation led to crowded conditions**



**Relocation: The normal living conditions of the people were greatly affected.**

**A relevant issue:**

**Justificability of disruptive  
protective measures**

# Justification of disruptive protection actions



**Good > Bad**

**Workers**

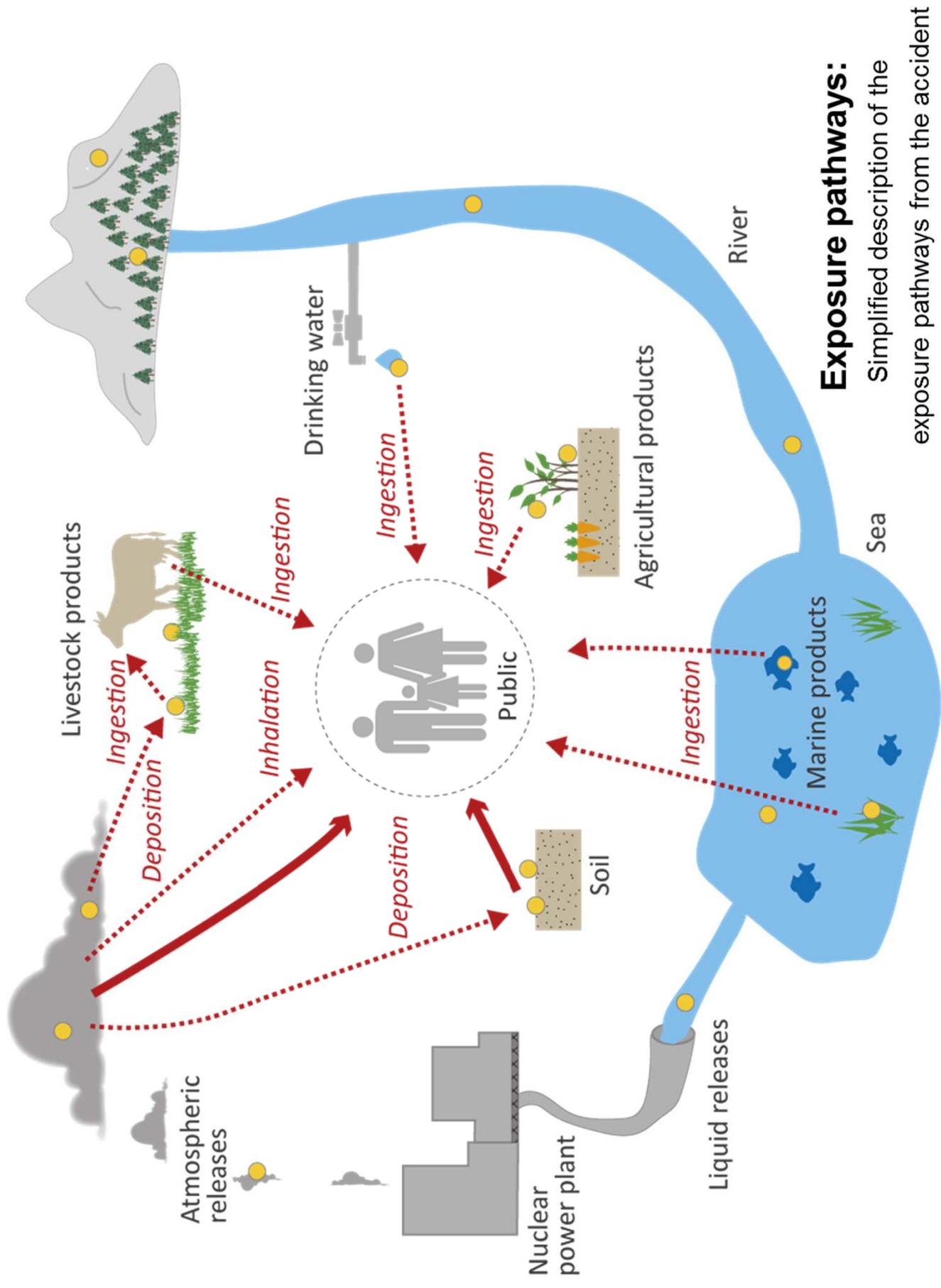
# **Shortcomings in the implementation of occupational protection requirements:**

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- **In the early monitoring and recording of radiation doses of emergency workers.**
- **In the availability and use of protective equipment**
- **In associated training.**

# **3. Radiation Exposure**

**The early assessments of radiation doses  
were based on modeling and  
resulted in some overestimations.**



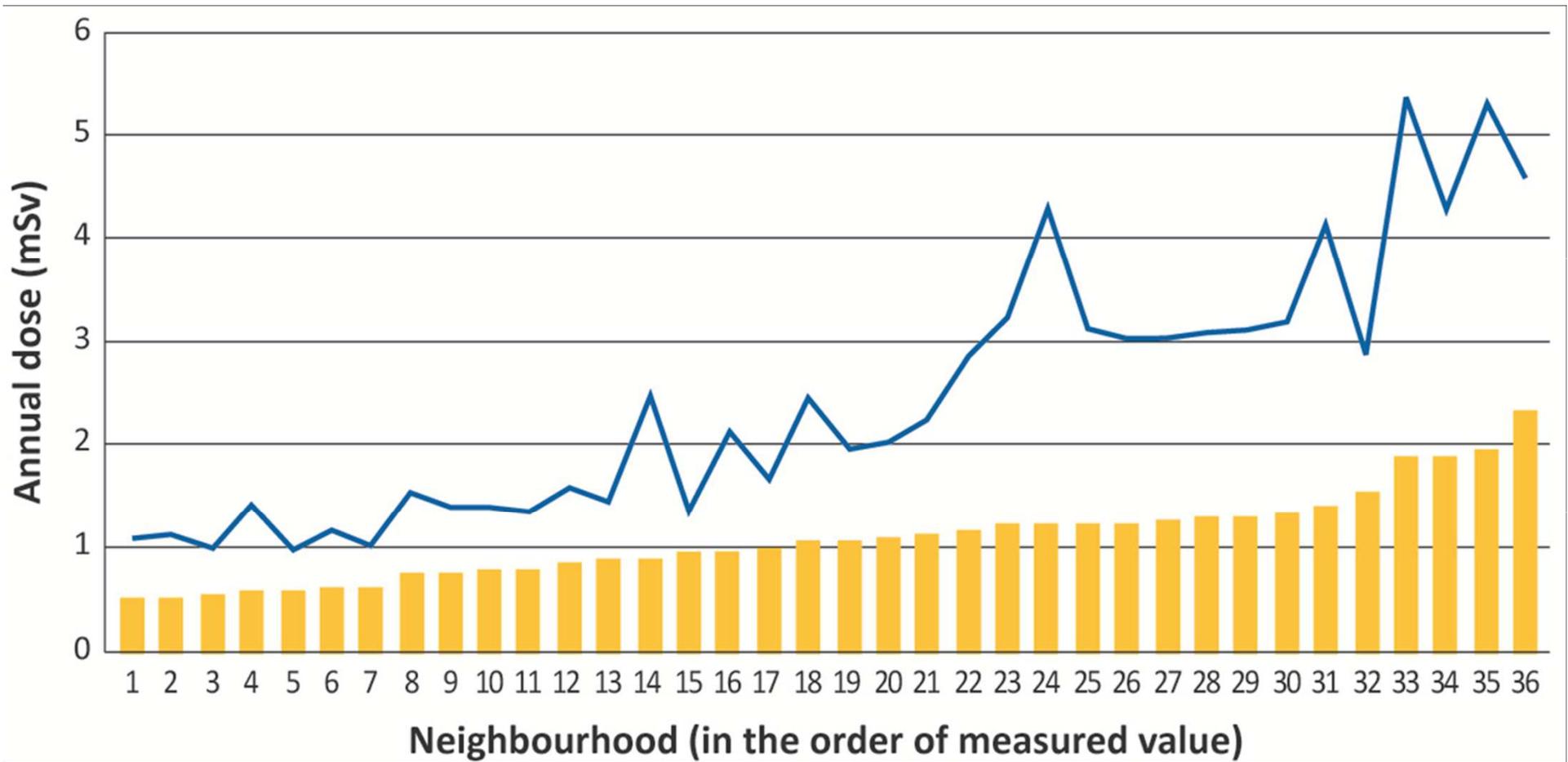
### Exposure pathways:

Simplified description of the

exposure pathways from the accident



**We also used personal monitoring data provided  
by the local authorities in order to assess the  
actual individual doses incurred  
....and their distribution!**



Comparison of external individual doses estimates by modeling (**blue line**) versus personal monitoring measurements (**yellow bars**) for a representative affected city, in various neighborhoods of the city.

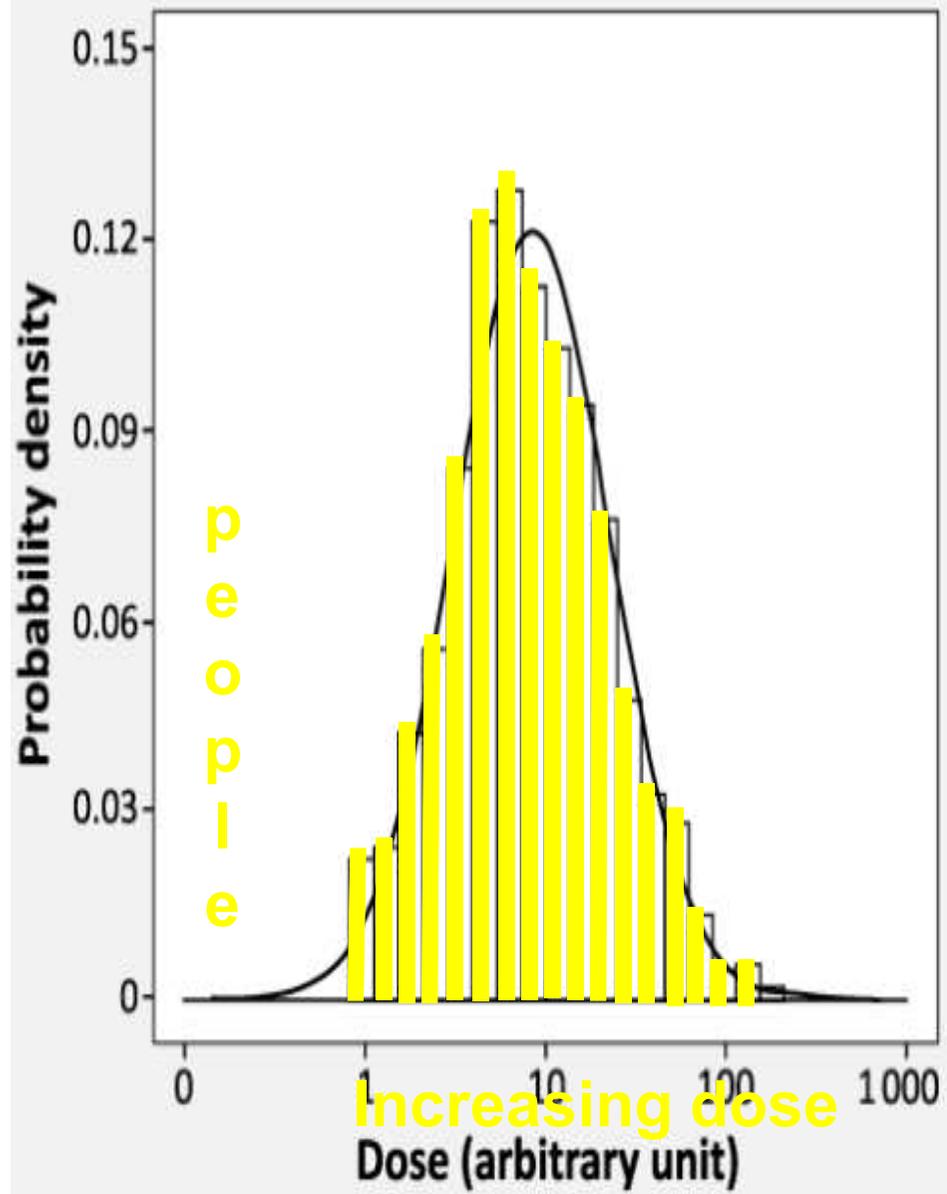
# **Statistical analysis of estimated and measured doses**

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**Deep statistical analysis of the data performed.**

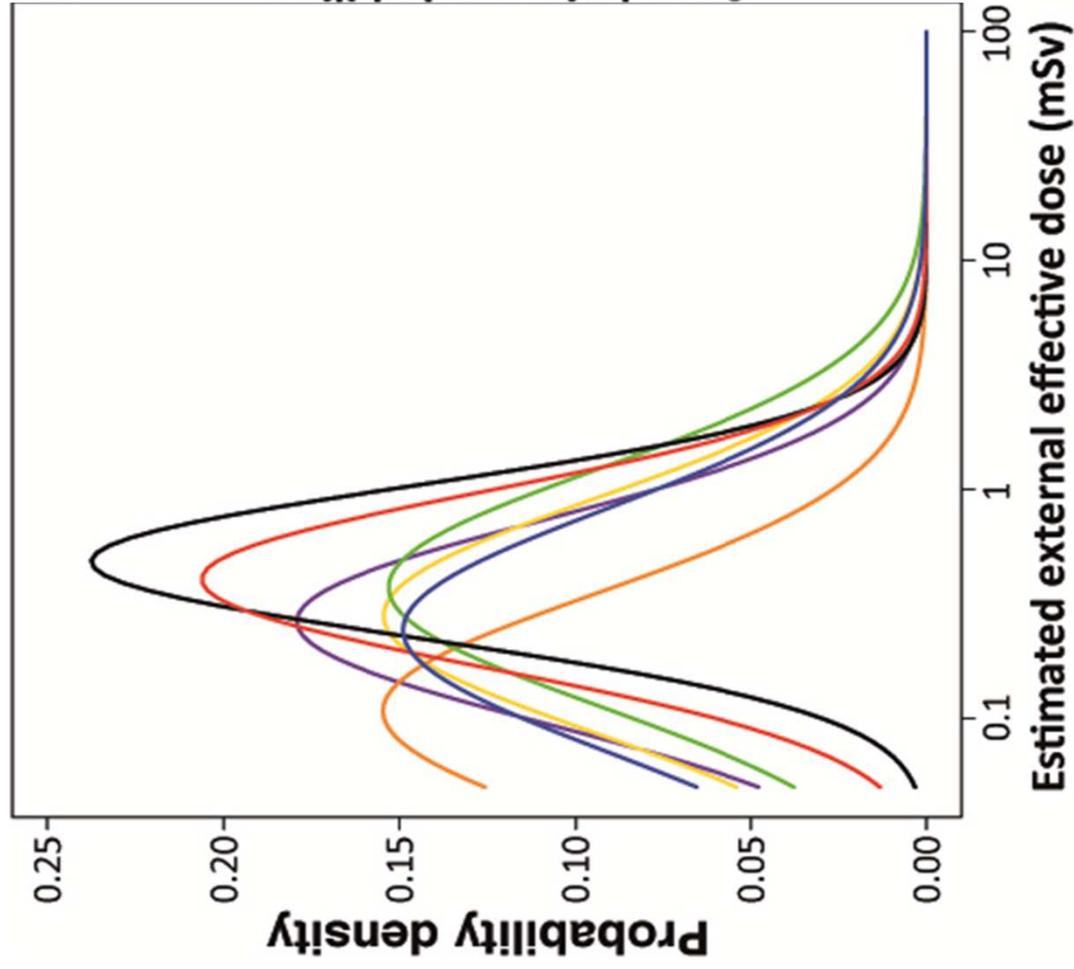
**Purpose:**

**Better understanding of doses and their variations.**

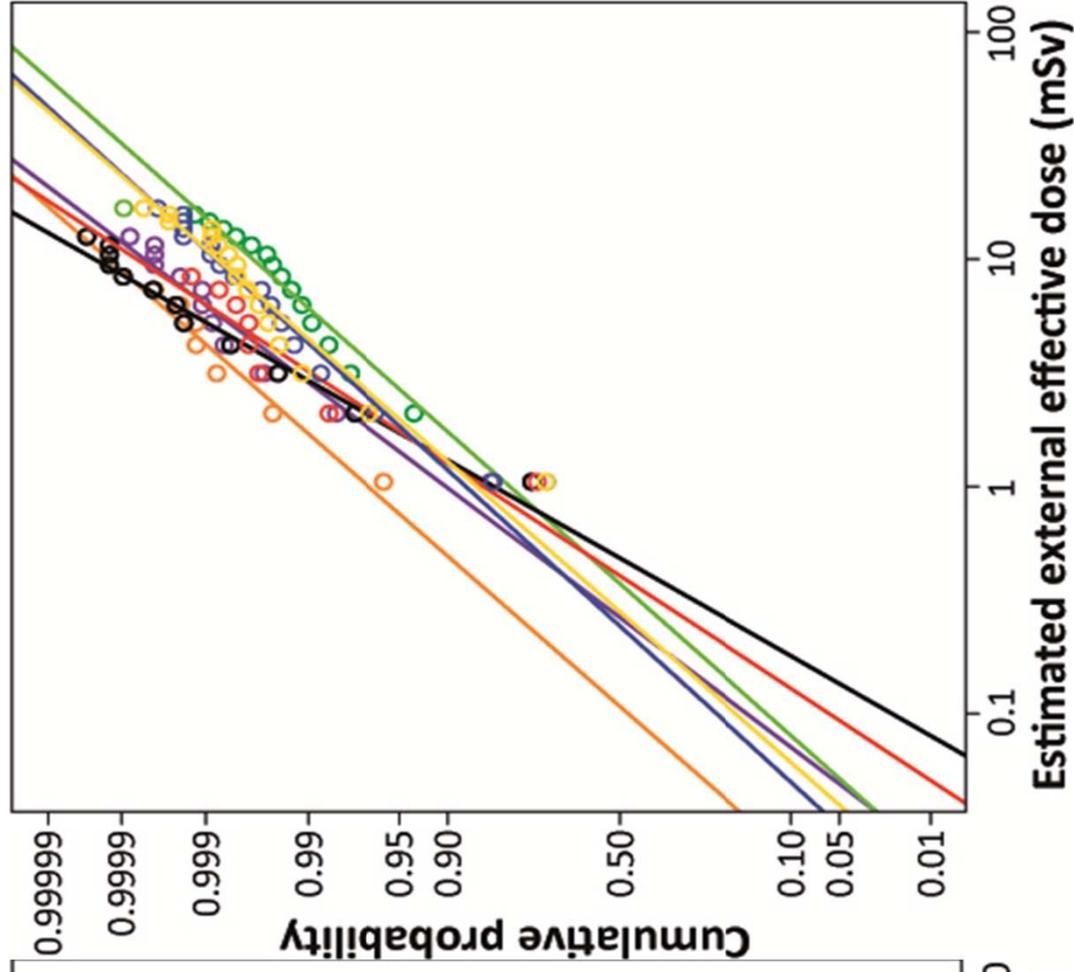


**Doses of members of the public**

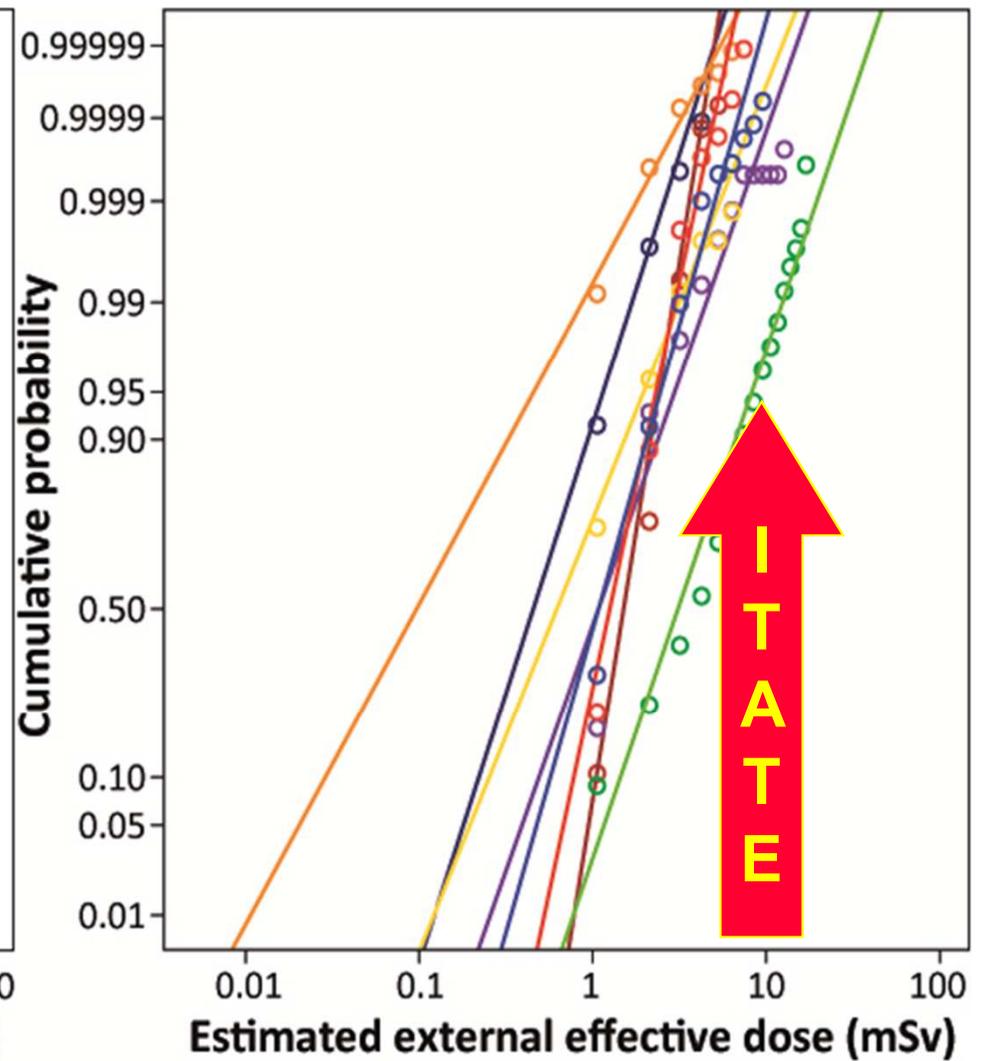
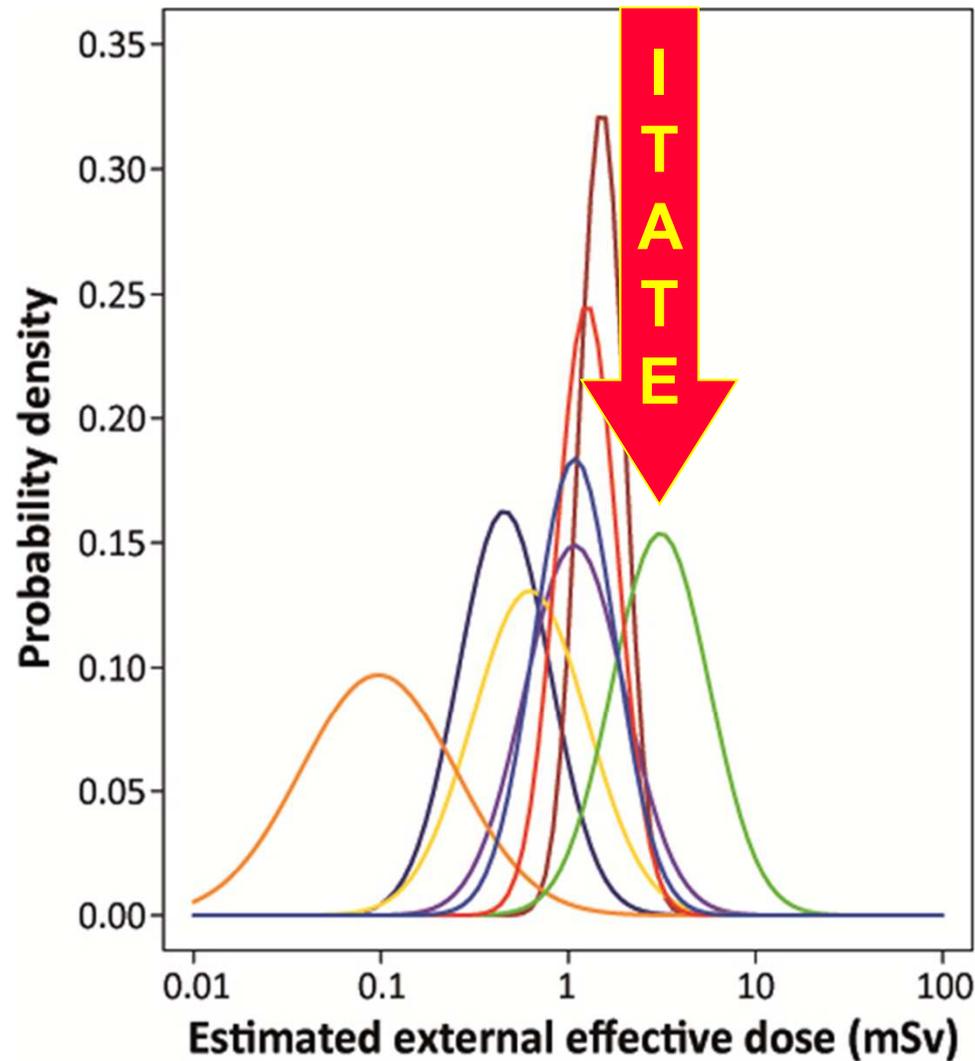
- **Our estimates indicate that the effective doses incurred by members of the public were low.**
- **They are comparable to effective doses incurred due to global levels of natural radiation.**



- Futaba: Mean = 0.24 mSv, range CI 95% = (0.022, 2.7) mSv
- Kawachi: Mean = 0.4 mSv, range CI 95% = (0.07, 2.3) mSv
- Minamisoma: Mean = 0.48 mSv, range CI 95% = (0.11, 2.2) mSv
- Namie: Mean = 0.37 mSv, range CI 95% = (0.035, 3.9) mSv

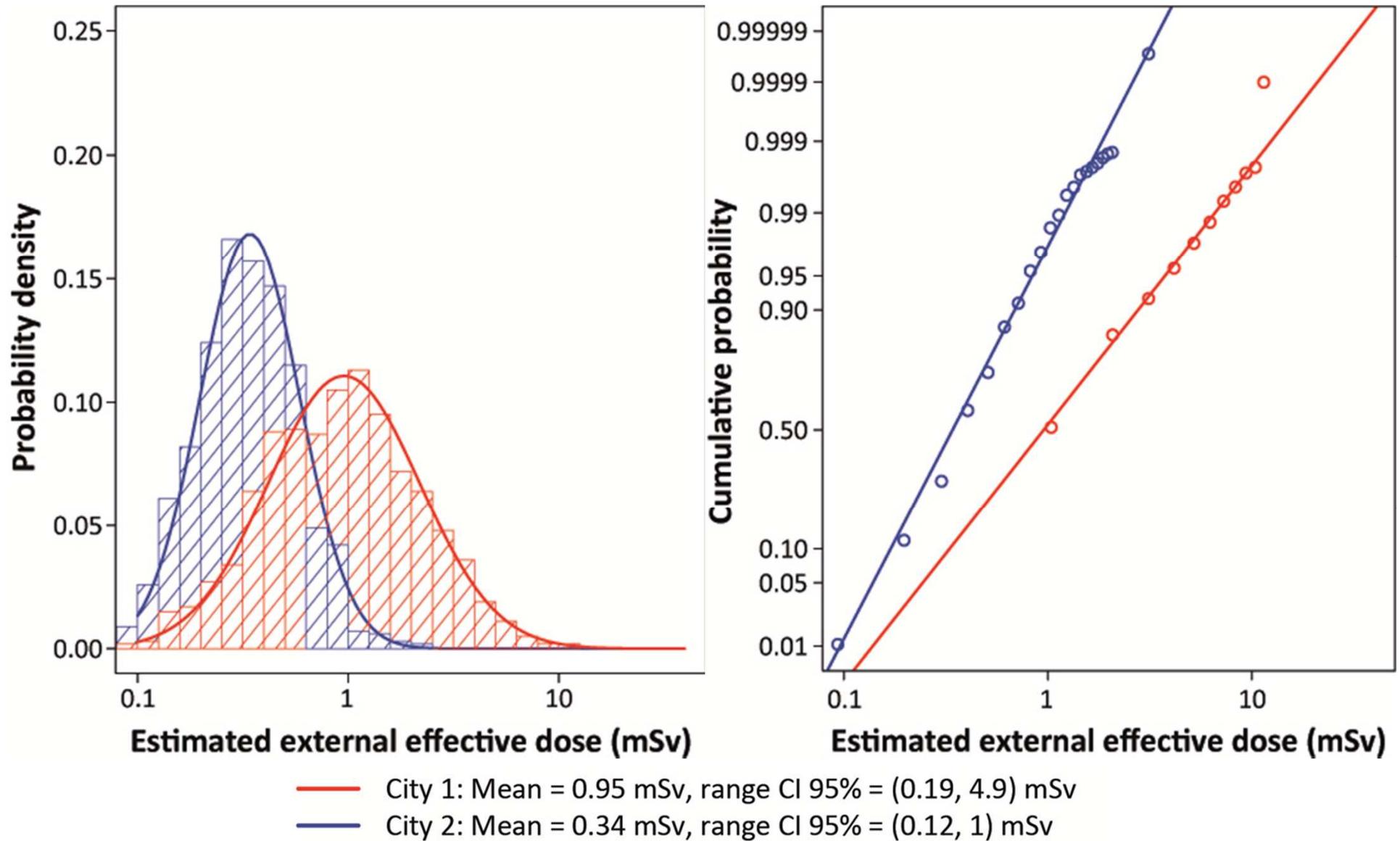


- Naraha: Mean = 0.11 mSv, range CI 95% = (0.01, 1.1) mSv
- Okuma: Mean = 0.28 mSv, range CI 95% = (0.027, 2.9) mSv
- Tomioka: Mean = 0.26 mSv, range CI 95% = (0.036, 2) mSv



- Date: Mean = 1.1 mSv, range CI 95% = (0.41, 2.9) mSv
- Fukushima: Mean = 1.3 mSv, range CI 95% = (0.6, 2.6) mSv
- litate: Mean = 3.1 mSv, range CI 95% = (0.96, 10) mSv
- Iwaki: Mean = 0.097 mSv, range CI 95% = (0.015, 0.62) mSv

- Katsurao: Mean = 0.62 mSv, range CI 95% = (0.16, 2.5) mSv
- Kawamata: Mean = 1.1 mSv, range CI 95% = (0.32, 3.6) mSv
- Nihonmatsu: Mean = 1.5 mSv, range CI 95% = (0.87, 2.6) mSv
- Tamura: Mean = 0.46 mSv, range CI 95% = (0.15, 1.4) mSv

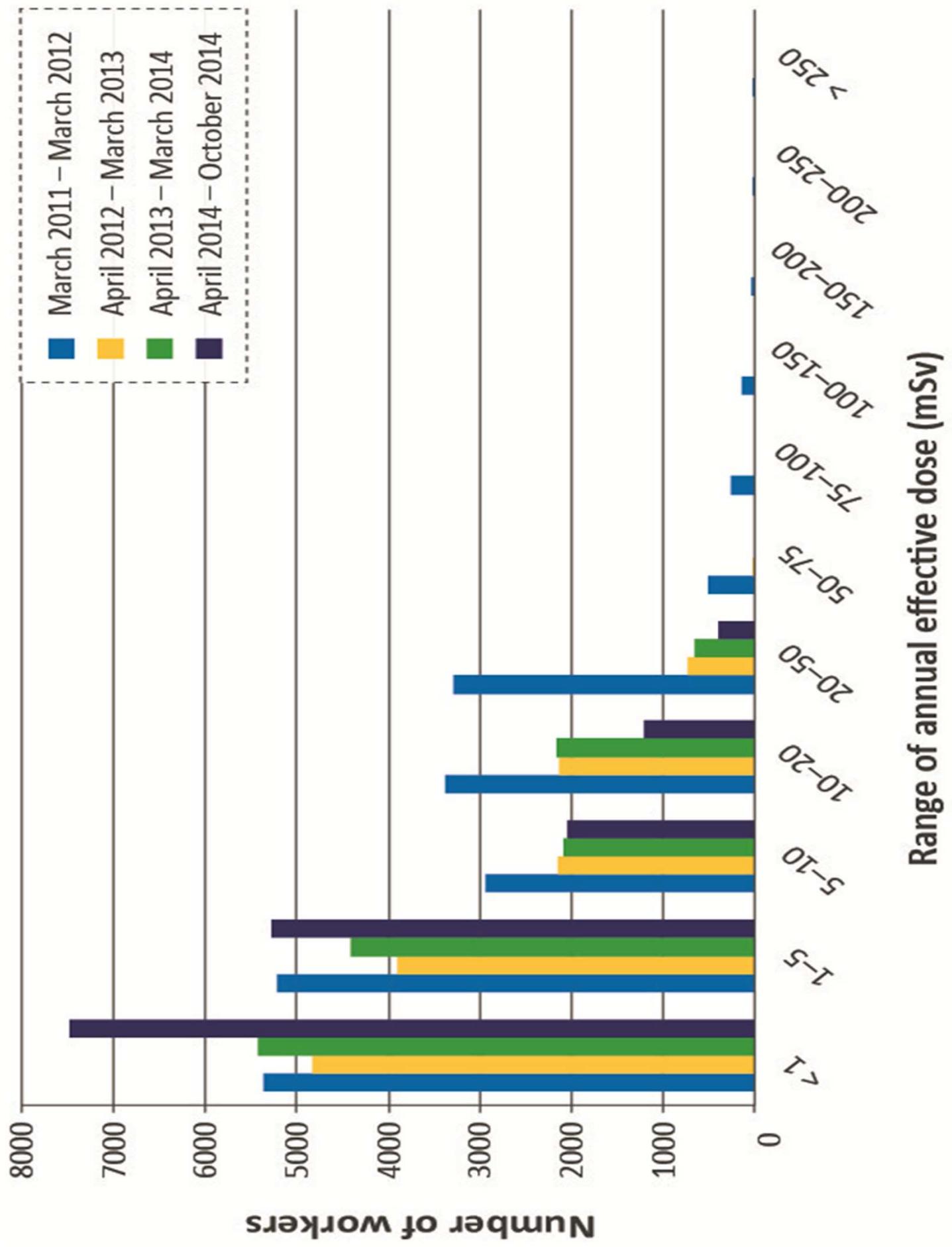


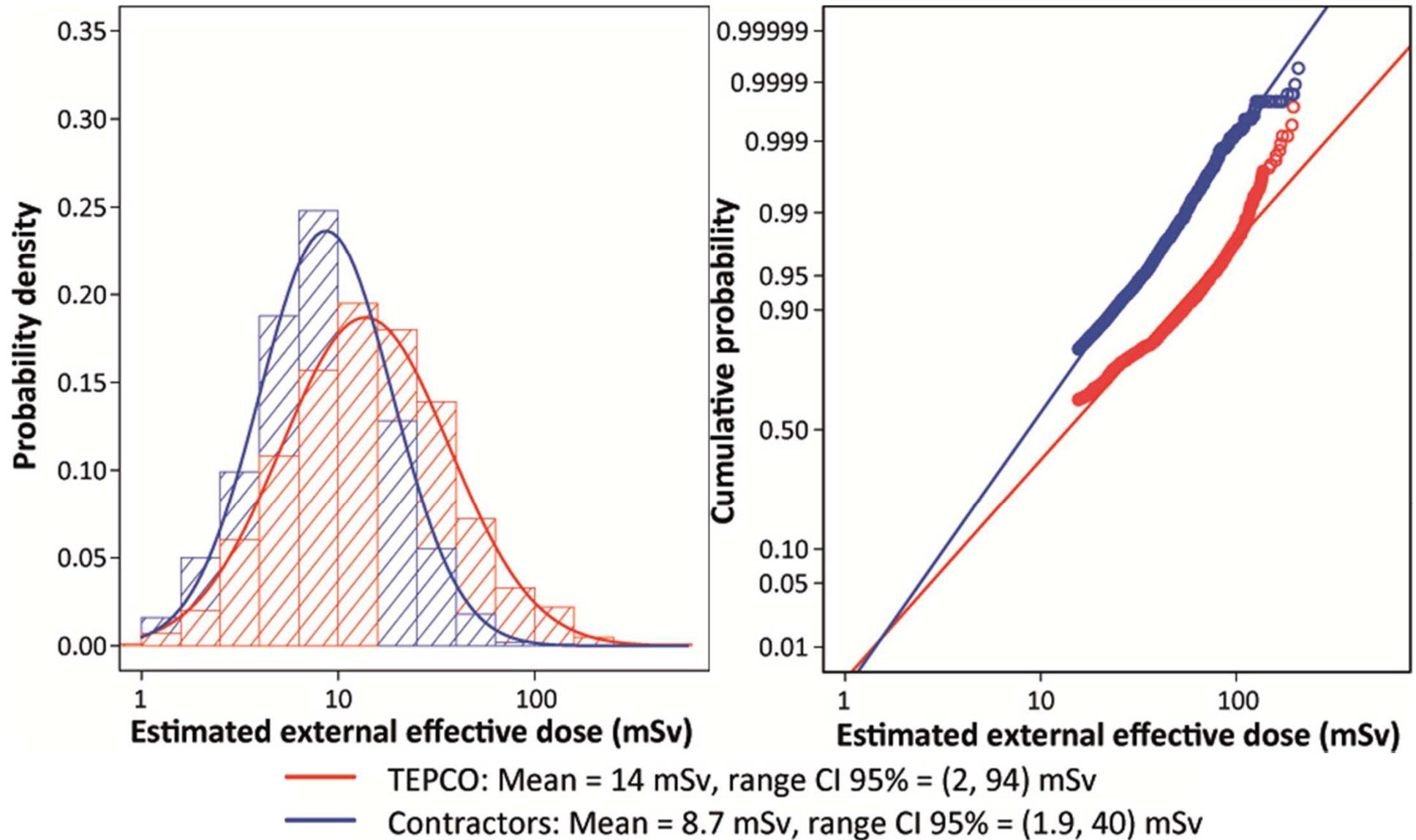
**Probability distribution of monitored personal dose equivalents of members of the public for two cities in the affected area.**

**The personal dose equivalent are low: averages below 1 mSv per year, providing 95% confidence that individuals sustained doses below 5 mSv.**

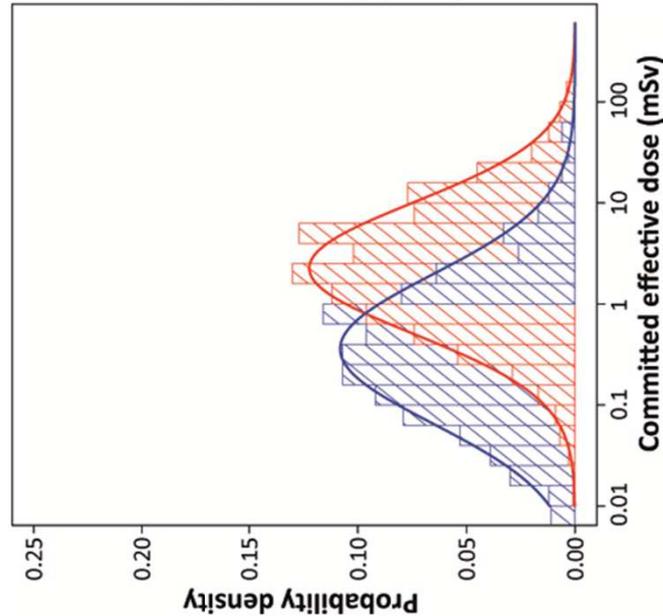
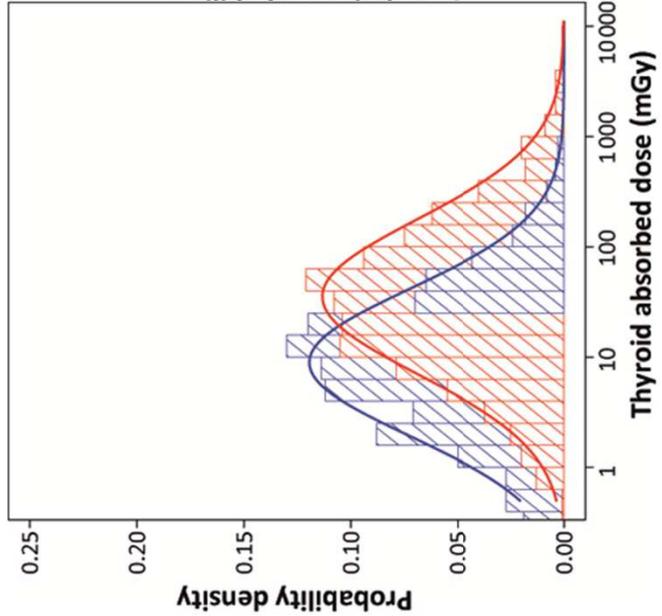
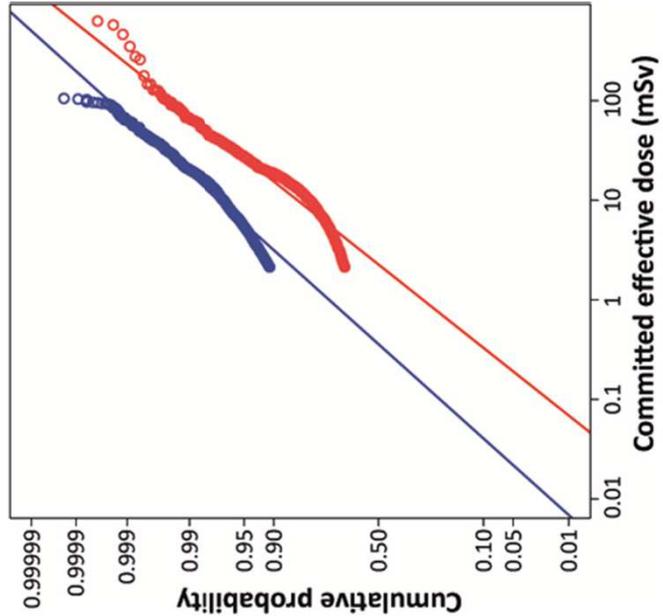
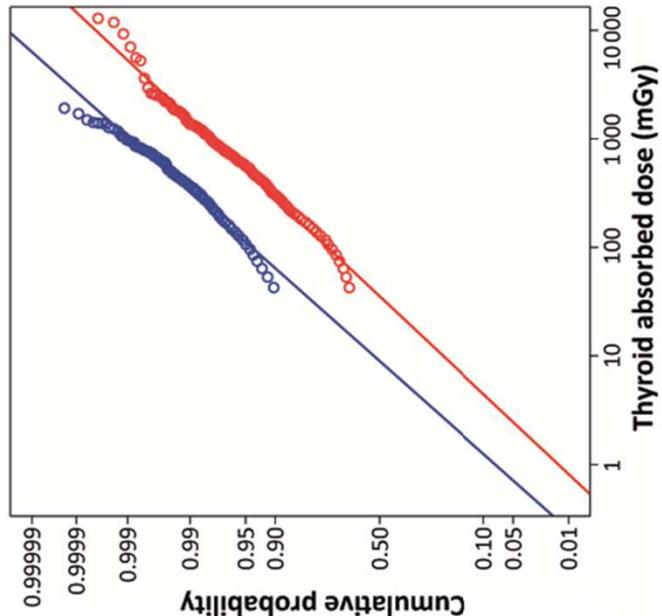
# Occupational Doses

- Effective doses of most of the **>23 000 emergency workers < occupational limits.**
- **174** exceeded the original criterion for emergency workers
- **6** exceeded the temporarily revised criterion





**Distribution of personal dose equivalent monitored for workers from TEPCO and contractors for 2011.**



## **4. Radiation Health Effects**

**No radiation-related deaths or acute diseases have been observed among the workers and general public exposed to radiation from the accident!**

- **At this time, it is not possible to discount the potential occurrence of late effects.**
- **However, given the low levels of doses reported:...**

**....“no discernible increased incidence of radiation-related late health effects are expected among exposed members of the public and their descendants”**



**United Nations**

# **Report of the United Nations Scientific Committee on the Effects of Atomic Radiation**

**Fifty-ninth session  
(21-25 May 2012)**

**ATTRIBUTING HEALTH EFFECTS TO IONIZING  
RADIATION EXPOSURE AND INFERRING RISKS**

# Pregnancy

**Should I  
terminate my  
pregnancy?**



**There are not unwanted terminations of pregnancy  
attributable to the radiological situation**

# Prenatal effects

**Prenatal radiation effects** have not been observed and are not expected to occur



**The reported doses are well below the threshold at which prenatal radiation effects may take place**

# Hereditary effects

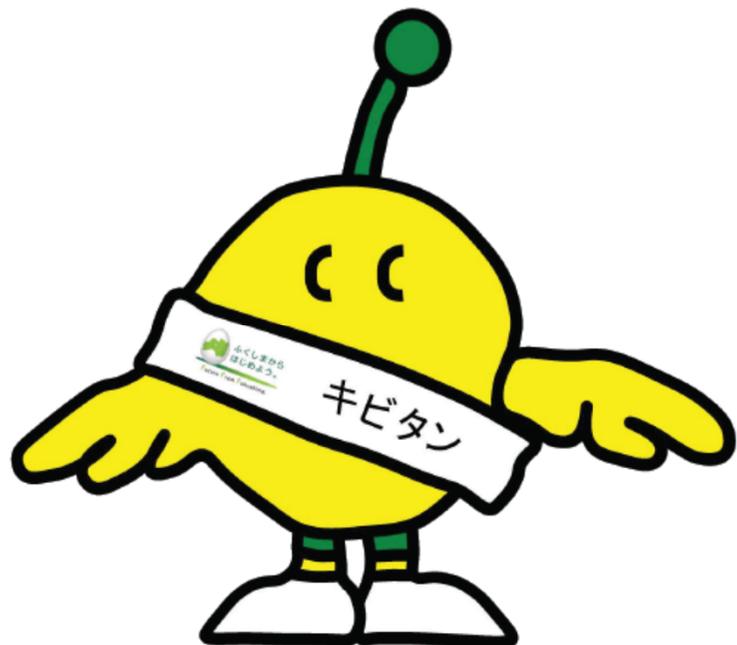
## **UNSCEAR dictum:**

**“although demonstrated in animal studies, an increase in the incidence of hereditary effects in human populations cannot at present be attributed to radiation exposure”.**

# The Thyroid Issue

## Particular concern:

- Intake of  $^{131}\text{I}$  by children.
- Subsequent doses to pediatric thyroid glands
- Potential occurrence of thyroid cancers.



**Fukushima  
Prefecture**

**+**



**Fukushima  
Medical University**

# The Fukushima Health Management Survey

- Implemented **to monitor the health** of the affected population of Fukushima Prefecture.
- Aimed at the **early detection of diseases**, as well as prevention of lifestyle related diseases.

# Thyroid

and the

## Fukushima Health Management Survey

- Intensive screening of children's thyroid glands
- Using highly sensitive equipment.
- Detected asymptomatic thyroid abnormalities among a significant number of surveyed children (which would not have been detectable).

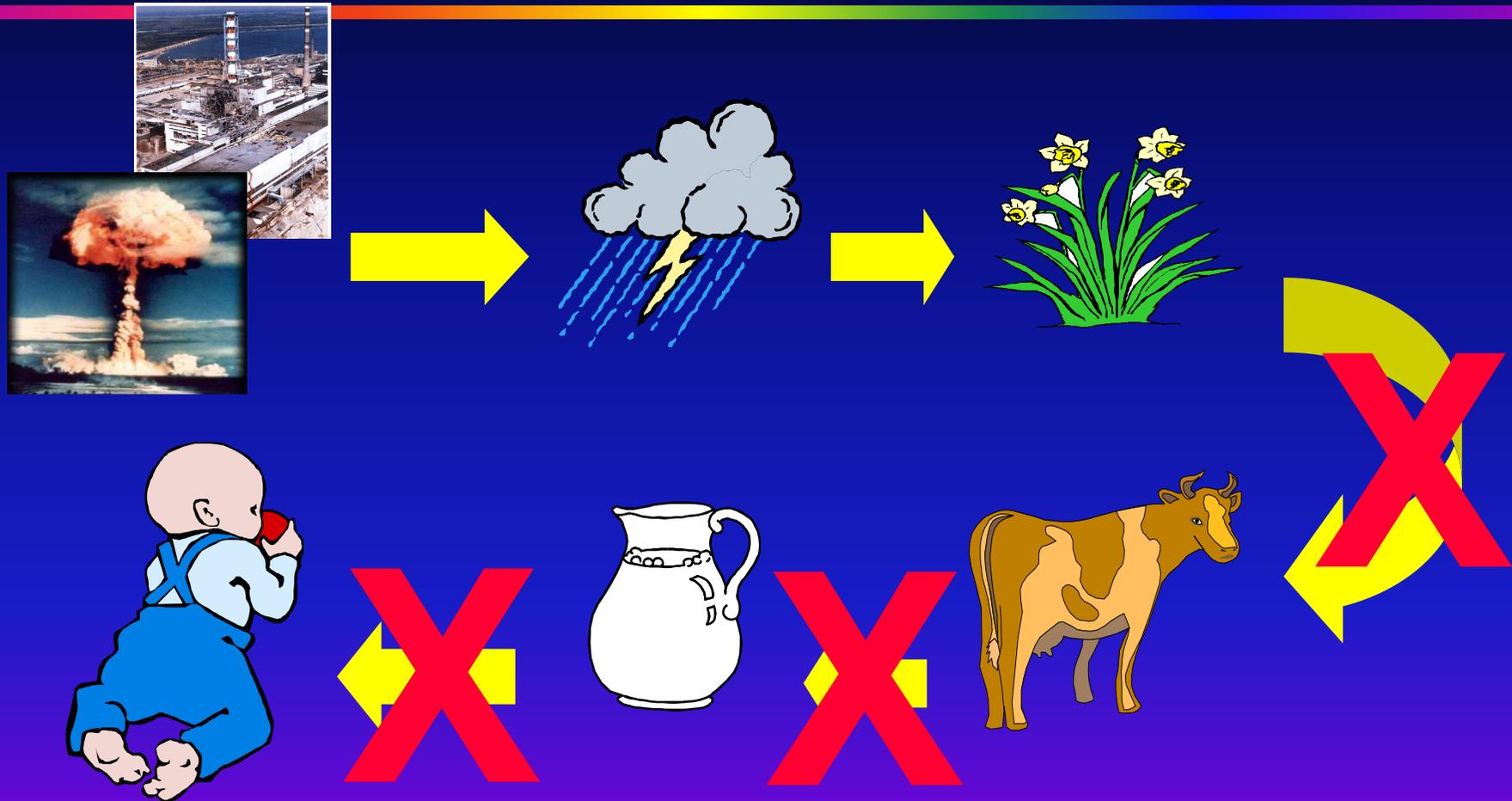
## **The abnormalities are not associated to radiation:**

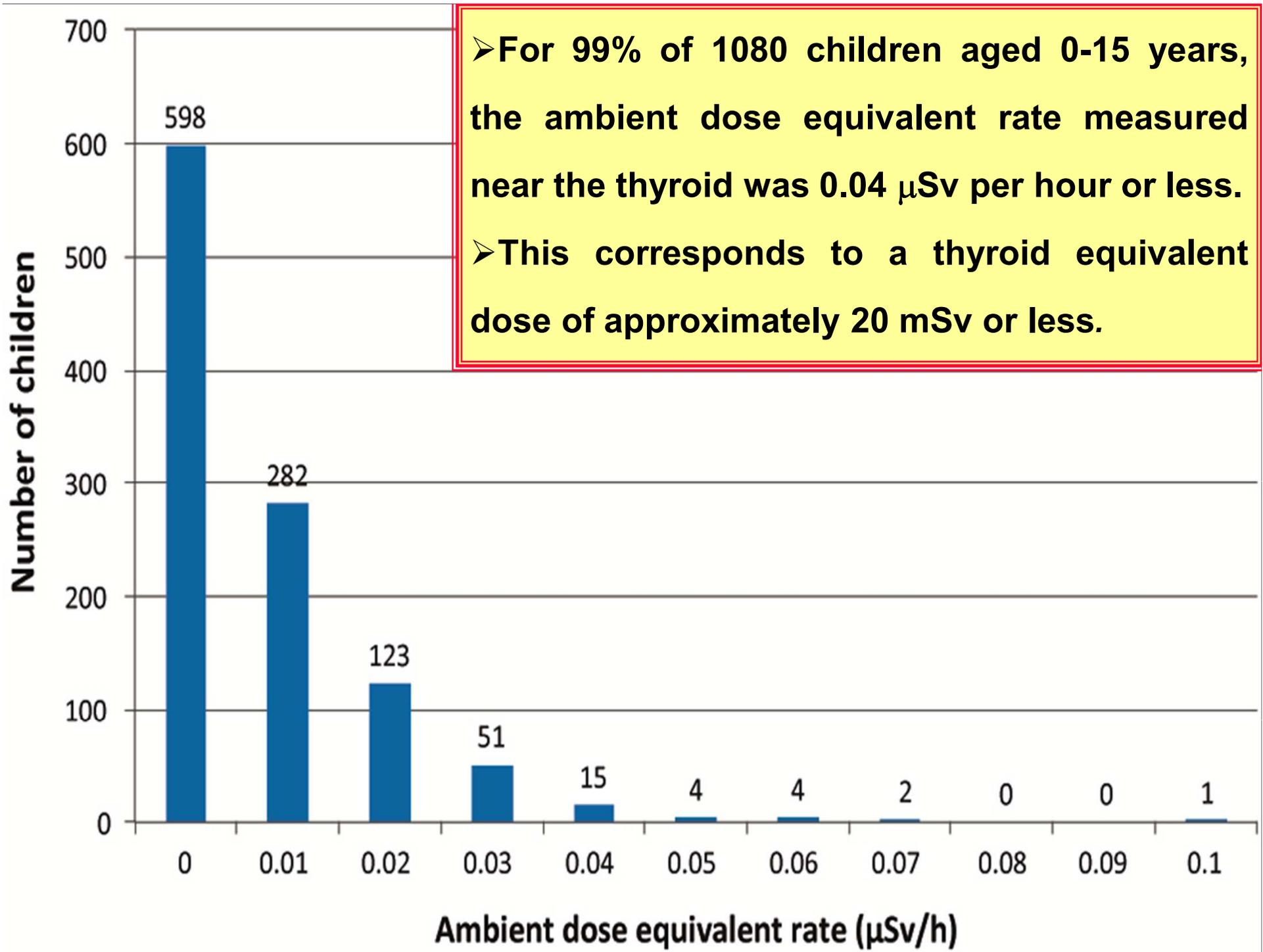
- **Similar results on children living far away.**
- **Latency time for radiation effect longer.**
- **Cancers not found in children under five years.**

- Thyroid were low because limited  $^{131}\text{I}$  intake due to **restrictions on milk, drinking water and food.**

**(there are scarcity of data immediately following the accident and obvious uncertainties on intakes.)**

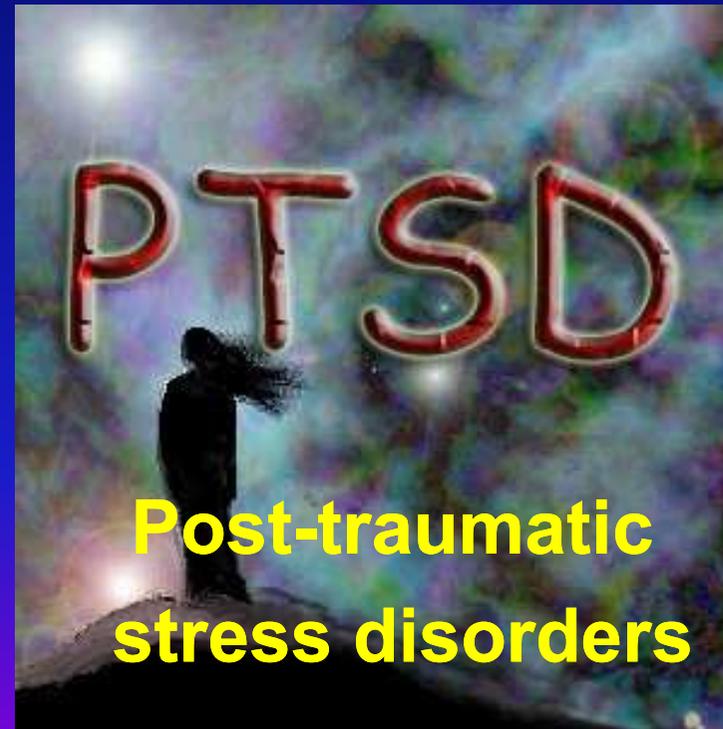
# Pasture-cow-milk pathway ( $^{131}\text{I}$ )



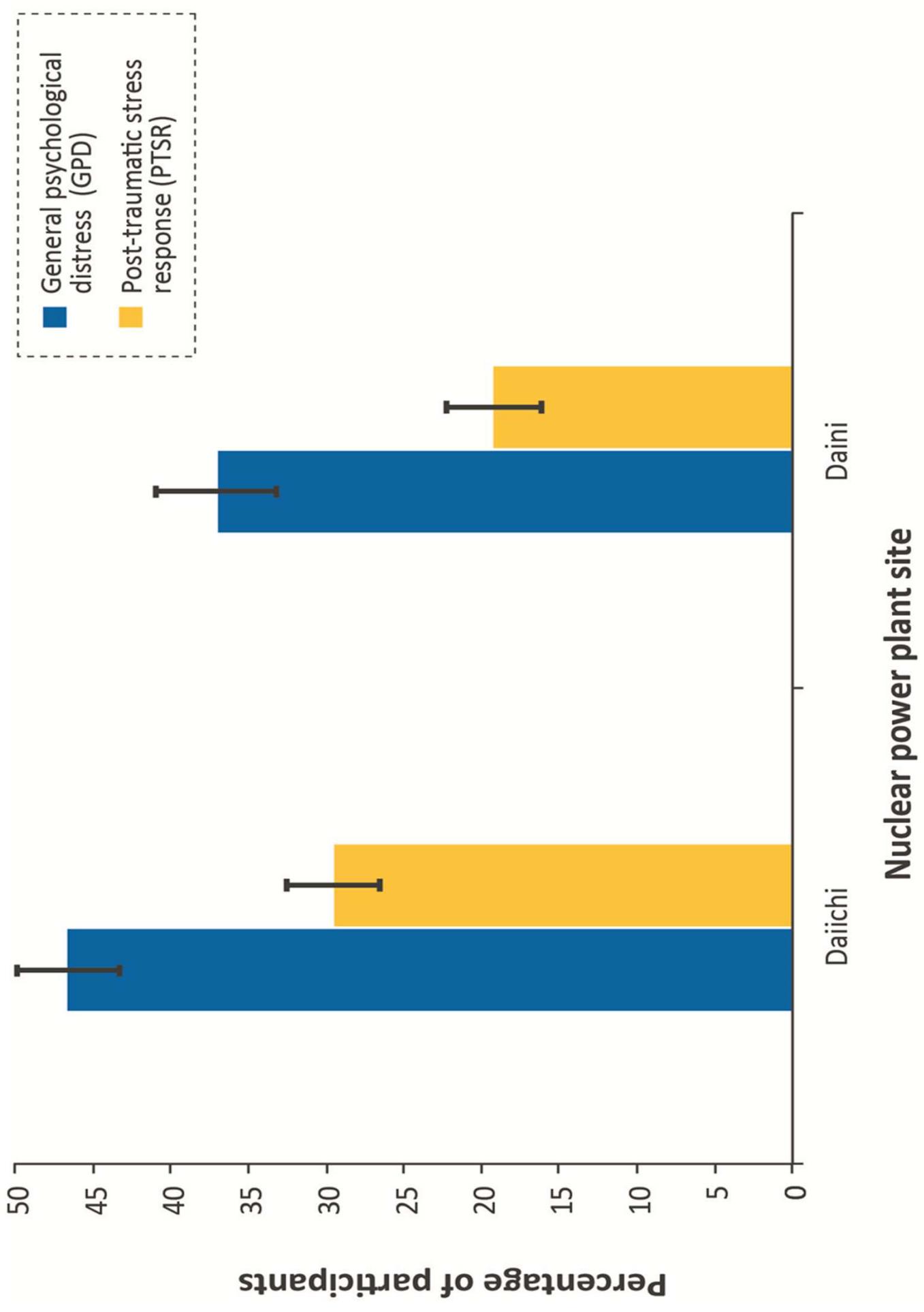


# Psychological consequences

- A most important health consequence:  
**fear and stigma related to perceived radiation risk!**
- Effects such as....



....have already been reported.



# **5. Environmental protection**

- **No effects in plants and animals reported**
- **Limited observational studies.**
- **Based on previous experiences and the levels of radionuclides present in the environment:...**

**....it is unlikely that there would be any major radiological consequences for biota populations or ecosystems.**

# **OBSERVATIONS AND LESSONS**

# On releases

## Needed:

- **Prompt quantification and characterization of the amount and composition of the release.**
- **Comprehensive and coordinated programme of long term environmental monitoring.**

# On protection

## Need:

- **Explanations of the radiation protection criteria that be understandable for non-specialists.**
- **Justification of disruptive protection measures.**
- **Consistent and coherent standards for acceptable radioactivity in consumer products and on land.**
- **Availability of suitable and sufficient personal protective equipment for workers.**

# On exposures

- **Personal monitoring of the public provides reliable estimates of radiation doses.**
- **Importance of restricting consumption of fresh milk from grazing cows by children confirmed .**
- **Robust system necessary for monitoring and recording occupational radiation doses.**

# On effects

- **Health surveys** are useful, but should not be interpreted as **epidemiological studies**.
- Need to address **psychological consequences**.
- Factual information on effects to be communicated in an understandable manner....

**..indicating unambiguously that health effects are not attributable to radiation exposure at levels similar than background levels.**

# On environment

- **Focus on protecting people.**
- **Doses to biota could be significant on individuals.**
- **Knowledge needs to be strengthened.**
- **Adopt integrated perspective to ensure sustainability of agriculture, forestry, fishery and tourism and use of natural resources.**

# Epilogue

## **1. Fukushima was a severe test for radiation protection:**

- workers were exposed to a totally unplanned situation, and
- massive amounts of radioactive substances were released into the environment and expose the public over vast habitats.

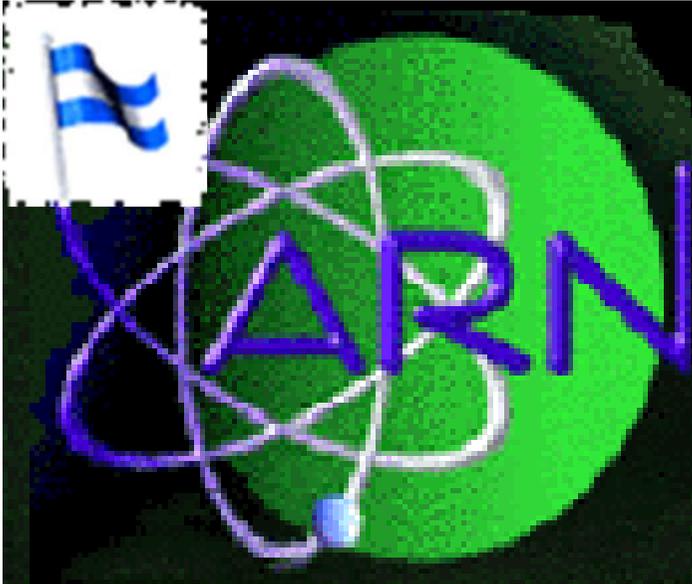
## **2. However, the accident appears to have resulted in relatively small radiation doses in general:**

- most workers were within the regulatory dose limits, and
- most area residents were exposed to low-level radiation comparable to natural background radiation levels.

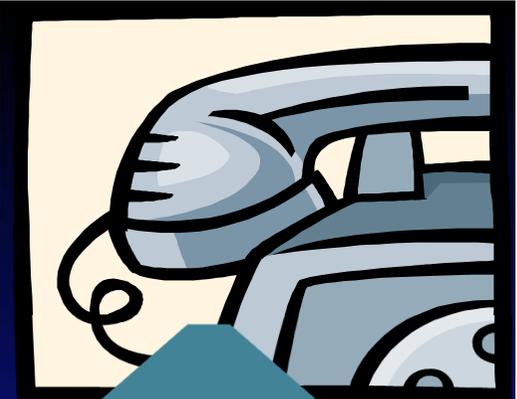
**3. No early health effects occurred and, at this time,  
no late radiation health effects are attributable.**

**4. Radiation protection appears to have been  
successful .....**

**.... but at significant social consequences!**



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*Thank you!*

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