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Optimization of exposure and countryside waste management for different accidental radioactive release

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Abstract. Since the Fukushima accident, Japanese scientists have been intensively monitoring ambient radiations in the highly contaminated territories situated within 80 km of the nuclear site. The surveys that were conducted through mainly carborne, airborne and in situ gamma-ray measurement devices, enabled to efficiently characterize the spatial distribution and temporal evolution of air dose rates induced by Caesium-134 and Caesium-137 in the terrestrial systems. These measurements revealed that radiation levels decreased at rates greater than expected from physical decay in 2011-2012 (up to a factor of 2), and dependent on the type of environment (i.e. urban, agricultural or forest). Unlike carborne measurements that may have been strongly influenced by the depuration of road surfaces, no obvious reason can be invoked for airborne measurements, especially above forests that are known to efficiently retain and recycle radiocaesium.

The purpose of our research project is to develop a comprehensive understanding of the data acquired by Japanese, and identify the environmental mechanisms or factors that may explain such decays. The methodology relies on the use of a process-based and spatially-distributed dynamic model that predicts radiocaesium transfer and associated air dose rates inside/above a terrestrial environment (e.g., forests, croplands, meadows, bare soils and urban areas).

Despite the lack of site-specific data, our numerical study predicts decrease rates that are globally consistent with both aerial and in situ observations. The simulation at a flying altitude of 200 m indicated that ambient radiation levels decreased over the first 12 months by about 45% over dense urban areas, 15% above evergreen coniferous forests and between 2 and 12% above agricultural lands, owing to environmental processes that are identified and discussed. In particular, we demonstrate that the decrease over evergreen coniferous regions might be due the combined effects of canopy depuration (through biological and physical mechanisms) and the shielding of gamma rays emitted from the forest floor by vegetation. Our study finally suggests that airborne surveys might have not reflected dose rates at ground level in forest systems, which were predicted to slightly increase by 5 to 10% during the same period of time.

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Optimization of exposure and waste management for different accidental releases

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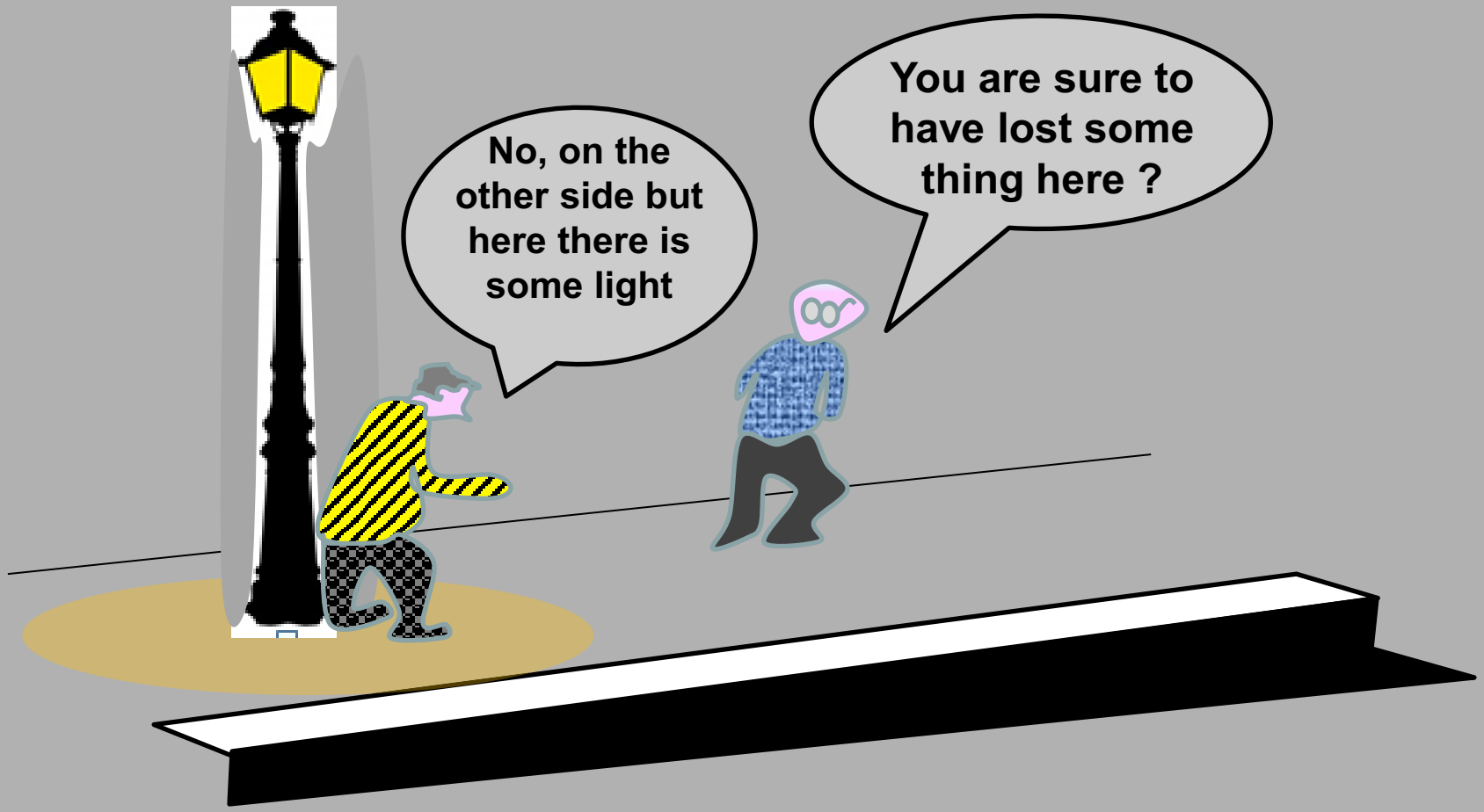
Stackholder - France

- Paris 2016

What means optimization ?

- Multi-criteria analysis based on realities
  - Protection: radiological and conventional
  - Wealth : country and individuals
  - Time, work and pleasure of living
- Definition of the boundary between:
- concentration + dilution +
- confinement => dispersion +
- radioactive waste no waste

What to avoid



I - REFERENCE VALUES

What criteria?

- Dose criteria
  0.1 mSv - 1 mSv - 20 mSv - 100 mSv – 0.3 Sv – 5 Sv
  ← Natural range →
- Dose rate : Sv *in 1 year, month, day* ?
  External – internal (inhalation/ ingestion 1st crop & next crops)
- Specific activity ,surface activity.
  - Food : in kBq/kg
  - Waste : in kBq/kg or $Sv.h^{-1}.m^{-2}$
- Evolution with time

4 Orders of magnitude, not black and white, Time is important, Protection margin useful ?

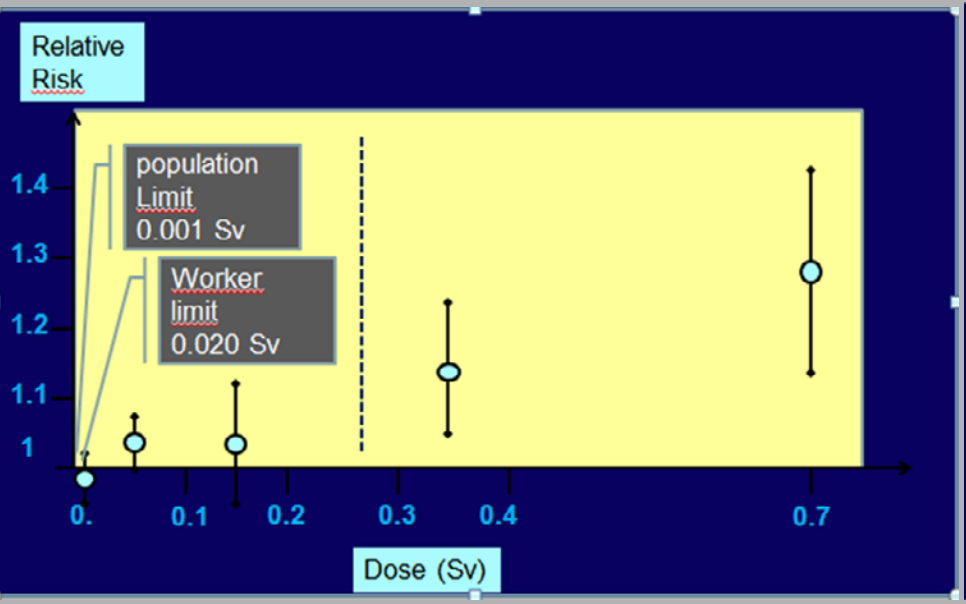
What danger ?

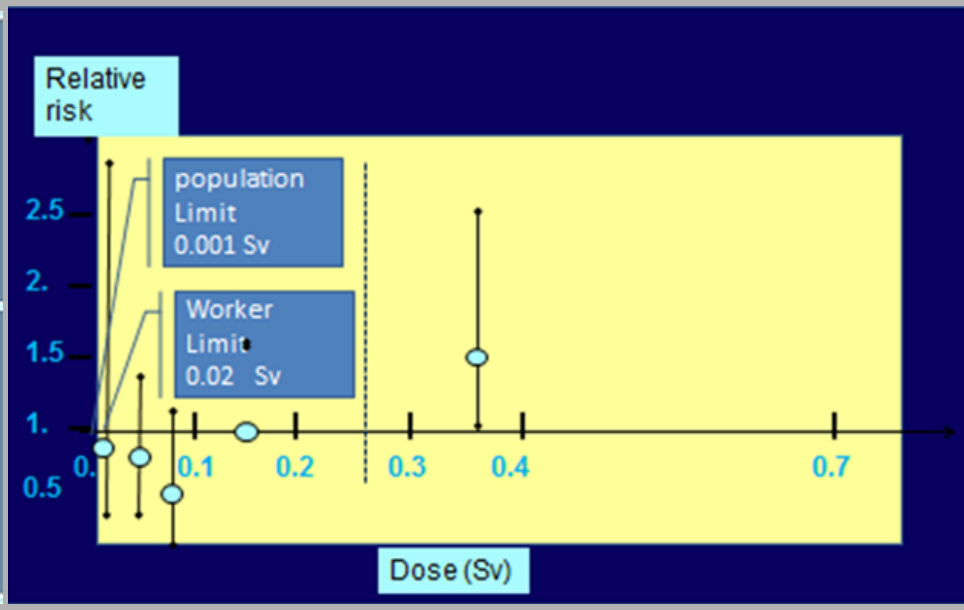
1. Meltdown is necessarily associated to a significant release of energy. Releases are at a big height which brings an important protection to the neighborhood.
2. Delay before release = very short-lived nuclides disappear. Suppress effect on forest by β.
3. Melting is not explosion : Non-volatile Nuclides not emitted.

- Evacuation induces other more conventional but real dangers.
- The cure can be worse than the disease, especially if the evil is imaginary.

Reference values as elements of optimization

Relation between dose & relative risk for solid cancers and leukemia : Hiroshima Nagasaki

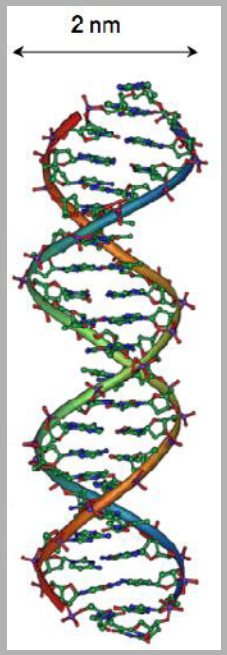




ICRP reference : 0.001, 0.02 and 0.1 Sv

In Japan: 0.3 Sv for workers = a good choice
No clinical effect – no detectable stochastic effect

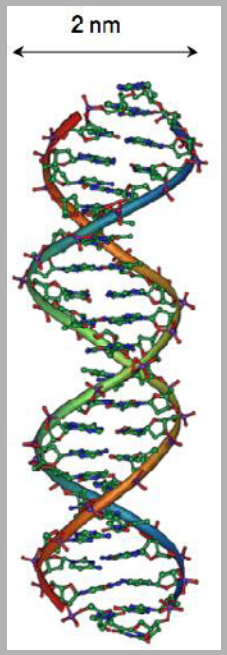
DNA damages short term ? (weeks)



DNA Damage to **thyroid** cells	spontaneous over 1 month	Chernobyl young children	Fukushima young children
exposure	-	**3** Gy (2 and more) Inhal. & **ingest.**	Max **0.08** Gy
simple strand breaks	300 000 – 1 700 000	3000	80
Nucleobase loss	400 000	6000	160
Bases modification	100 000		
Double-strand breaks	**240**	120 (**50%**)	3 (**1%**)

no effect will be visible (exist) in Japan

DNA damages in long term ? (Years)



DNA damages per cell and per day	« spontaneous »	Radio-induced damages rate 100 milliGray/y
simple strand breaks	10 000 - 55 000	0.3
Nucleobase loss	12 600	0.6
Bases modification	3 200	
Double-strand breaks	8	0.012

(Burkart W et al. CR Acad Sci III 1999; 322:89-101;
Ward JF Prog Nucl Acids Res Mol Biol. 1988; 35: 95-125)

Reference values for food and feed

Bq/kg	Infant food	Dairy produce	Other major foods	Liquid food (CA), & *water (WHO)*	Minor food	Feed
I131	150 /*100*	500 / *100*	2000/ 100	125 / *10*	20000	
Cesium 134 - 137	400/ *1000*	1000 / *1000*	1250 / *1000*	1000 / *10*	12500	Pigs…….. 1350 Poultry, lambs, calves……. 2500 Other……. 5000
Tritium	- / *1 000*	- / *10 000*	/ *10 000*	- / *10 000*		*(As Organic molecules)*
Pu239	1 / *1*	20 / *10*	80 / *10*	20 / *1*	800	

1rst crop Food ban Fundamental

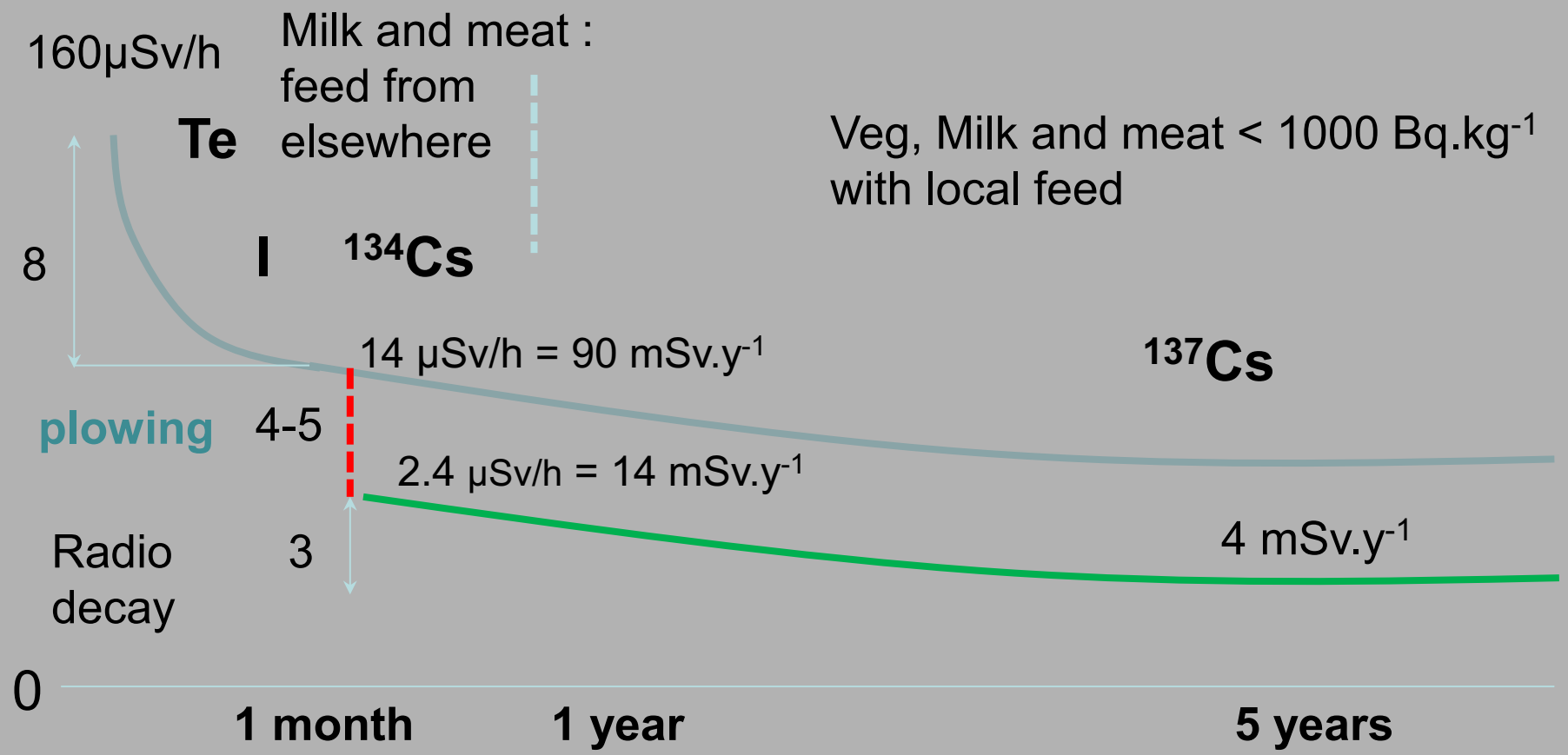
0.1 mSv : very low but today +/- unavoidable.
No reason to choose lower values
(Maximum, average, 95% ? M= Max/10)

Deposition – transfers – dose rate per hour and per year, specific activity

Case dry deposition for 1 MBq.m^{-2} Total deposition					
External irradiation	infinite surface	Cs134	5.5 µSv.h^{-1}	33 mSv.an^{-1}	Bq ^{134}Cs & ^{137}Cs not equivalent
		Cs137	2. µSv.h^{-1}	12 mSv.an^{-1}	
	Homogeneous after ploughing 3 Bq/g	Cs134	0.9 µSv.h^{-1}	5,3 mSv.an^{-1}	Fed. Guid n° 12 Depth 30 cm
		Cs137	0.33 µSv.h^{-1}	2 mSv.an^{-1}	
Vegetable	Foliar deposition	aerosols	≈10^{6} Bq.kg^{-1}	existing crop	1 to 5 kg$_{\text{Fresh W}}$.m^{-2}
	Soil-plant transfer	Cs 134 137	30 – 300 Bq.kg^{-1}	next crops	(Fresh weight)
Cow Milk	feed contamination	Cs 134 137	1.10^{5} Bq.L^{-1} max	short term	(Dynamic model)
Cow meat	soil> grass>meat	Cs137	50 – 500 Bq.kg^{-1}	Long term	
Exemption levels	BSS - Transport	Cs 134 137	10 Bq.g^{-1}	Japan 7 Bq.g^{-1}	local/national

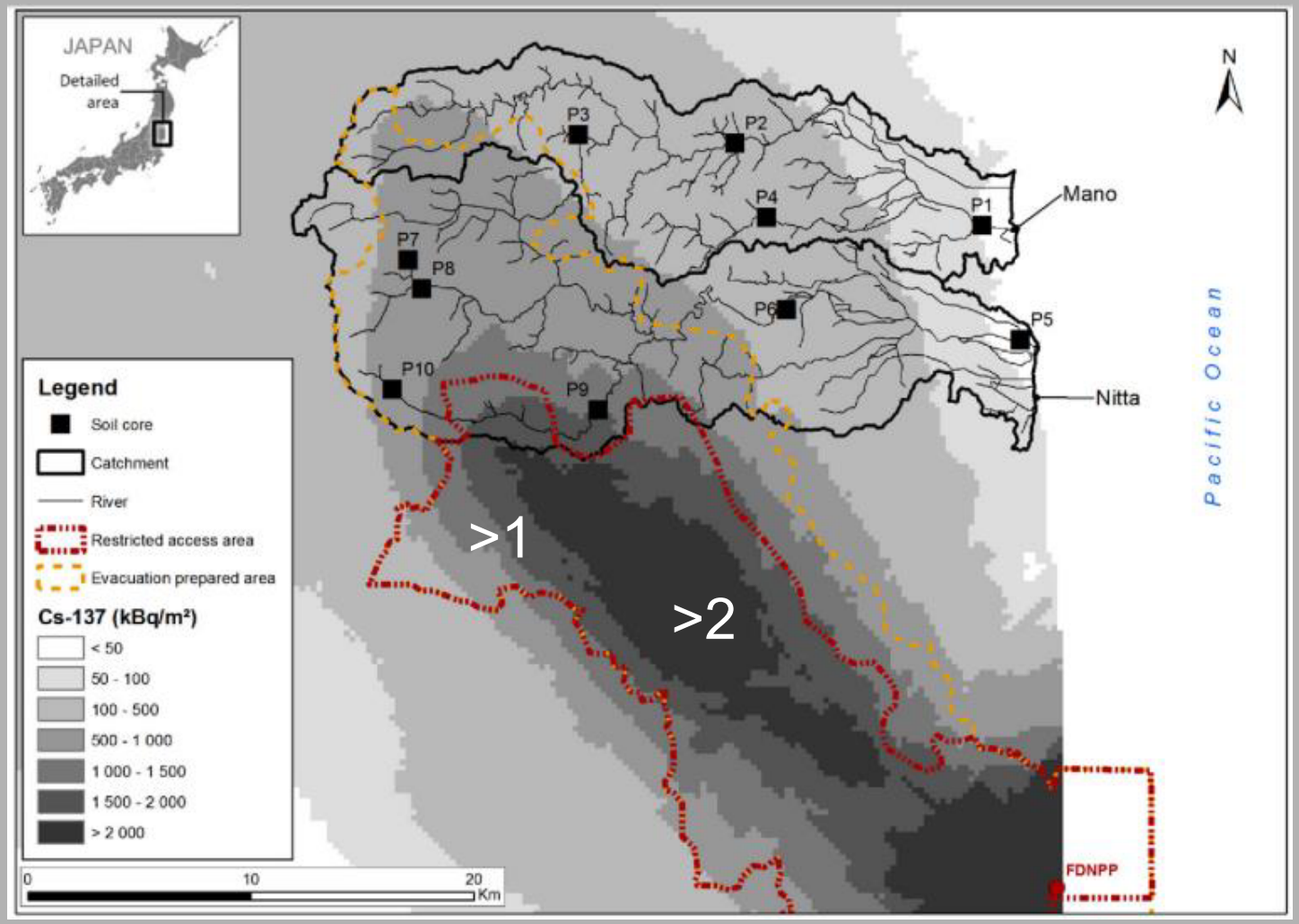
2 - 3 MBq.m^{-2} of Cs 137, a physical boundary

External dose rate as function of time for 2 MBq.m^{-2} of each Cs and other criteria

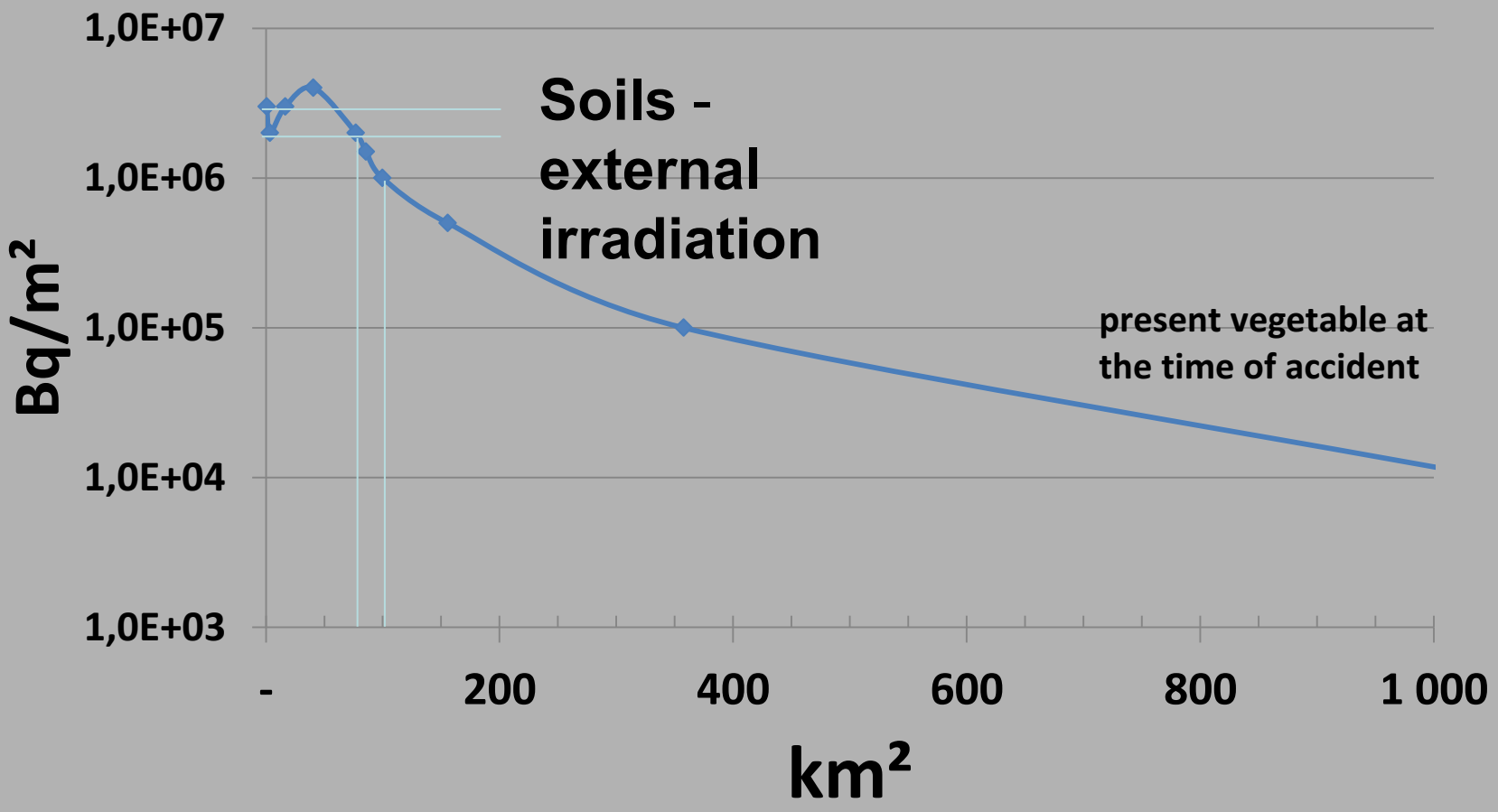


2 (or 3?) MBq.m^{-2} of Cs 137, a consistency in time

An illustration



Decrease of deposition versus surface



II - WASTE

Remediation and Waste management

- The best waste is the waste that does not exist.
- Soil is a wealth to preserve
- Food is an important but short-term trouble.

To avoid waste

- Plowing, digging over
- Vegetable grubbing and burial by plowing, digging over.
- Distribution of uncontaminated Feed
- If contaminated milk, disposed on farm by spreading with urines/slurry

III – OTHER NUCLIDES

Tritium, tritiated water

- Is present in CANDU & ITER (risk = fire ?)
- water (HTO), organic (in environment, plants), (Gas HT: no risk), metallic hydrides.
- **HTO** : Very low radiotoxicity – rapid turnover 12 y period
- Very quick decrease in plants in 2 days (100 to 1000).
- No bioaccumulation, no bioconcentration. (major element)
- No health risk, but psychological risk.
- ***Food ban for some days, for few km for 10 g T.***
- Reference value 10^4 Bq/kg far too low at short term. Should be 10^6 10^7 Bq/kg for intervention.
- Dilution is absolutely the best, (especially in ocean).

Plutonium

- Fuel reprocessing
- Dense metal, non-volatile, no external irradiation, non-metabolized element.
- Transfer to plants and animals very small.
- Resuspension is of minor importance.
- For a standard 1g release, ***food restriction for leaf vegetable on few km***.
- Incineration is possible but useless.
- Standard impact assessment much over estimated. (density, veg. washing, dose factors)

Conclusions

- A major nuclear accident (with food ban) has presently no health effect, and environmental/waste effects are mainly psychological. (~~LNT law~~)
- Consistency between the criteria is necessary.
- Dilution has to be a large part of the post-accidental management.
- Food and Feed ban can be done at large scale. Soils should be preserved.
- Experts should not stress population and decision makers.