Food management following the Chernobyl Accident

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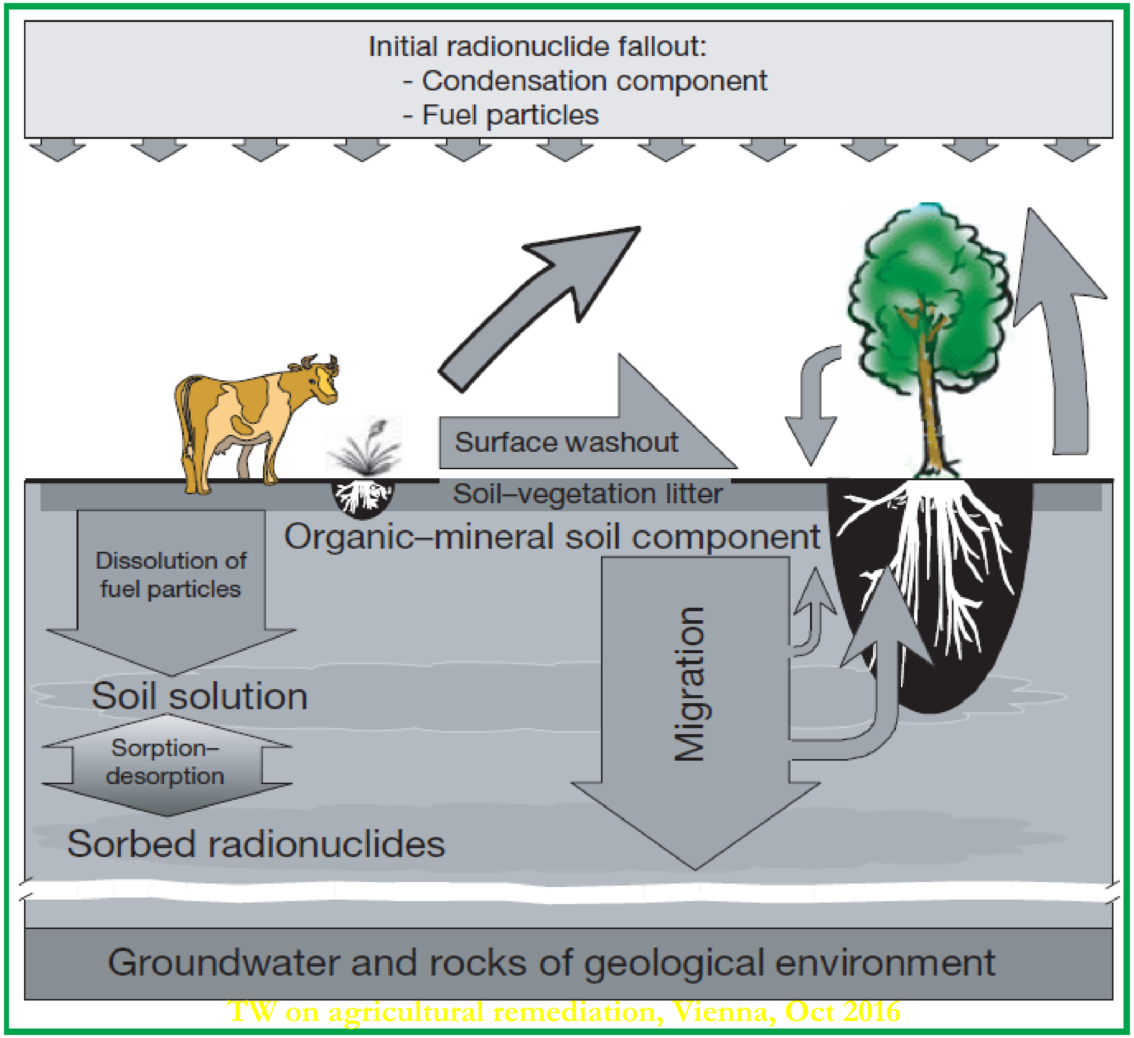
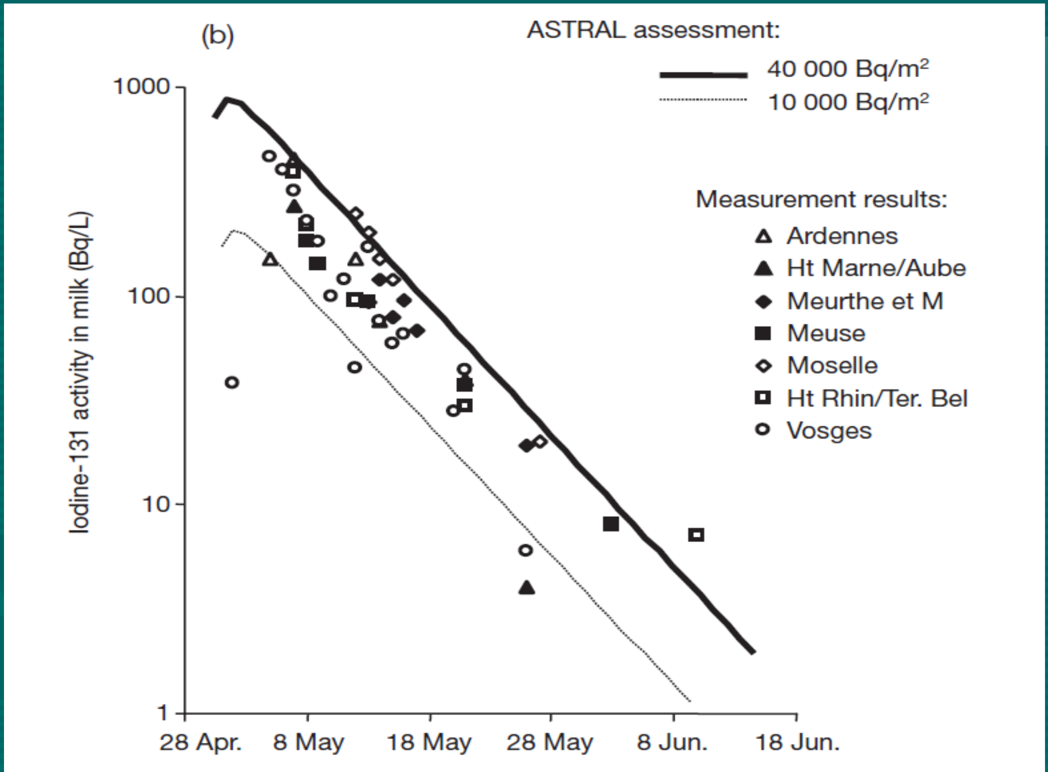
Main transfer pathways of radionuclides in terrestrial environments



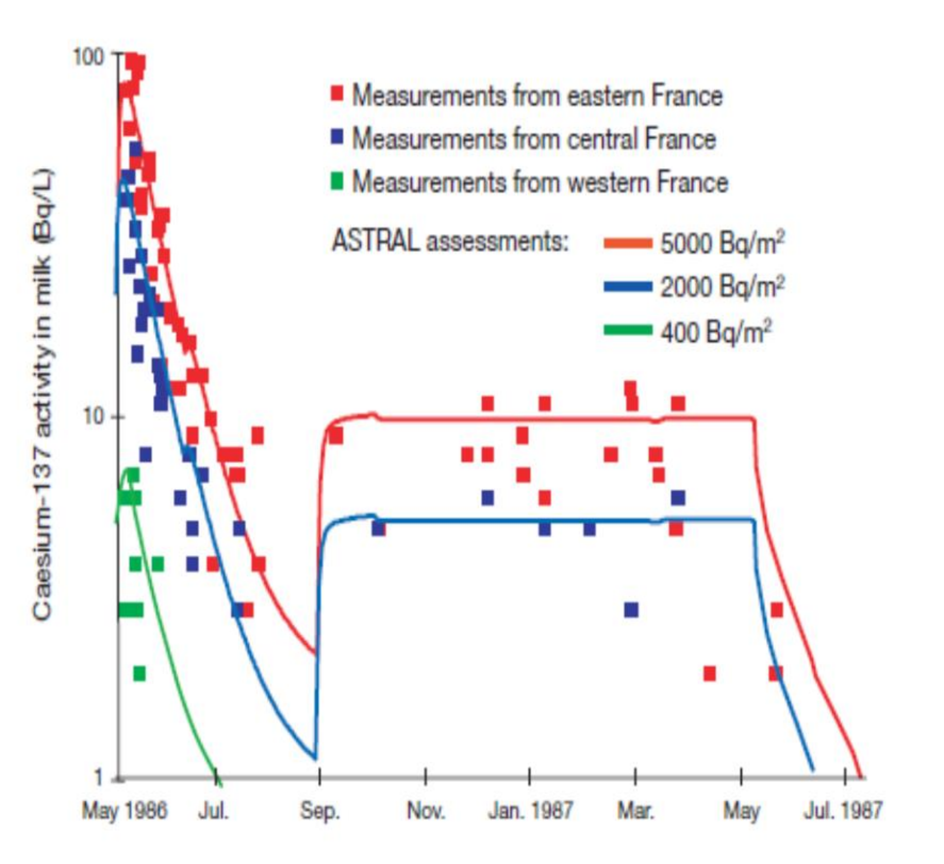
^{131}I dynamics in milk in France [Renaud et al 1999]

- Effective half-time 4-5 d
- Reduction by a factor about 1000 in two months
- Processes: radioactive decay, plant growth and weathering
- Short-lived iodine radioisotopes essentially absent in foods

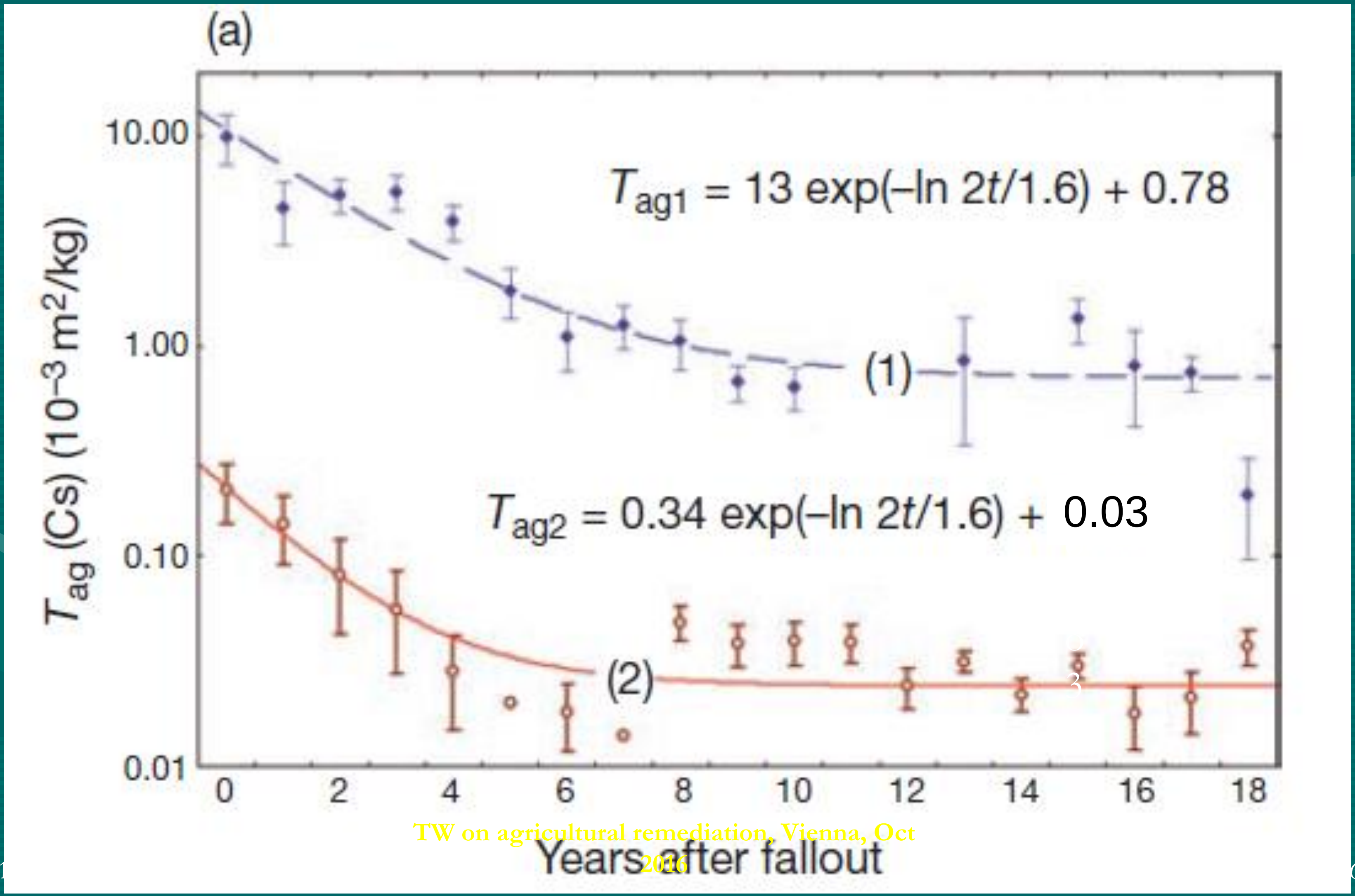


Cs-137 in milk in France soon after the Chernobyl accident [Renaud et al 1999]

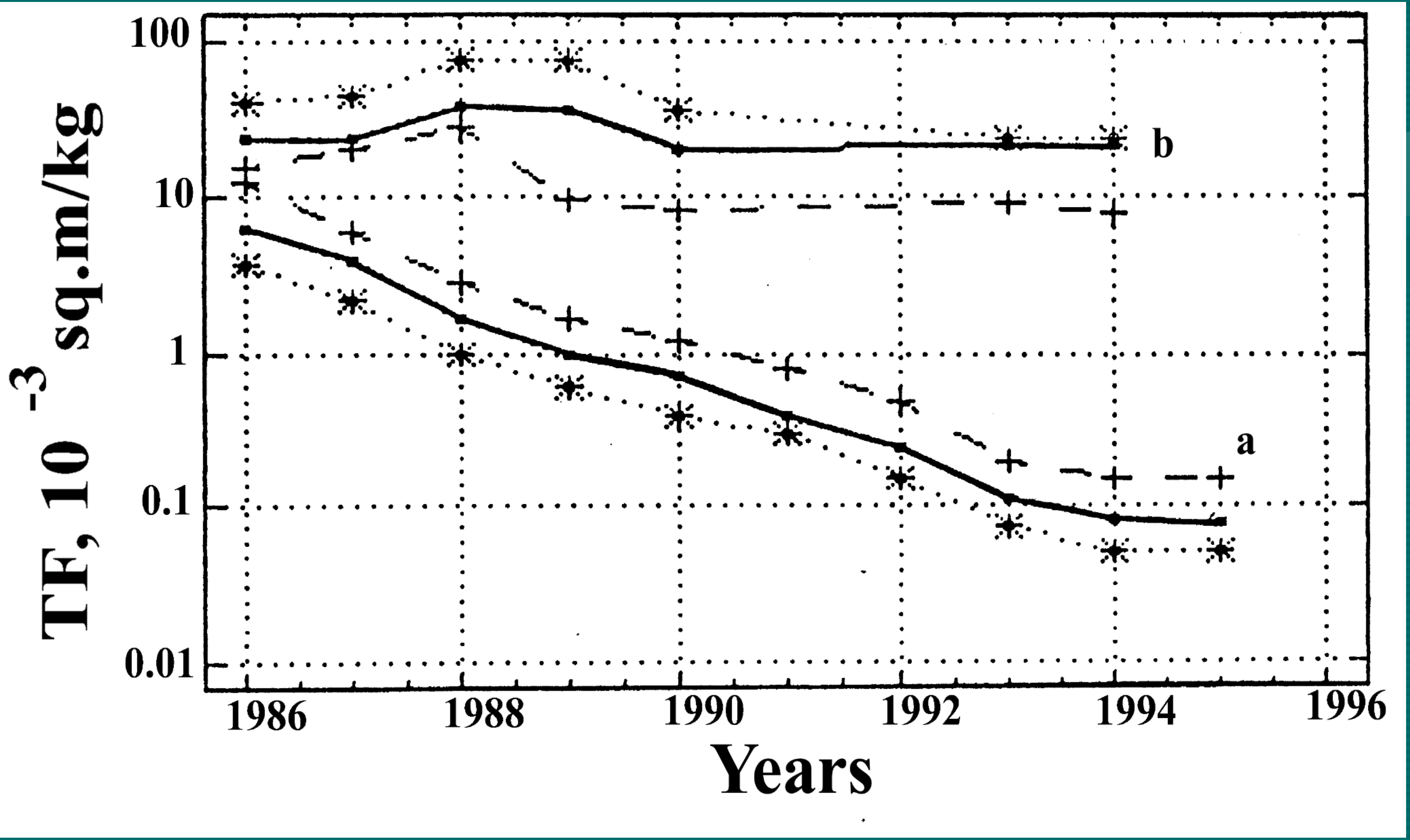
- Initial effective half-time of 10-15 days
- Reduction by a factor about 10-30 in 100 days
- Processes: radioactive decay, plant growth and weathering
- Contaminated fodder used in autumn-winter 1987



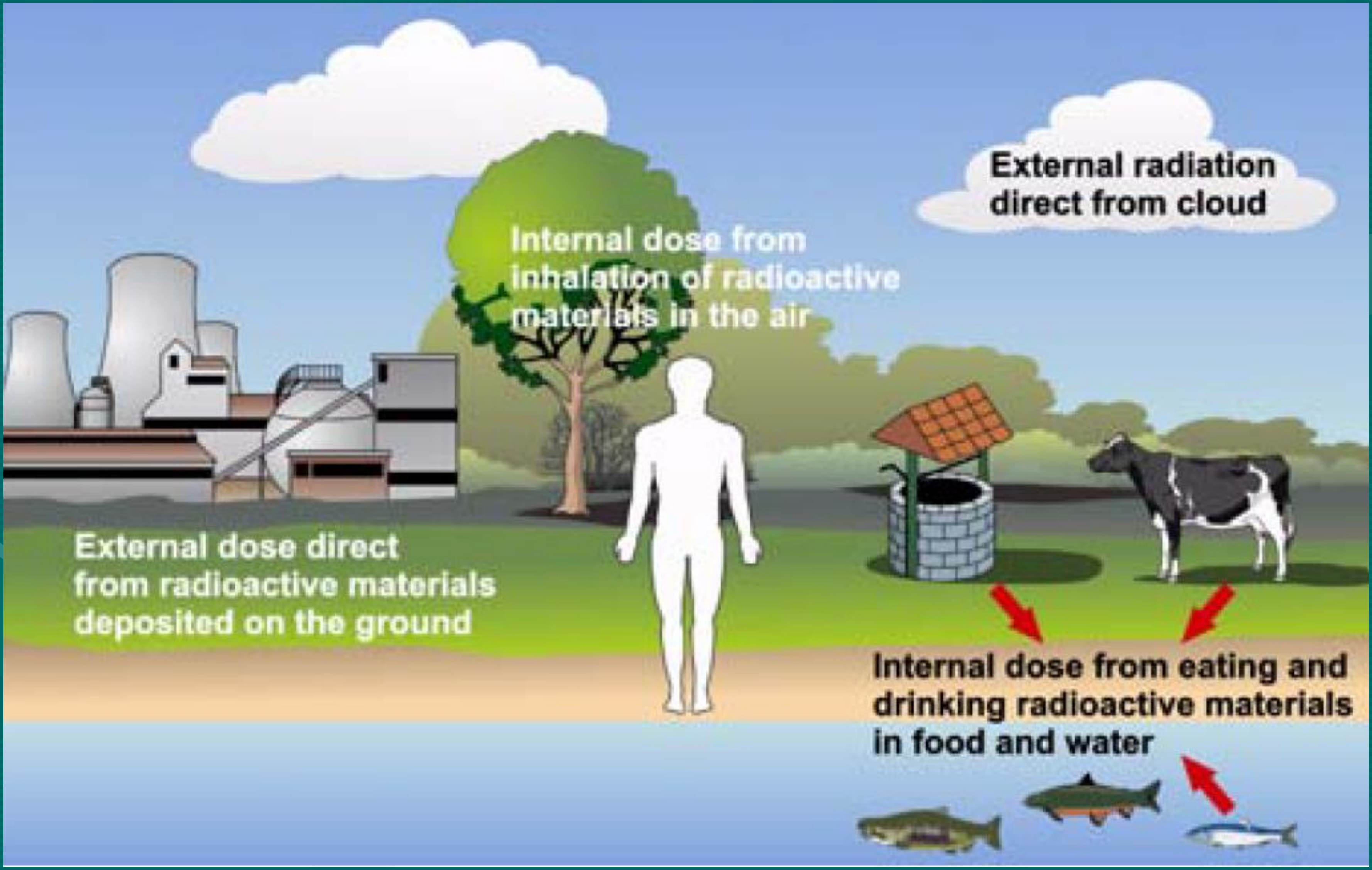
Dynamics of Cs-137 transfer to cow milk after the Chernobyl accident



Typical dynamics of ^{137}Cs transfer from soil to milk (a) and mushrooms (b, Boletus luteus)



Human exposure pathways



Contribution of ingestion to public exposure depends on:

- Radionuclide composition (half-life, radiation type and energy, environmental mobility, metabolic properties)
- Natural conditions (environment, climate, soil type, season)
- Agricultural practices (plant/animal breeding, crops, technologies)
- Population food habits (food preferences, use of ‘wild food’, cooking)

Radionuclide intake in the human body and associated effective dose

- **Intake in the Human Body:**

$$I_r(0,t) = \int_0^t dt \cdot \sum_k V_k(t) \cdot C_{kr}(t)$$, Bq

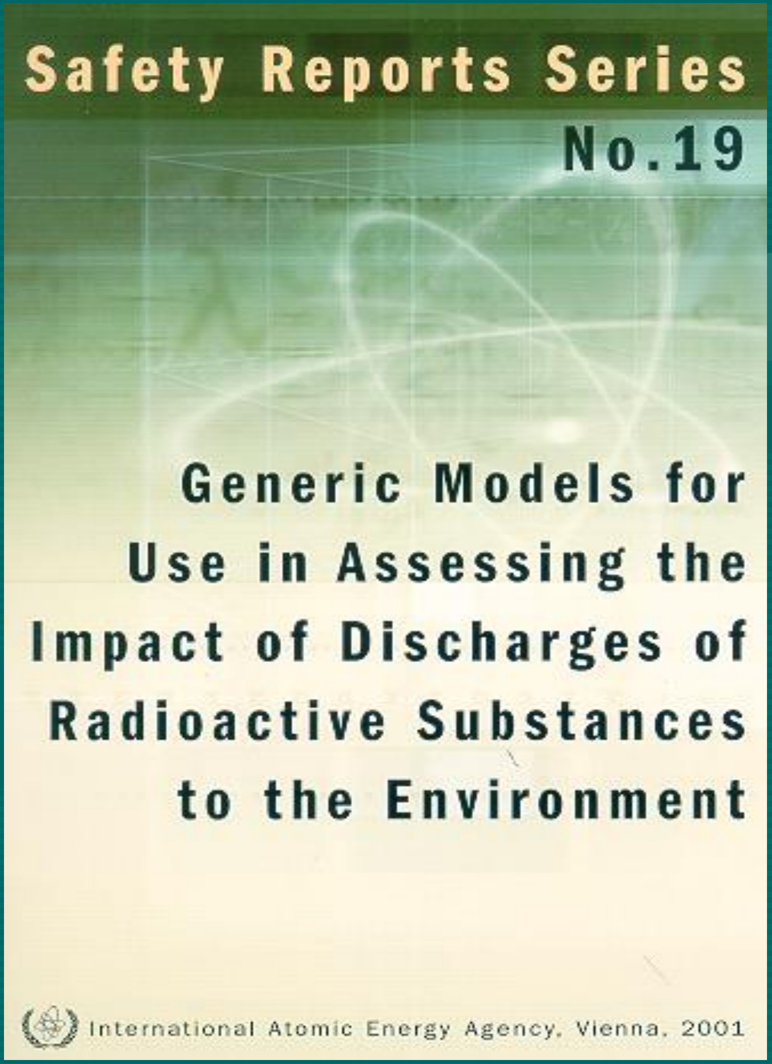
Where V_k is consumption rate,

C_k is radionuclide concentration in product *k*.

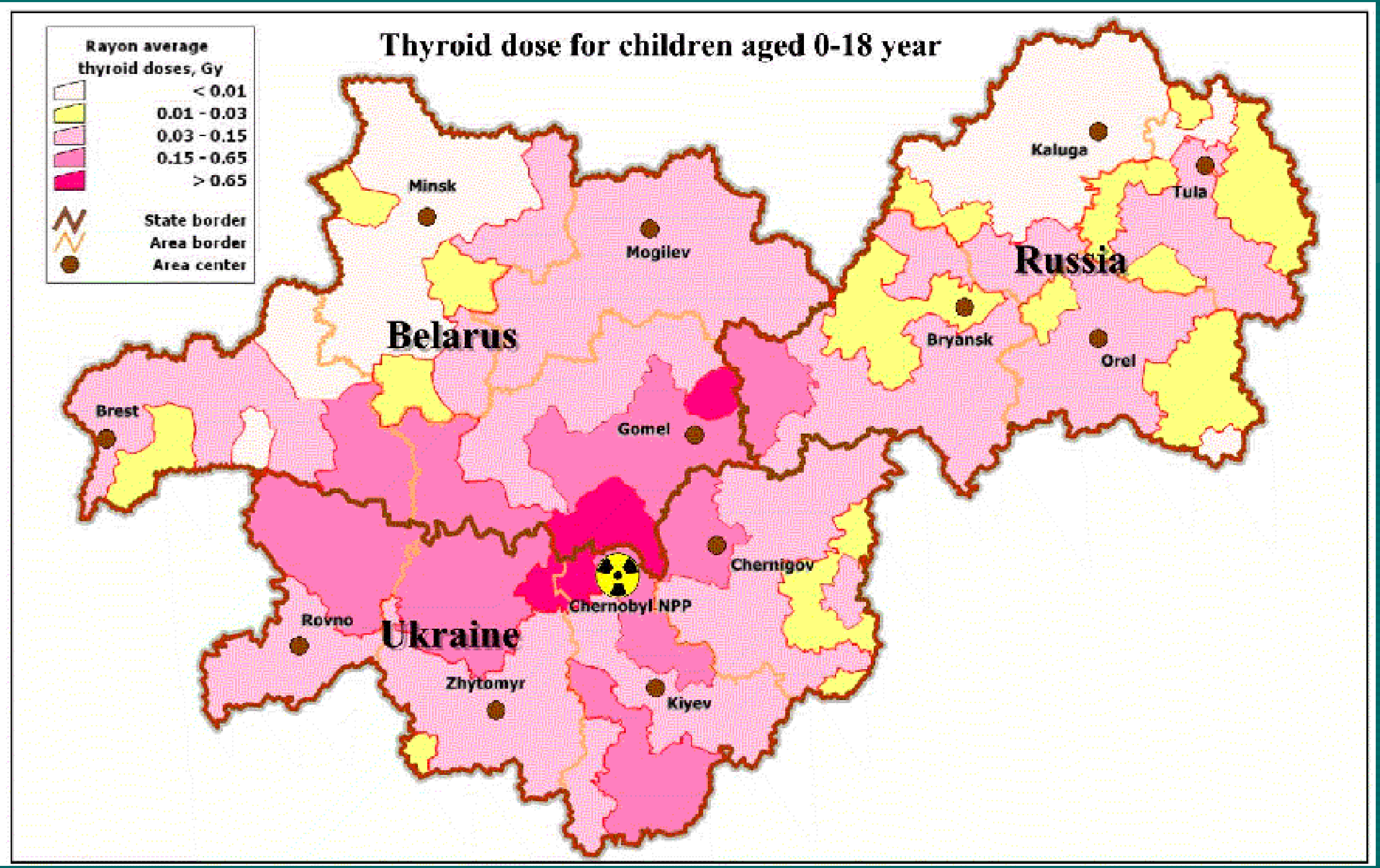
- **Effective internal dose:**

$$E = I_r \cdot d_r \text{ (mSv)}$$

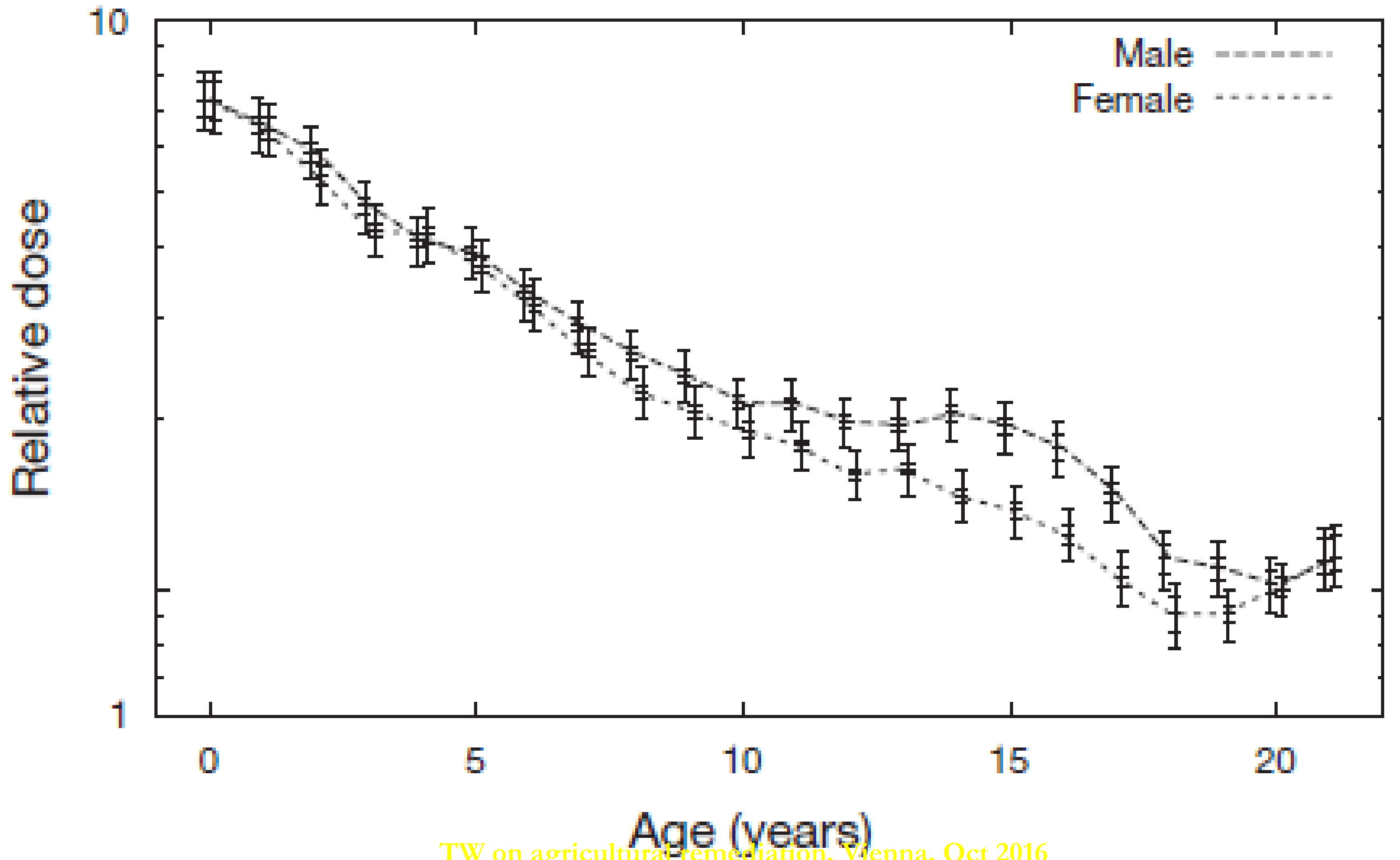
Where d_r (mSv/Bq) is dose coefficient (ICRP-56, -67; BSS)



Average thyroid doses of children and adolescents living in the most affected regions [UNSCEAR 2008]



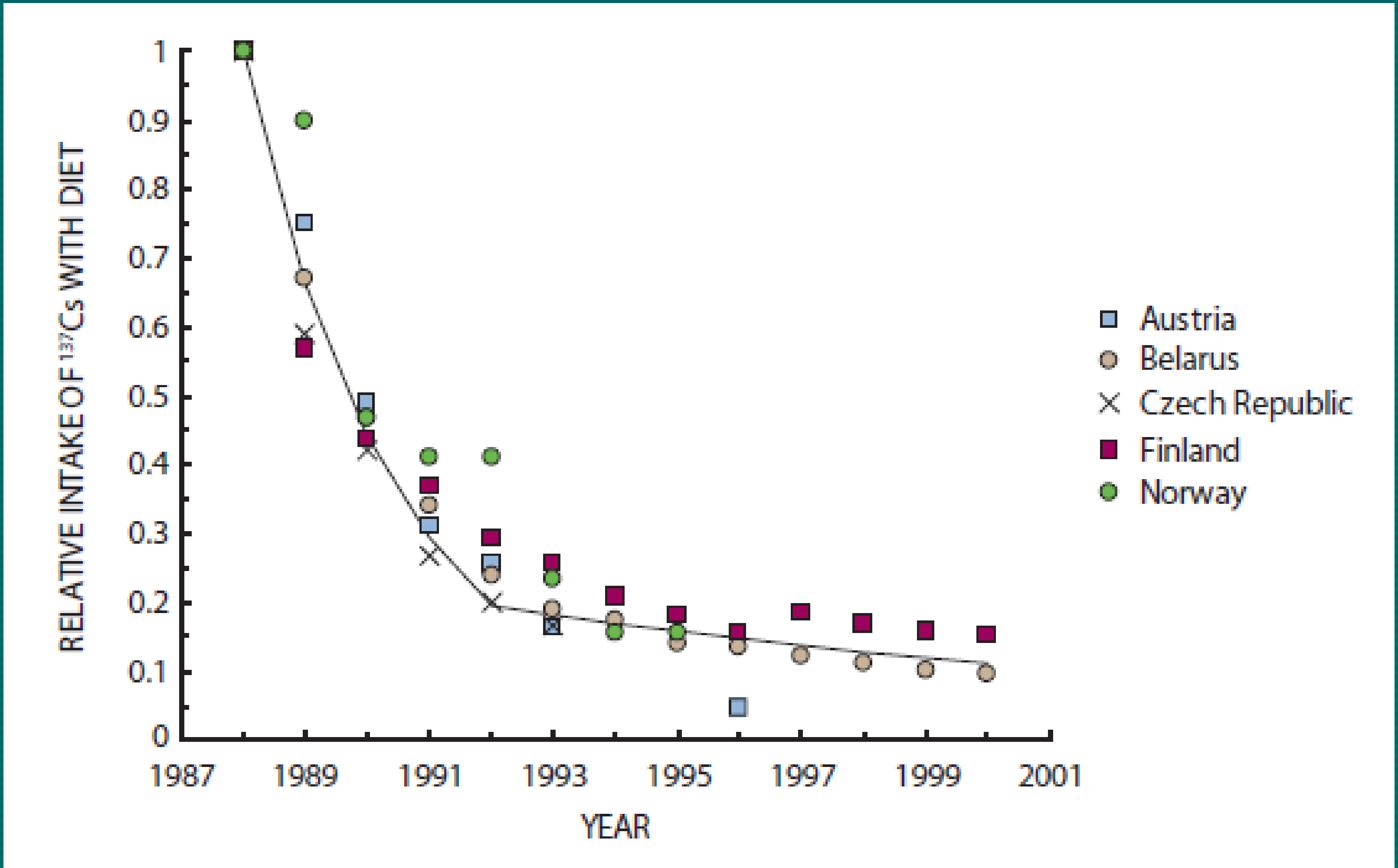
From 350 ths.thyroid measurements: Age-sex dependence of the mean thyroid dose of inhabitants of a settlement [Heidenreich et al 2001]



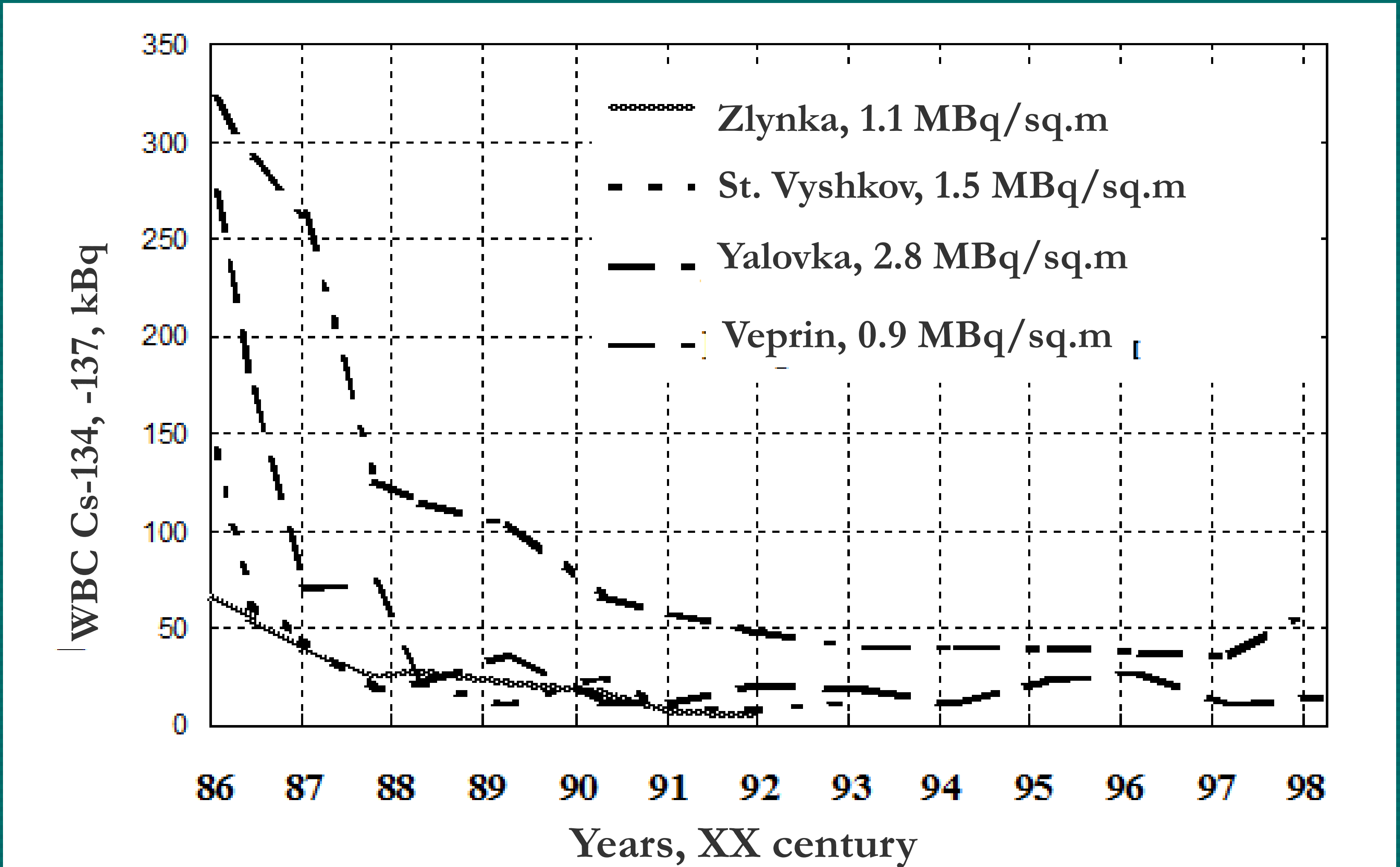
Collective thyroid doses in the three more affected countries

Country	Collective thyroid dose (ths. man·Gy)
Belarus Russian Federation Ukraine	550 200-300 740
Total	1 500-1 600

Long-term time dependence of Cs-137 dietary intake in Europe [Drozdovich et al 2007]



Dynamics of Cs-137, -134 whole body content in adult residents of some Bryansk villages, Russia



Mean Chernobyl related effective internal doses of adult rural residents (mSv) over first 20 y and afterwards

^{137}Cs in soil, MBq/m^2	Soil type/Time period					
	Black		Podzol		Peat	
	1986–2005	2006–2056	1986–2005	2006–2056	1986–2005	2006–2056
0.04–0.6	1–10	0.1–1	3–40	0.4–6	10–100	1–20
0.6–4	–		40–150	6–30	–	

Collective effective doses in 1986–2005 to the populations of Belarus, Russia and Ukraine, thousand Man-Sv

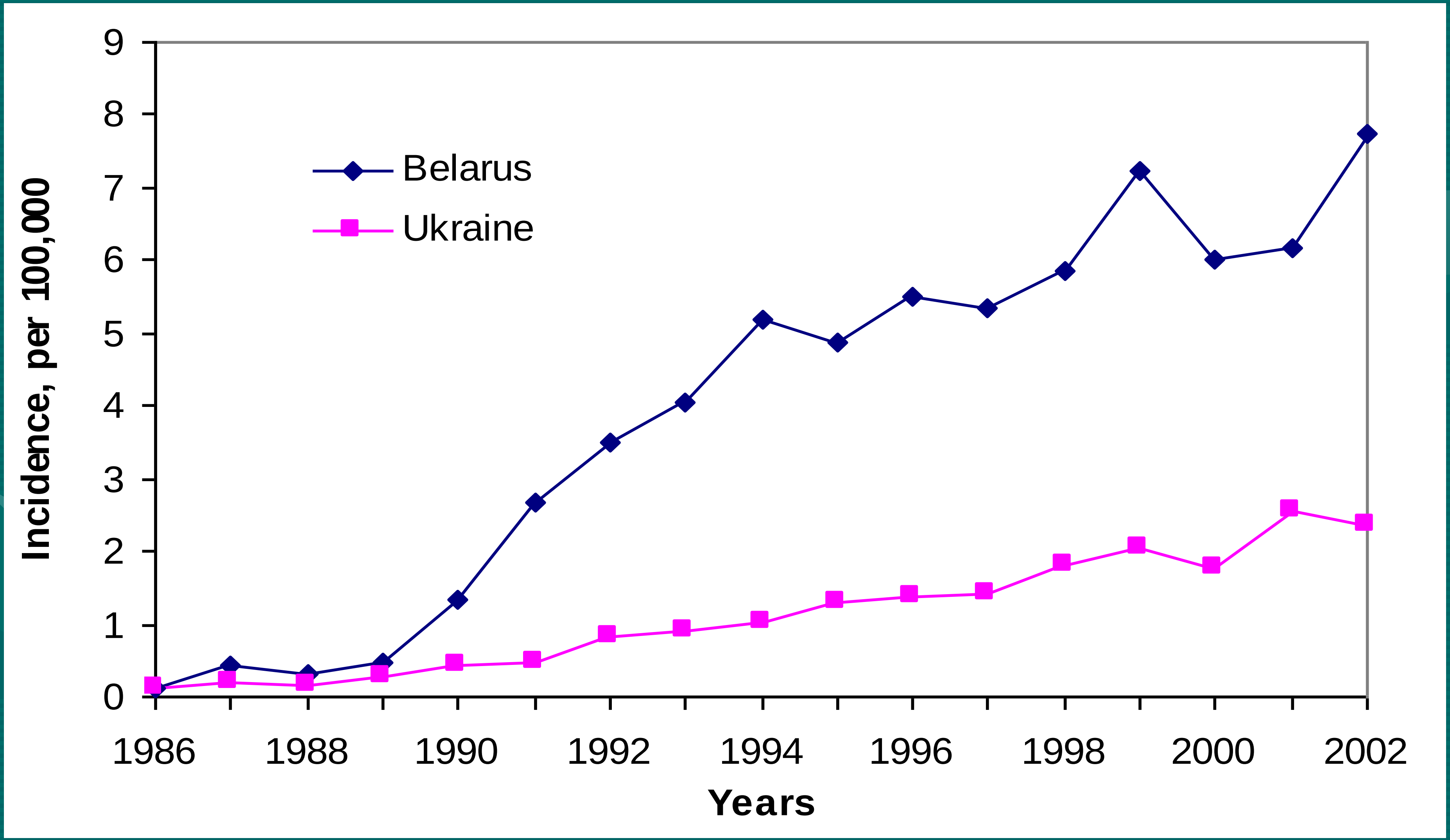
Country	Population, million persons	Collective dose, 1000 man Sv		
		External	Internal	Total
Belarus	1.9	12	7	19
Russia	2.0	11	6	17
Ukraine	1.3	8	9	17
Total	5.2	31	22	53

[a]Excluding thyroid dose.

Thyroid cancer

- Children and adolescents in B, R and U received in spring 1986 substantial thyroid doses due to the consumption of milk contaminated with radioiodine.
- In total, about 7000 thyroid cancer cases have been detected in this cohort (~ 18 mln) during 1991–2005; many of them are likely to be associated with radiation exposure.
- More than 99% of cases were successfully treated, but fifteen persons died (as of 2004).

Incidence rate of thyroid cancer in children exposed to ^{131}I due to the Chernobyl accident (Jacob et al., 2005)



Major components of post-Chernobyl food management

- Food safety standards
- Food monitoring and inspection
- Agricultural countermeasures
- Provision of clean food (mostly, milk and meat over the 1^{st} year or longer)

Food safety standards

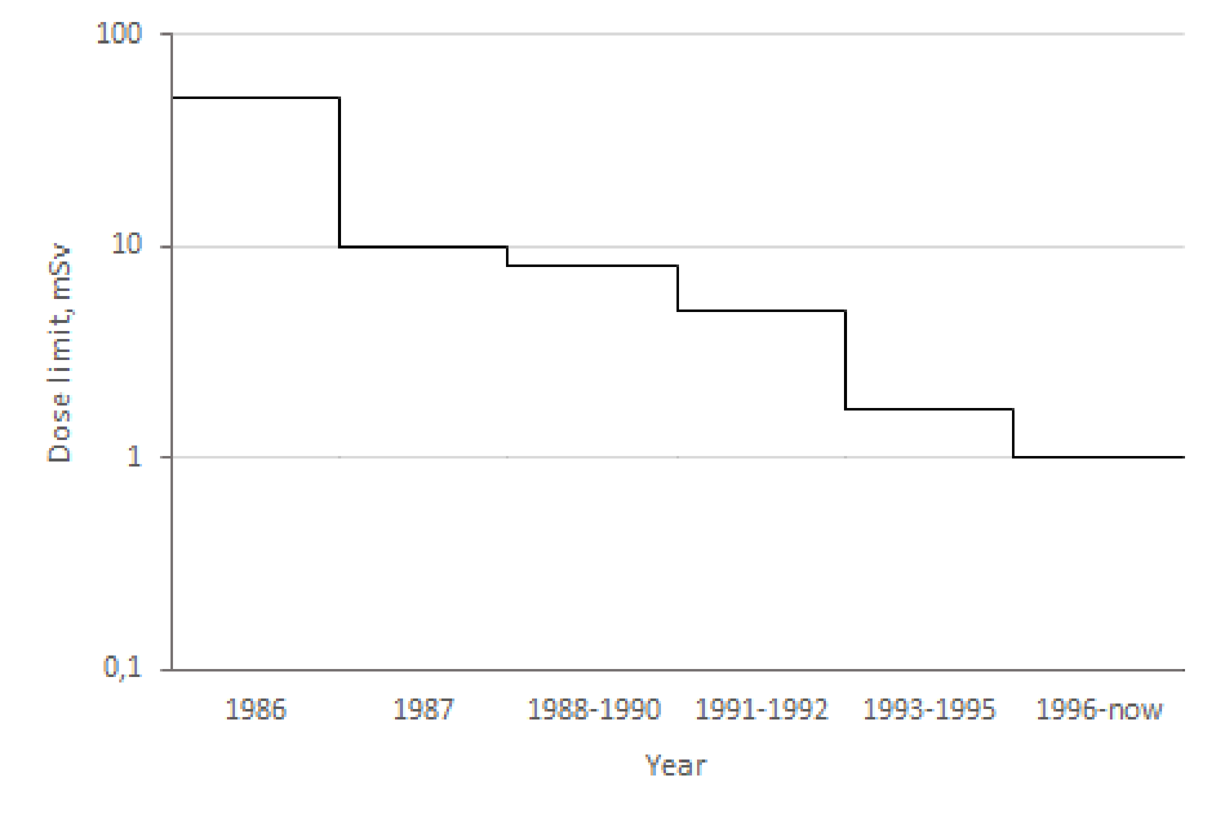
- FSU standards (TPL) for radionuclides in foods established since May 1986 and gradually reduced
- Special model has been applied to define TPL values (Bq kg^{-1}) for radionuclides in various foods.
- EC-1986 for Cs-137 in post-Chernobyl period established in 1986 and kept until now:
  – 370 Bq/kg for milk and baby food, and
  – 600 Bq/kg for the rest

In the FSU, different TPLs were established for N groups of foods with account for radioecological or technological ratios of their radionuclide concentrations [1987, 1990, etc]

$$TPL_i = \frac{DC \cdot k_i}{e_{ing}(>17) \cdot \sum_{i}^{N} m_i \cdot k_i}$$

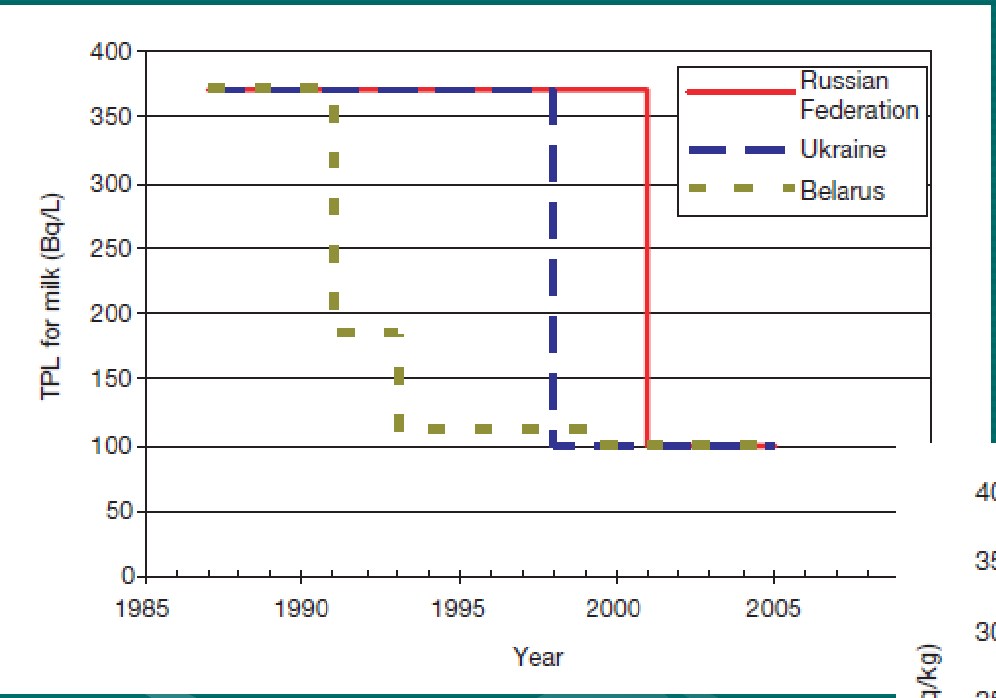
- ***DC*** is the individual dose criterion for food (mSv);
- $\boldsymbol{k_i}$ is the ratio of the radionuclide concentration in the *i*-th group of food products to that in milk;
- $\boldsymbol{e_{ing}(>17)}$ is the ingestion dose coefficient for adults (mSv/Bq) – ICRP-56, 67,72;
- $\boldsymbol{m_i}$ is the mass of *i*-th group of food products consumed by an adult per year (kg).

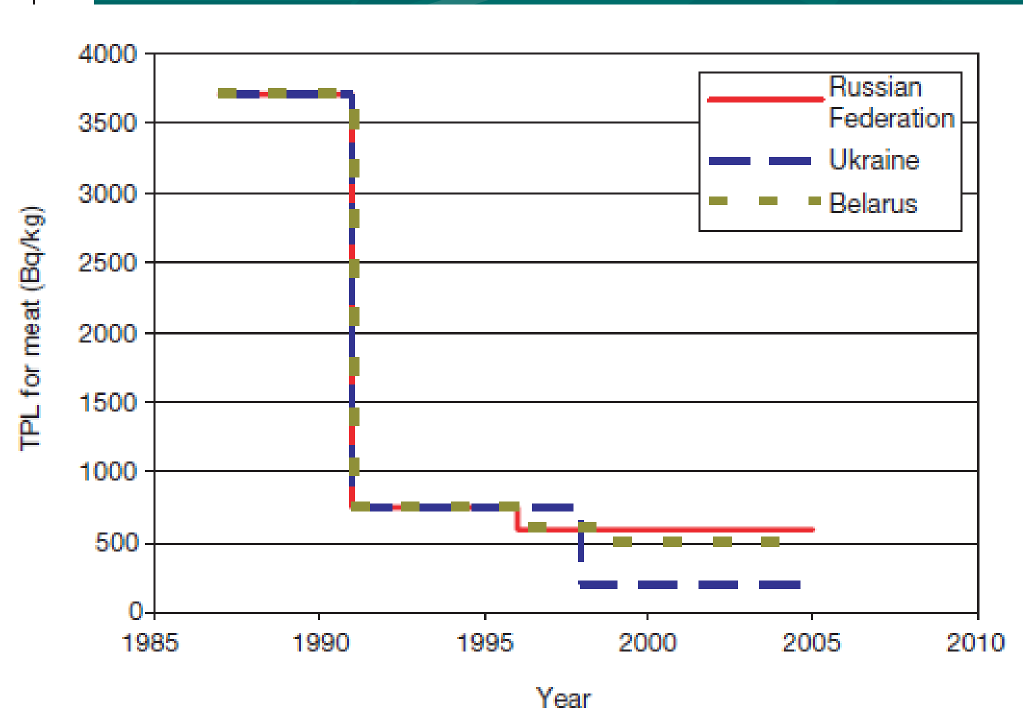
FSU dose criterion for food control (mSv per year)



- Post-Chernobyl dose criteria for food control were enforced by factual radionuclide content in foods
- USSR NCRP reduced them gradually along with reduction of factual radionuclide content in foods
- The approach is similar to current Reference Levels

Changes with time of TPLs for milk and meat in USSR, Belarus, Russia and Ukraine





Food monitoring and inspection

- Important component of the post-Chernobyl control of internal exposure of the public
- ^{131}I, ^{137}Cs and ^{134}Cs, ^{90}Sr
- Two inspection levels:
  - at agricultural production plants, and
  - foods ready for cooking and consumption as distributed through food markets and shops
- In 1986:
  - about 1000 labs, including 16 mobile ones, 3500 specialists using 3250 measurement devices;
  - 700 ths. milk samples, 120 ths. meat samples, more than 1 mln. other food samples and 500 ths. DW samples

Food-related countermeasures (protective and remedial actions)

- Food monitoring and inspection
- Agricultural countermeasures:
  - Soil-based (special ploughing, fertilisation, etc.)
  - Plant-based (change of crops, etc.)
  - Animal-based (clean fodder, Prussian Blue, etc.)
- Food processing (milk to butter and cheese, boiling of mushrooms, etc.)
- Some change of human food habits (restricted consumption of wild food, etc.)

Post-Chernobyl remedial actions [Jacob et al. 2009]

Remedial action	Reduction factor	Time of effectiveness	Costs (€)	Degree of acceptability
Radical improvement of pasture	1.7 – 8	4	350–2350 per cow	1.0
Ferrocyn application to cows	2 – 3	Time of application	30–60 per cow	0.75
Clean feed for pigs	3	Time of application	6–20	0.6
Mineral fertiliser for potatoes	2	1 year	0.8–2.5	1.0
Public information on "wild foods"	1.5	2 years	3	0.5
Removal of contaminated soil	1.5	Infinite	525	0.1

Averted collective internal effective dose (thousand Man-Sv) following countermeasure implementation in agriculture (1986-2005)

Farming	Belarus	Russia	Ukraine	Total
House-hold	2 - 3	1 – 2	1 – 2	4 – 7
Collec-tive	4 - 6	2 – 3	2 – 3	8 - 12
Both	6 - 9	3 - 5	3 - 5	12 - 19

Excluding thyroid dose

Conclusions and Lessons

- Ingestion dose substantially contributed to the dose of the public. It dominated in the thyroid dose and comprised more than 40% of the collective effective dose in B, R and U.
- Intake of ^{131}I with foods (mostly, milk) have led to increased thyroid cancer incidence in children (as of 1986).
- Ingestion dose of the public from ^{137}Cs and ^{134}Cs strongly depends on soil conditions and agricultural practices. In some regions radionuclide intake with wild food is substantial.
- Post-accident food management may require:
  – Introduction of food safety standards
  – Food monitoring and inspection
  – Agricultural countermeasures
  – Provision of clean food
- Agricultural countermeasures and provision of clean food averted about 30% of internal effective dose of residents of the affected areas of B, R and U (excluding thyroid dose).

Thank you for your attention!