Some lessons from the management of the radiological contamination of the forest following the Chernobyl accident: a European perspective

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Introduction

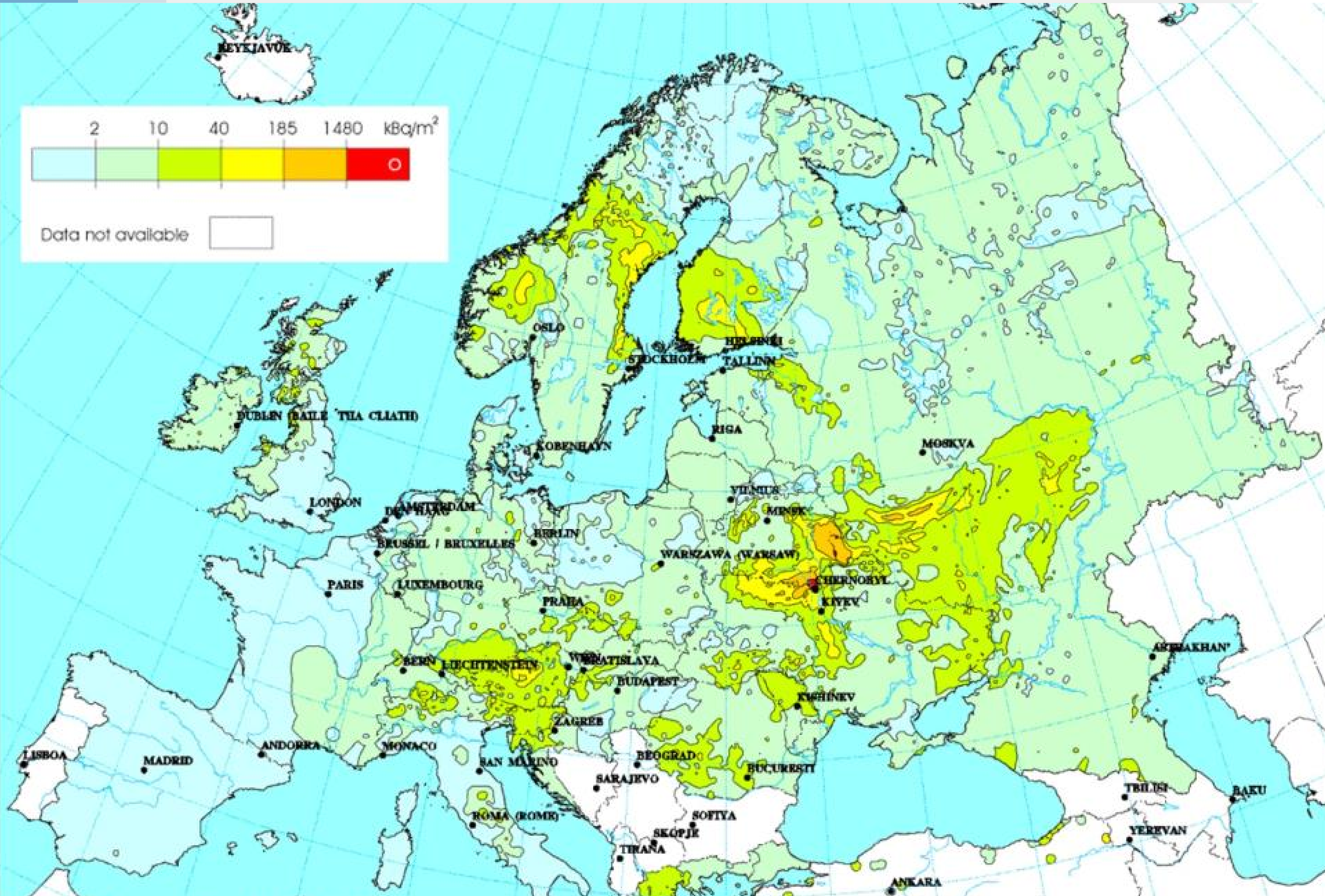
- Persistent contamination of the soil due to the fallout of the Chernobyl accident in Europe
- 29 years after the accident, this contamination is still detectable, mainly in forest areas, even outside Ukraine, Belarus and Russia
- No strategies to decontaminate the forest areas
- Consequences in terms of human exposure rather limited for these areas

Content

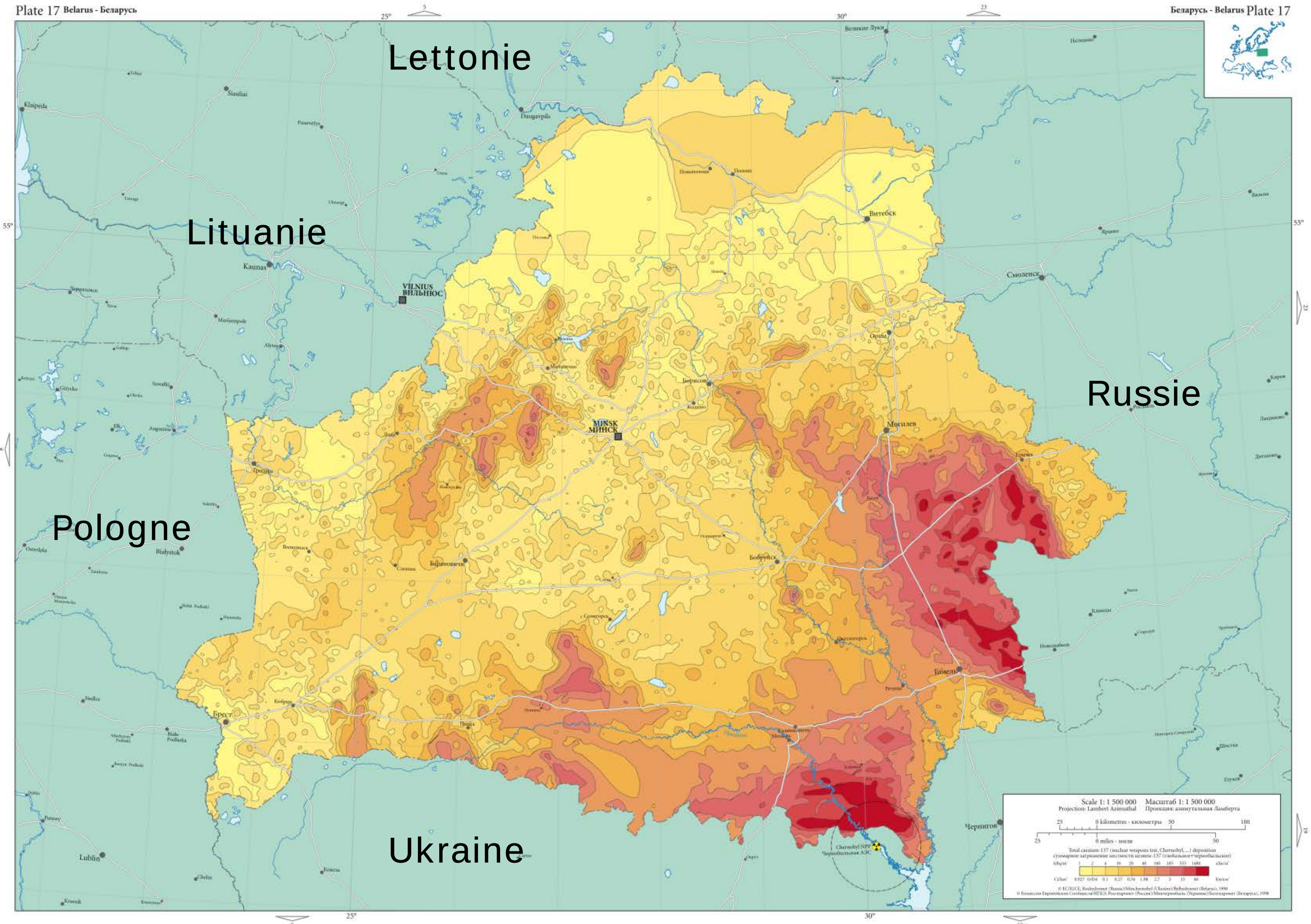
- Main contaminated areas observed in Europe after the Chernobyl accident
- Consequences for wood and its use for heating
- Contamination observed in mushrooms, berries, plants and wild animals
- Potential consequences associated with fires occurring in forests
- Strategies for managing the situation
- Developing the radiation protection culture among the inhabitants

Main contaminated areas in Europe after the Chernobyl accident

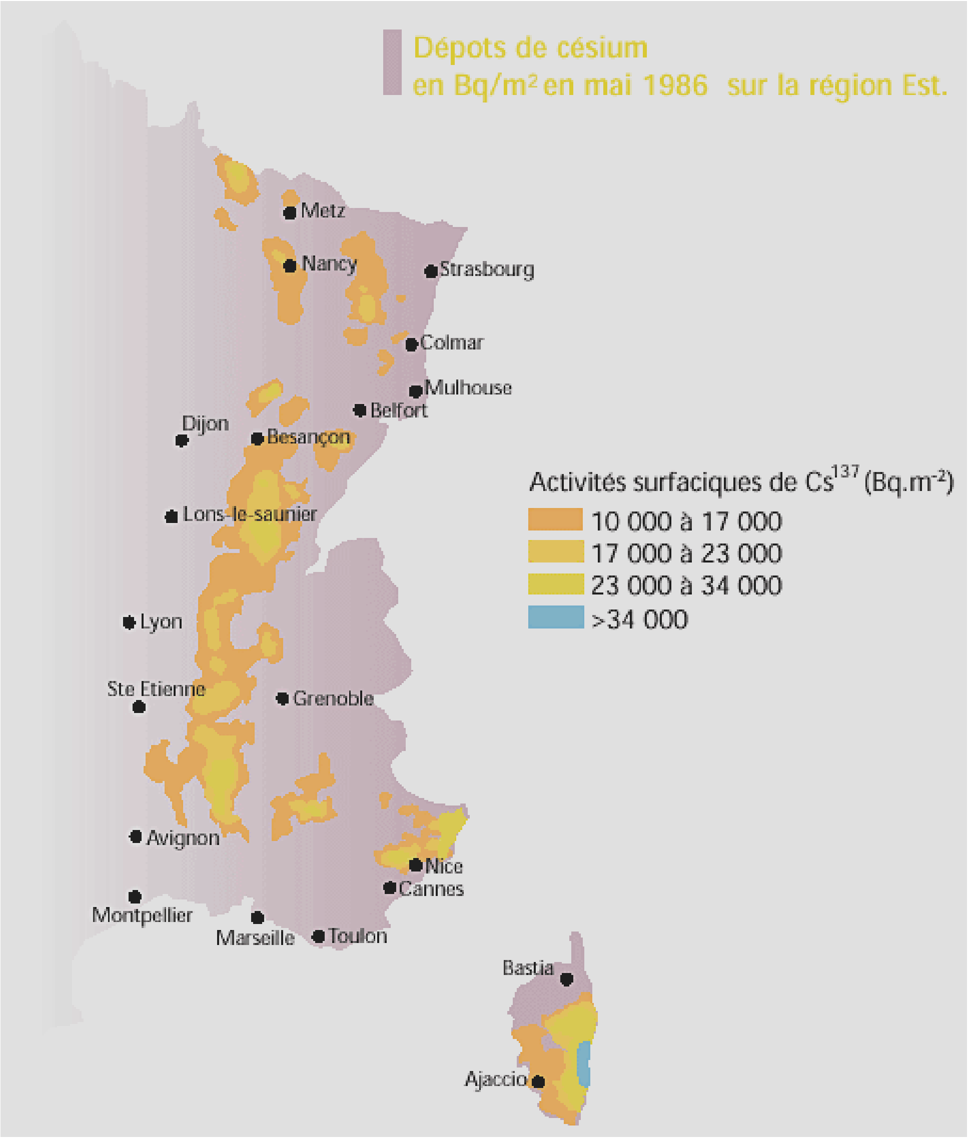
Chernobyl ^{137}Cs deposition (1986)



Contamination in Belarus in Cs-137 (1986)



Contamination in East part of France in Cs-137 (May 1986)



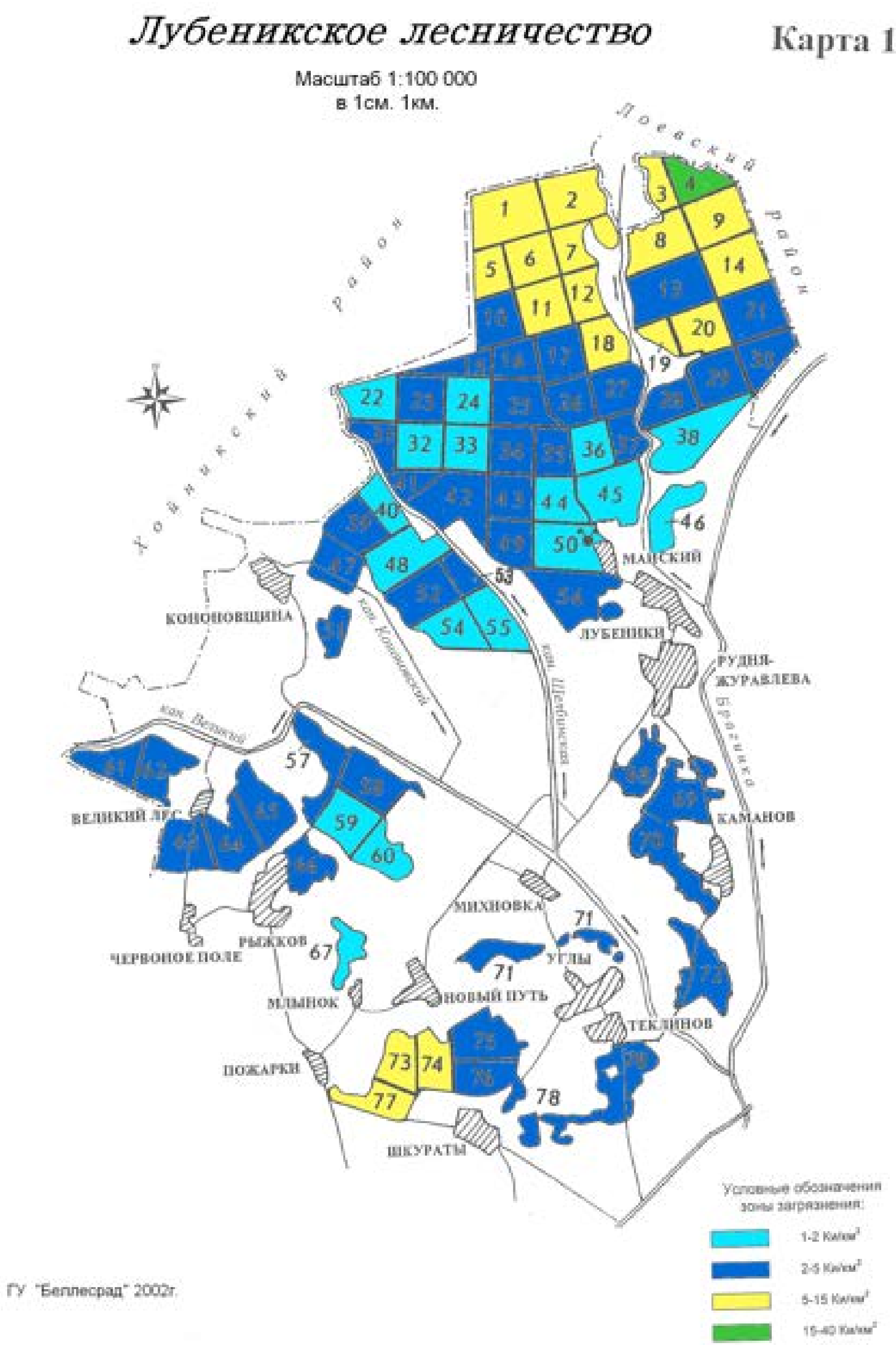
(Source : IRSN)

Limited decontamination of forests (1)

- Forests are highly diverse ecosystems
- Due to high filtering characteristics of trees, deposition was often higher in forests than in agricultural areas
- Sensitive issue for:
  - Occupational exposure (workers in forests were estimated to have received a dose up to 3 times higher than people living in the same area)
  - Recreational activities (external dose rate: up to 30 µSv/h in 1989)
  - Wood, berries, mushroom and wild animals

Limited decontamination of forests (2)

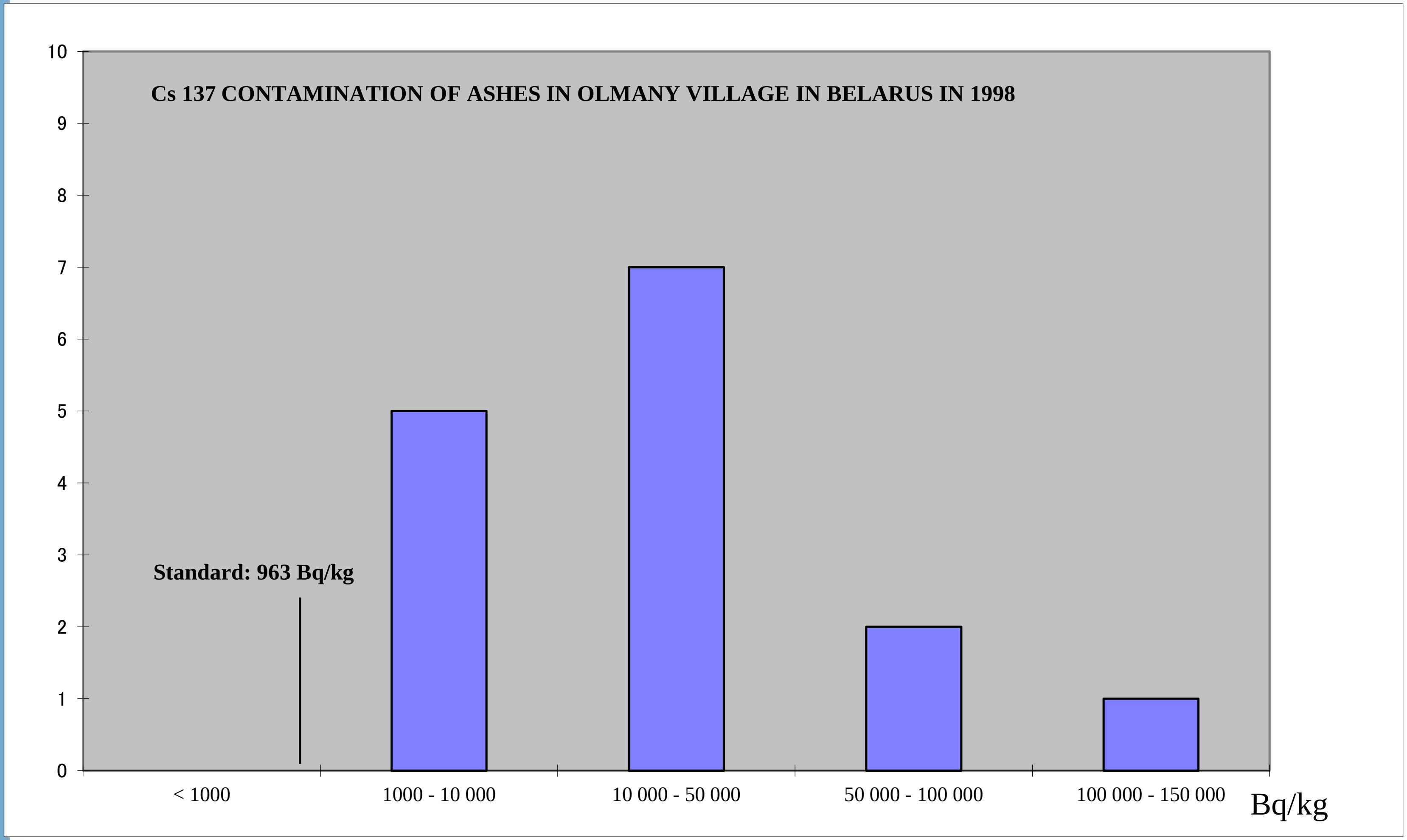
- Most effective strategies adopted:
  - Restriction of access
  - Prevention of forest fires
- Decontamination mainly limited to the “Red Forest” located in the South and West part of the exclusion zone
  - Pine forest in which the trees received up to 100 Gy
  - 375 ha were concerned with the removal of the top 10-15 cm of soil and the cut down of dead trees
  - Waste placed in trenches and covered with a layer of sand
  - A volume of 100,000 m^3 was buried
  - Reduction of the soil contamination by at least a factor of 10
- Re-forestation and sowing of grasses also undertaken to prevent the spread of existing soil contamination



Map of Cs-137 contamination of forests in Braguin District - Belarus (2002)

Consequences for wood and its use for heating

Consequences for wood and its use for heating (1)



Consequences for wood and its use for heating (2)

Ashes production

Assumptions:
2 buckets of ash per stove per week
4 kg weight per bucket
2 stoves per house
500 households in Olmany
7 months generation

Contamination assessment

Measurements of Cs-137 contamination of ashes

Range from 15,000 to 80,000 Bq/kg

Assumed value: average of 50,000 Bq/kg

Total production of ashes in the village estimated to 224 t/yr, resulting in 11,200 MBq/yr from the whole village

Ashes final use

Assumption:
All output from a household is put onto a 600 m2 surface garden

Final estimation
37.3 kBq/m2/yr added in each garden = 26% of the initial deposition of 187.5 kBq/m2 (decay corrected)

Contamination observed in mushrooms, berries, plants and wild animals

Contamination observed in mushrooms, berries, plants and wild animals:

Data from Belarus

Foodstuff measurements in Belarus from 2004 to 2006 (Bq/L- Bq/kg)

LCRC in Krasnoe LCRC in Dublin LCRC = Local Centre of Radiological Control	Mean 04-05-06	Maximum 04-05-06	Limit BY
Cow milk	**33-24-23** na-**34-66**	**178-206-100** na-**57-378**	**100**
Fodder	na-**392-58** na-**644-1492**	na-**1850-97** na-**988-5990**	**1300**
Mushrooms (dry)	**2660-995**-na na-**15232-13805**	**8215-1166-98000** na-**45000-37000**	**370**
Potatoes	**27-5-4** na-**<18-<18**	**972-32-27** na-**<18-<18**	**80**

na = not available

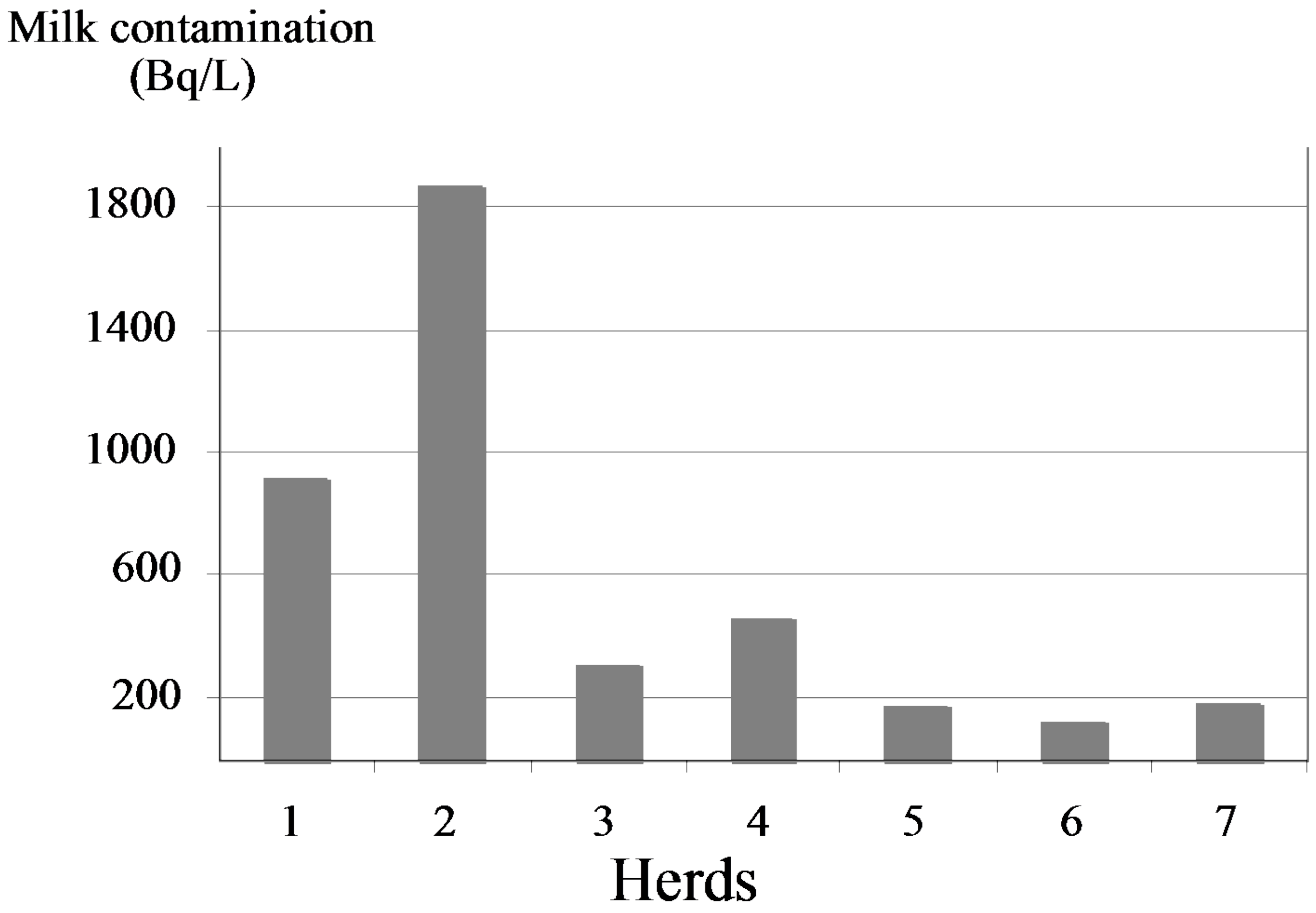
WBC - Collective Results 2004-2007 in Belarus

(19,000 Measurements in 4 Years – Bragin district)

Date	No.	Mean (Bq/kg)	Maximum (Bq/kg)	No > 50 Bq/kg	No > 100 Bq/kg
S 04	2056	27	2056	78	17
F 04	2592	32	□2658	□□ 249	□□64
S 05	2526	29	□□□259	□134	□□18
F 05	2612	24	□190	□109	□12
S 06	2530	25	□168	□□50	□□4
F 06	2486	31	□□982	□□□242	□□□43
S 07	2438	23	□□247	□□32	□□□3
F 07	1705	14	□235	□ 86	□ 7

S=SPRING ; F=FALL

Levels of milk contamination according to the herds of private farmers – Olmany – Belarus – 1996-1998



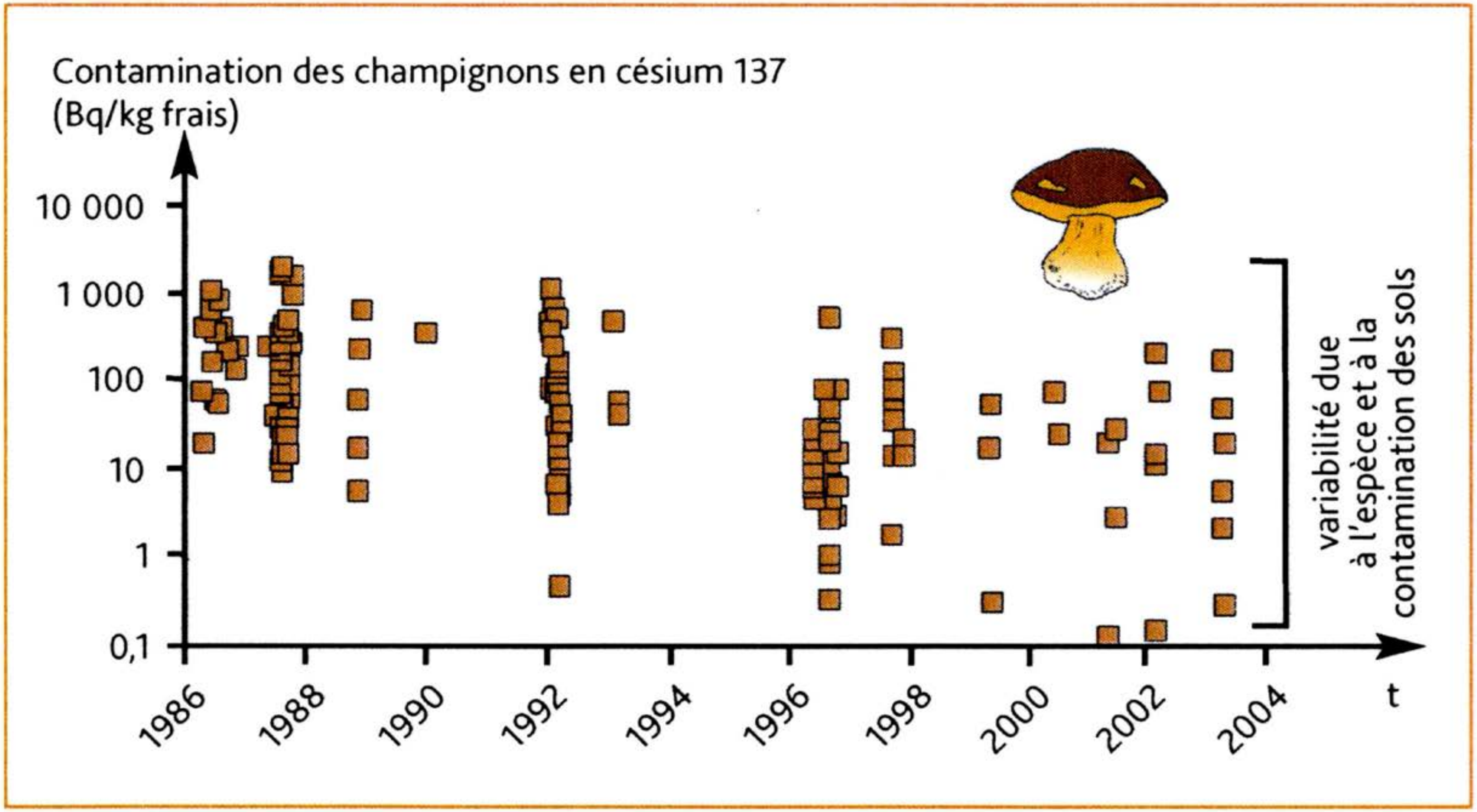
Range of levels of contamination of the key foodstuffs consumed in Olmany – Belarus – 1996-1998

	Foodstuffs	^{137}Cs contamination (Bq/kg)		
		Minimal	Maximal	Concentration limit (1996)
Sensitive	Mushrooms (Fresh)	400	16000	370
	Berries	100	3600	185
	Fresh milk	10	2000	111
	Pork	10	300	370
	Veal	around 100		
	Fish	50	2000	
Slightly sensitive	Beetroot	20	40	100
	Potatoes	10	100	100
	Cabbage	20	60	100
	Home-baked bread	around 50		
	Eggs	0	10	
Uncontaminated	Shop-bought food and food from uncontaminated areas	A few Bq/kg		

Contamination observed in mushrooms, berries, plants and wild animals:

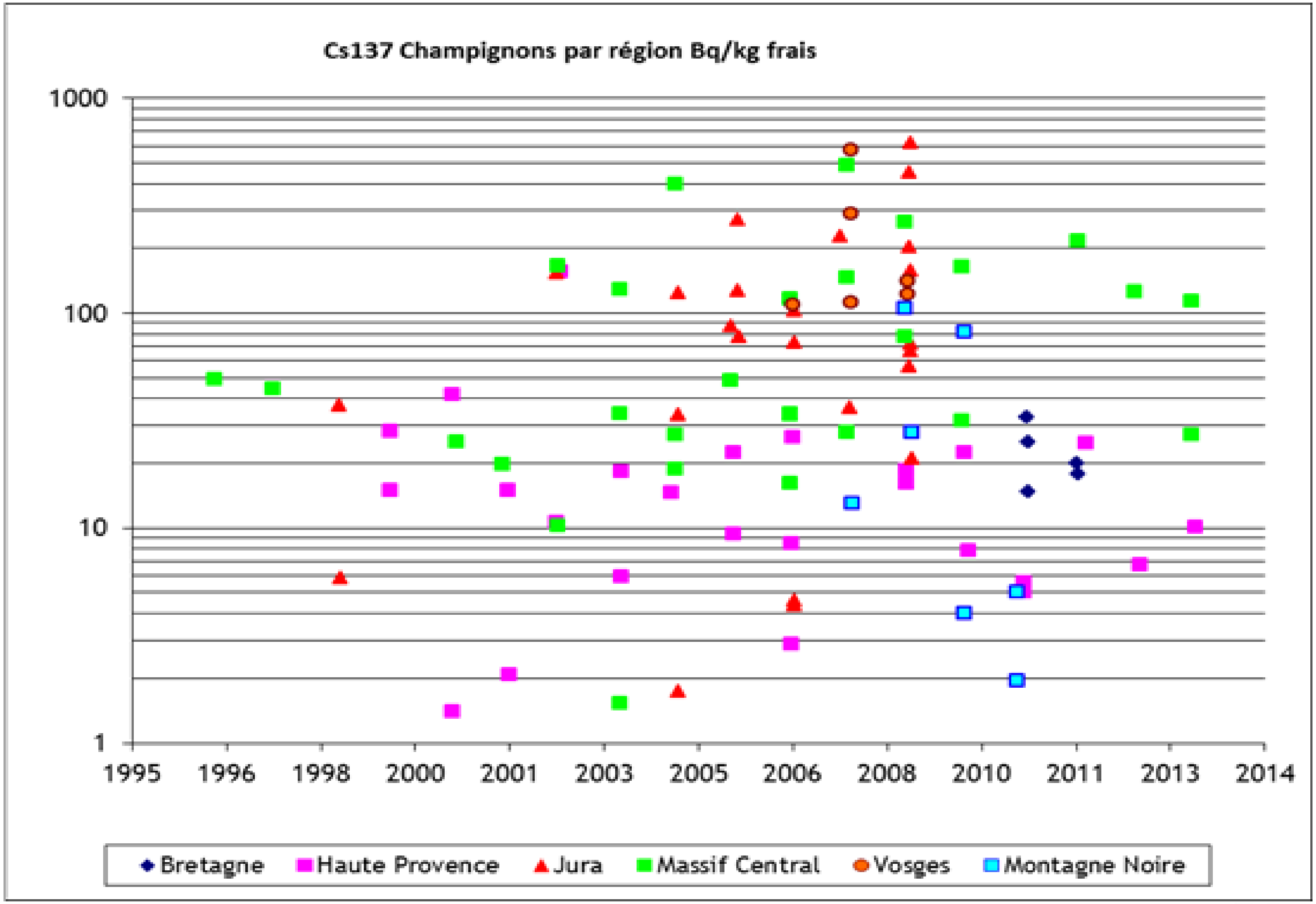
Data from other European countries

^{137}C concentration in mushrooms in France from 1986 to 2004 (Bq.kg^{-1} fresh)



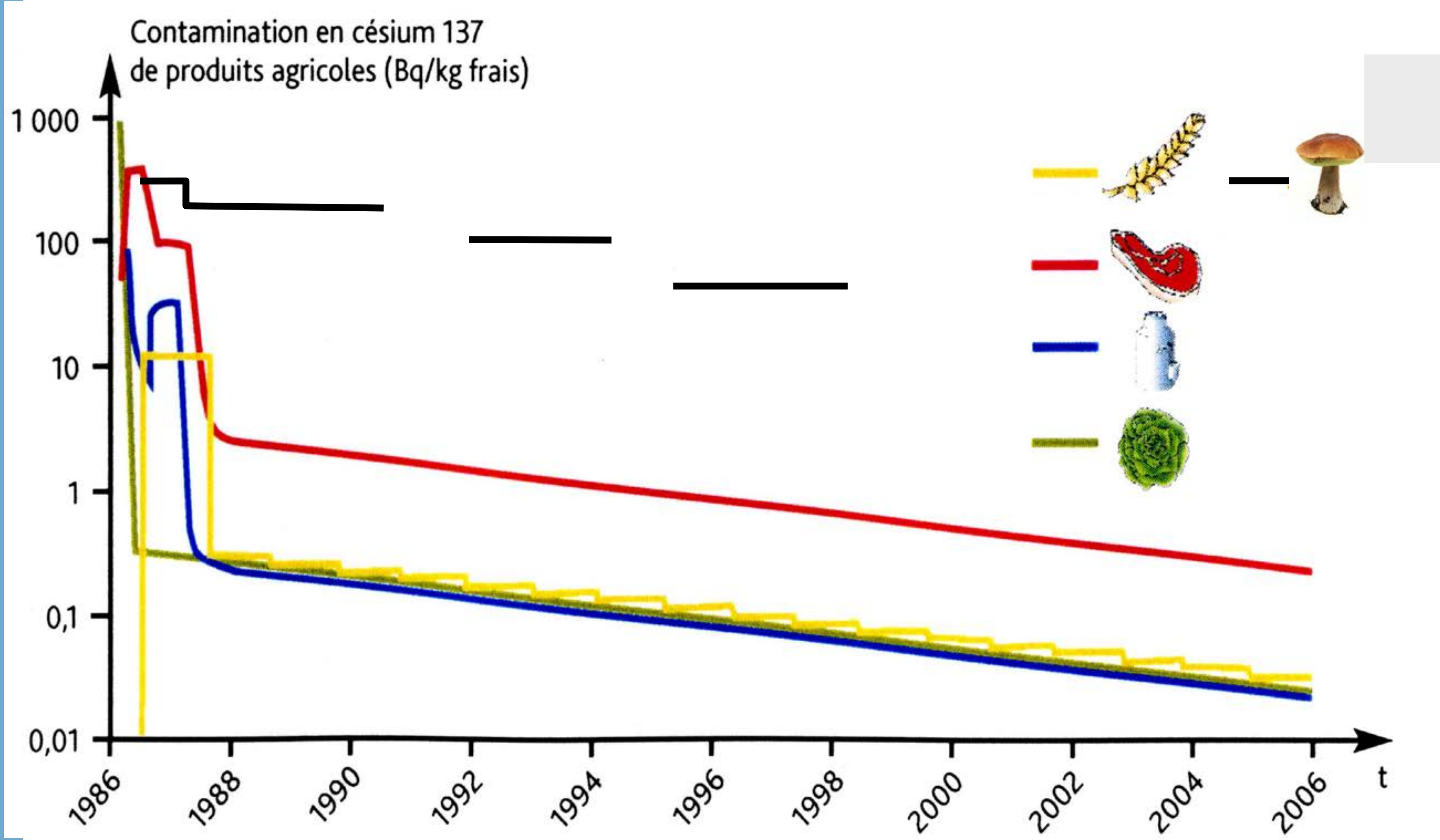
Data from OPRI, IPSN and IRSN

^{137}Cs concentration in mushrooms for different regions in France from 1995 to 2014 (Bq.kg-1 fresh)

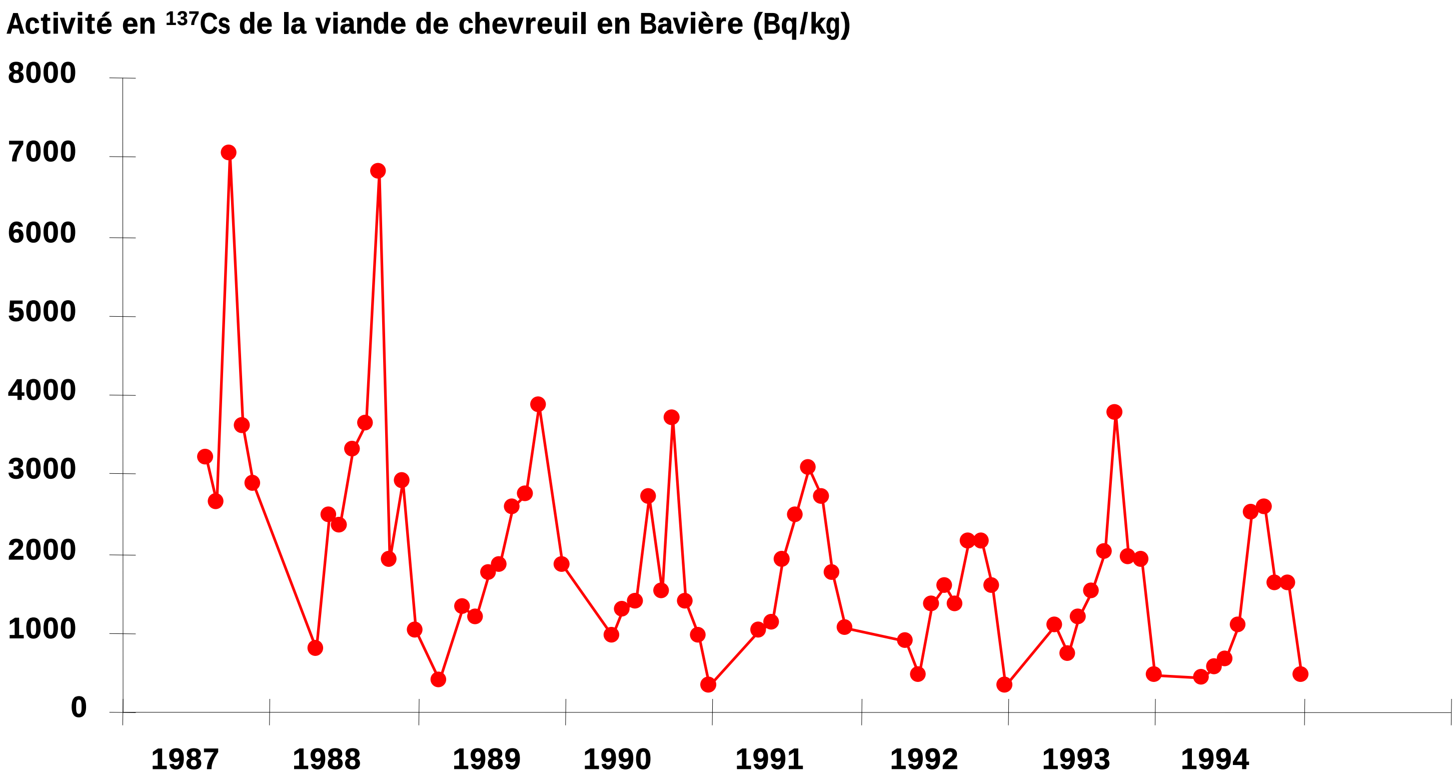


Data from IRSN

Evolution of average contamination in ^{137}Cs for cereals, beef, cow's milk and mushrooms in East part of France from 1986 à 2006 (Bq/kg fresh)



Evolution of ^{137}Cs concentration in deer meat in Bavaria from 1987 to 1994 (Bq / kg fresh)

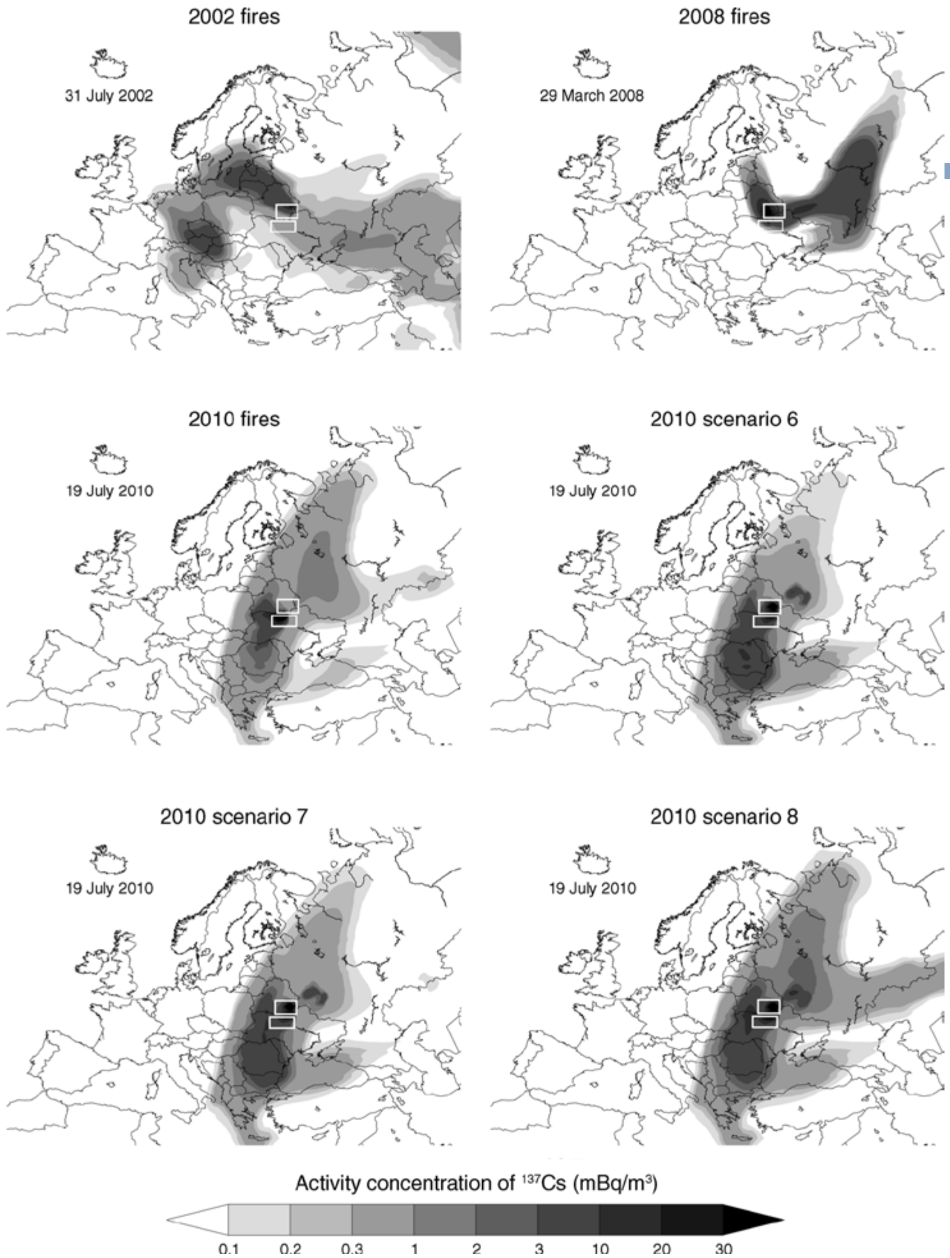


Large seasonal fluctuations.
Measured activity in the Vosges boar meat in 1996: up to 2,000 Bq / kg
During summer of 2014 in Saxony, 297 of 750 samples exceeded 600 Bq / kg fresh

Potential consequences associated with the fire occurring in forests

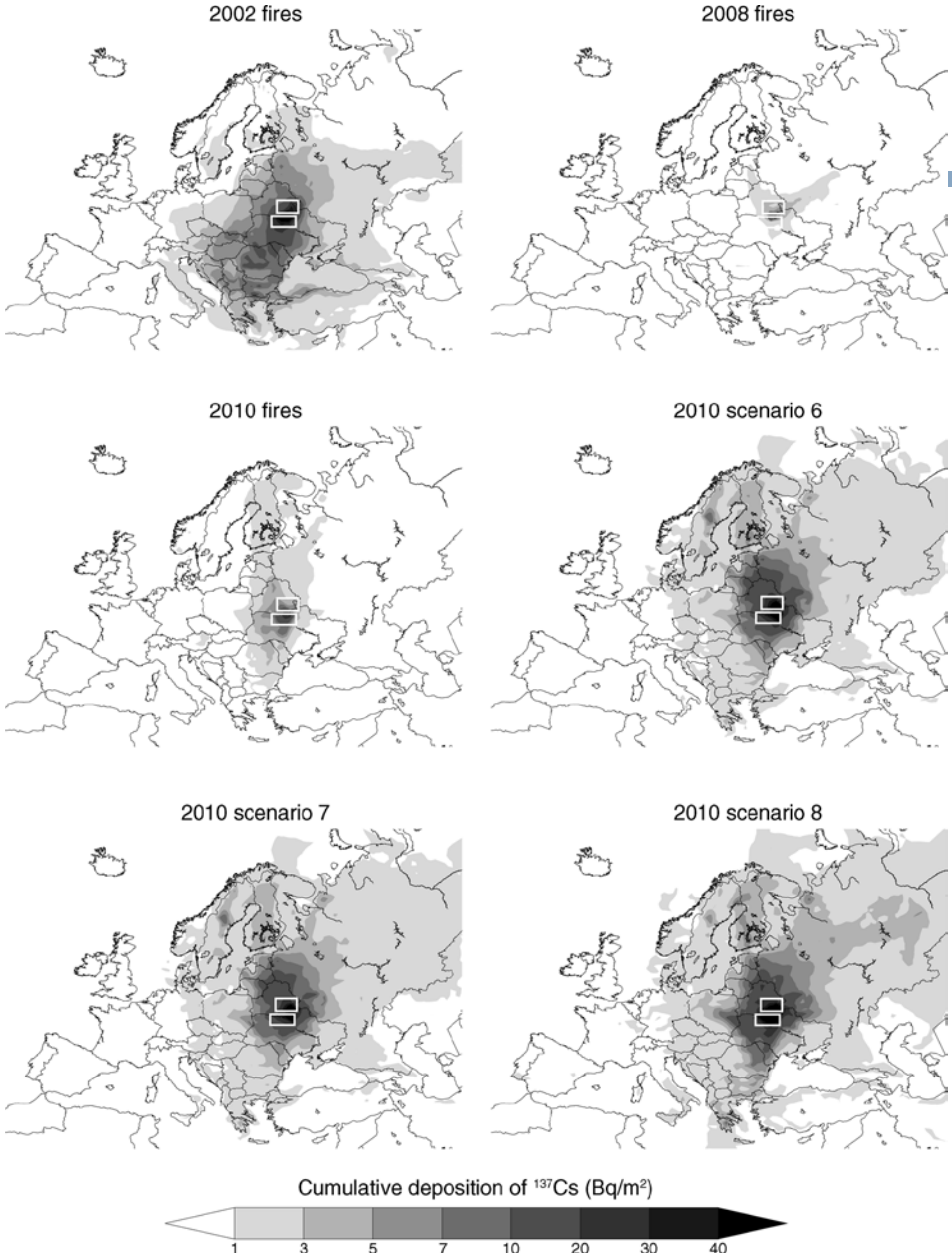
Potential consequences associated with the fire occurring in forests (1)

- Chernobyl disaster released 85 petabecquerels of radioactive caesium
- There is up to eight petabecquerels (PBq) in soil in the exclusion zone
- Intense fires in 2002, 2008, and 2010 resulted in the displacement of ^{137}Cs to the south
- Following three forest fires in Ukraine scientists measured radiation levels
- The fires caused 0.5 PBq to released over eastern Europe as smoke
- Cumulative amount of ^{137}Cs re-deposited over Europe was equivalent to 8% of that deposited following the initial Chernobyl disaster.



^{137}Cs emissions in the contaminated forests of Belarus and Ukraine after fire events in 2002, 2008, and 2010

Simulation of three different fire scenarios (2010 scenario 6, 2010 scenario 7, and 2010 scenario 8)



Deposition of ^{137}Cs (wet and dry) after fires in 2002, 2008, and 2010 in Ukraine and Belarus

Simulation of three Scenarios (2010 scenario 6, 2010 scenario 7, and 2010 scenario 8)

Potential consequences associated with the fire occurring in forests (2)

- In Kiev, people have received around 10 µSv due to these fires
- Recent fire in February 2015 has reinforced the concern
- The remaining contamination in forests could be remobilized along with a large number of other dangerous, long-lived, refractory radionuclides.
- Prediction that an expanding flammable area associated with climate change will lead to a high risk of radioactive contamination with characteristic fire peaks in the future.
- Current fire-fighting infrastructure in the region is considered inadequate due to understaffing and lack of funding.

Strategies for managing the situation

Identified strategies based on Chernobyl feedback experience

- *Restrictions and advices:*
  - Restrictions on gathering wild foods
  - Advice on the use of wood ash as a kitchen garden fertiliser
  - Selective harvesting of trees

- *“Active countermeasures”*
  - Forest soil treatment with potassium fertilisers and/or lime
  - Prevention of fire in forests
  - Pruning/defoliation of fruit trees and vines

Management of contamination of forests in Vosges region (France -1996) (1)

- In Vosges region (East part of France), great concern in 1996 due to:
  - Positive result of WBC for a young adult
  - Measurement of wild boar meat up to 2,000 Bq/kg
- Decision to organise a large measurement campaign of gamma radiation of forest areas (35 km^2) by helicopter
  - Average value: 5,500 Bq/m^2 ($\pm$ 2,000 Bq/m^2)
  - Maximum value: 24,000 Bq/m^2
- Estimation of internal exposure associated with higher values of wild food contamination:
  - Wild boar (200 g/week with 2,000 Bq/kg): 0.3 mSv/y
  - Mushrooms (100 g/week with 1,250 Bq/kg): 0.08 mSv/y

Management of contamination of forests in Vosges region (France -1996) (2)

- Decision to increase the monitoring in the region:
  - Measurement of 120 samples of food products in 1997
  - Enquiry through the national network of wild animal mortality
  - WBC survey for local population

Handbook describing the strategies (1)

- Development of strategies for preparedness in European research project EURANOS, based on Chernobyl feedback experience
- Preparation a datasheet template to facilitate comparison between countermeasure options
- The template includes:
  - Short description of the countermeasure,
  - Key attributes
  - Constraints
  - Effectiveness
  - Feasibility
  - Waste generated
  - Doses incurred
  - Costs
  - Side effects
  - Practical experience

Handbook describing the strategies (2)

Forest soil treatment with potassium fertilisers and/or lime

- Distribution of mineral fertilisers (NPK, PK), wood ash, lime to forest floor by ground level machine, hand distribution or by helicopter;
- Application rate has to be in reasonable relation to the nutrient status of forest
- Nitrogen and/or phosphorus are needed, together with potassium to improve tree growth and to counteract possible imbalances.
- Repeated applications may be necessary

Handbook describing the strategies (3)

Prevention of fire in forests

  - 40-70% of the Cs stored in vegetation could be released in the atmosphere during a fire
- Proposed countermeasures:
  - **Closing forests** and semi-natural areas to the public and banning any practices likely to cause fires
  - Actions to **prevent initiation and spread of fire** in most sensitive areas (e.g. railways, roads, electric lines, rubbish dumps):
    - Install/ maintain concrete barriers, safety fences or netting.
    - Widening of the road hard shoulders.
    - Improving inspection, surveillance networks.
    - Fuel management/clearing of dry vegetation from shrubland
  - Increase **readiness for fire fighting** in affected areas

Handbook describing the strategies (4)

Pruning/defoliation of fruit trees and vines

- If deposition occurs when trees are in leaf, foliar interception, retention and absorption of radionuclides are the dominant processes of contamination for fruit bearing plants.
- Following uptake by leaves, radionuclides can be translocated to fruits and other parts of the plant.
- **Countermeasures to be implemented**: Pruning and/or defoliation by chemical, mechanical or manual methods soon after deposition to prevent or reduce the translocation of radionuclides from leaves to the other plant components

Developing the radiation protection culture among the inhabitants

Co-expertise and radiation protection culture (1)

- The process of co-expertise relies on:
  - Establishment of places for dialogue allowing experts to listen and discuss together with affected people their questions, concerns, challenges, but also expectations
  - Assessment conducted jointly by locals and experts on the situation of the people and their community
  - Implementation of projects to address the problems identified at the individual and community levels with the support of local professionals, experts and authorities
  - Evaluation and dissemination of results

Co-expertise and radiation protection culture (2)

- Co-expertise leads to promote the practical radiological protection culture within the affected communities, defined as:

  The knowledge and skills enabling citizens to make choices and behave wisely in situations involving potential or actual exposure to ionizing radiation

- This progressively allows everyone to:
  - Interpret results of measurements: ambient levels, external and internal doses, contamination of products
  - Build her/his own benchmarks against radioactivity in day-to-day life
  - Make her/his own decisions and protect her/himself and loved ones = self-help protection
- Access to measurements by the people with suitable devices is critical

The ETHOS project and the CORE program in Belarus (1996-2008)

Approach based on the direct involvement of the inhabitants in their own protection with the help of the local and national authorities and experts

- The development of the radiation protection culture among the population based on 4 pillars:
  - A radiation monitoring of proximity
  - A practical education at school
  - An inclusive health surveillance
  - A cultural approach of the memory of the accident
- The setting up of social and economic measures to favour the local development

The ETHOS approach

1. **Listening and learning** from the villagers about their concerns, difficulties and wishes

2. Developing a **common evaluation** of the local radiological situation

3. **Implementing protective actions** for improving the local situation

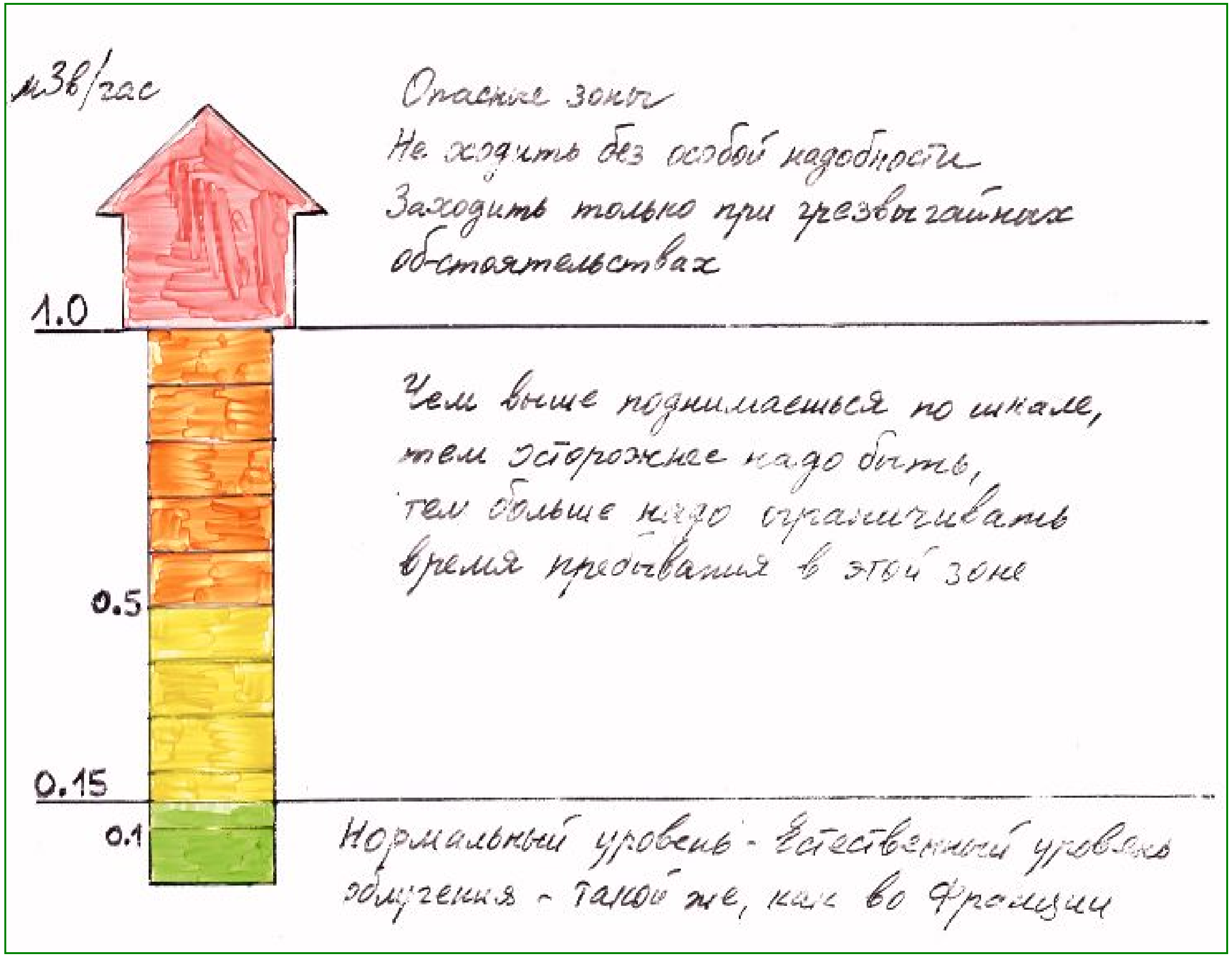
4. **Establishing (or re-establishing) links** between villagers and the local authorities and professionals

Listening about concerns - Public Meetings

Access to local expertise

Empowerment of villagers

Local farmers meeting



Radiological scale for external exposure adopted by a village

'Milk mapping' for summer production

Optimization of winter milk production of a “private” farmer (Selection of hay and use of Prussian blue)

The ethical principles underpinning the empowerment approach in post-accident situation

Following our experience in post-accident situation:

- **Some pitfalls have to be avoided** regarding people empowerment:
  - Trivialising the radiological risk
  - Abandoning people facing the risk alone
  - Manipulating people to make them staying in contaminated area
  - Trying to protecting people without (against ?) them
- **Ethical principles have to be adopted**:
  - Refusal to take decision for the people about their future (respect of their autonomy and freedom)
  - Commitment to be at the service of improving the protection and living conditions for the population (well-being)
  - Adopting a prudent attitude toward the radiological risk

Conclusion

- Decontamination of forests rather limited after the Chernobyl accident
- Still a concern more than 29 years after the accident for the consumption of products from the forests
- Organisation of vigilance for avoiding fires in forest areas
- Development of monitoring and radiation protection culture for managing the risk associated with contaminated forests

Main references

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