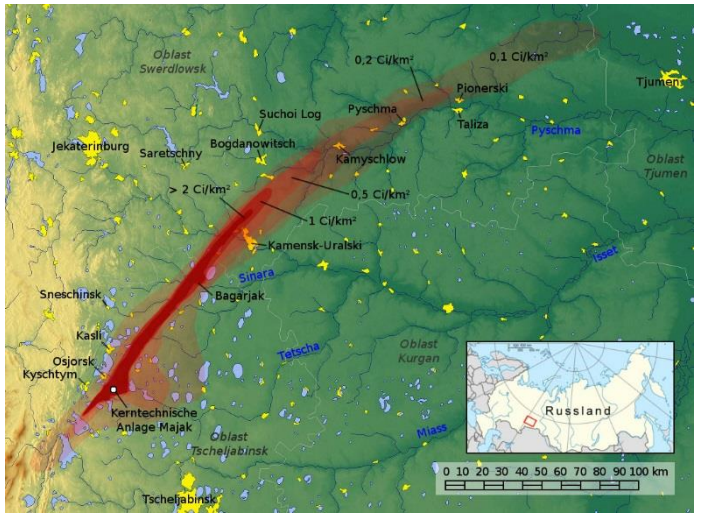
NUCLEAR ACCIDENTS

Relevant accidents for animal products

Radioactive atmospheric releases (TBq)				
Isotopes	Kyshtym	Windscale	Chernobyl	Fukushima Daiichi
I-131	NA	1800	1,760,000	100,000-400,000
Cs-137	260	180	~85,000	7,000-20,000
Cs-134			~47,000	8,300-20,000
Po-210		42		
Sr-90	2,000	0.75	10,000	3.3-140
Pu isotopes	3	0.02	6,100	0.0035-1.2
Zr-95	18,400	16	196,000	17
Ce-144 & 141	48,700	13	212,000	11
Ru-106	2,700	3	>73,000	0.002

Kyshtym accident

- 29 September 1957
- Producing weapons grade Pu at Chelyabinsk-40 (now Ozersk), Urals, USSR
- Failure of cooling system for storage tank
- Non nuclear thermal explosion
- Contaminated plume - East Urals radioactive trace (EURT)



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Batorshin et al 2013 Experience in eliminating the consequences of the 1957 accident at the Mayak Production Association. IEM, IAEA

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Emergency phase - countermeasures

- EURT 23000 km^2
  - defined as: ^{90} Sr deposition density> 3.7 kBq / m^2
- Major initial contributor to dose was external γ radiation
- Highest rad content in most foodstuffs - ^{144} Ce & ^{95} Zr (60-70%) ([total rad]10-10000 kBq/kg dw)
- Milk – ^{90} Sr was 70% of rad content of milk
- Food intervention limits imposed

Fesenko et al 2010 Remediation of contaminated environments: description of case studies. In TRS 475, ed Fesenko and Howard.

Remediation

- Long term intensive remediation from spring 1958
- Focus on deposition density and soil type
- High ^{90}Sr uptake in some soils with low exch[Ca]
  - Grey forest soils, chernozem, acid soils
- Remediation strategy focused on agricultural, fisheries and forestry production
- Remediation reference level – 74 kBq.m^2 ^{90}Sr
  - 1000 km^2, 55% agricultural land

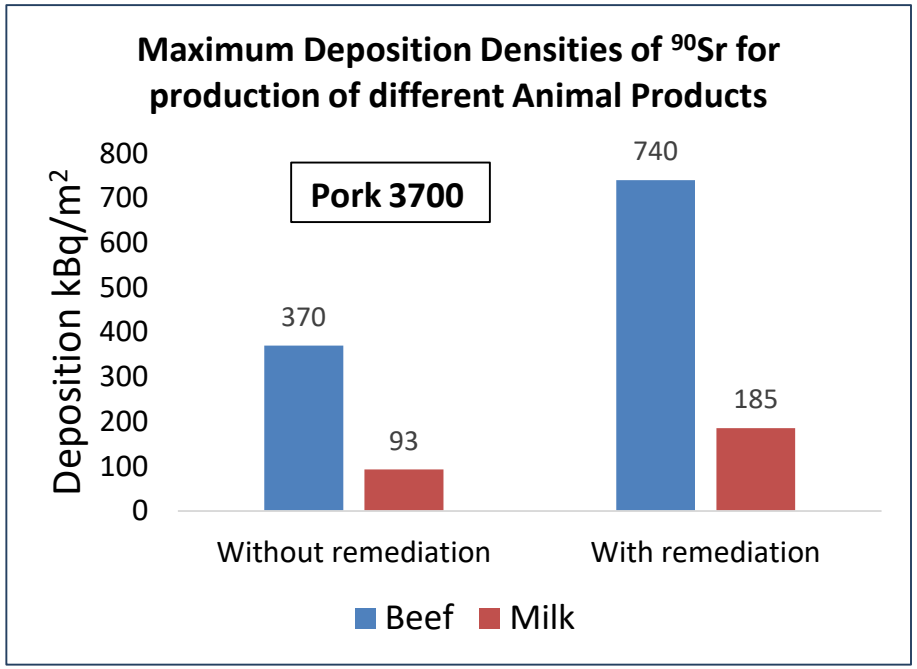
Remediation of animals

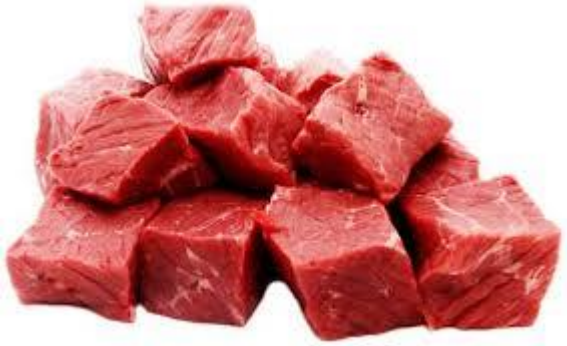
- ^{90}Sr mainly deposited in animal bones
  - the long biological half-life of ^{90}Sr in the bone led to sustained secretion of ^{90}Sr into milk
- enhanced contamination if there is chronic ^{90}Sr intake by dairy animals
- Ingestion of contaminated food was key long term exposure pathway, only milk 5-8 y after accident

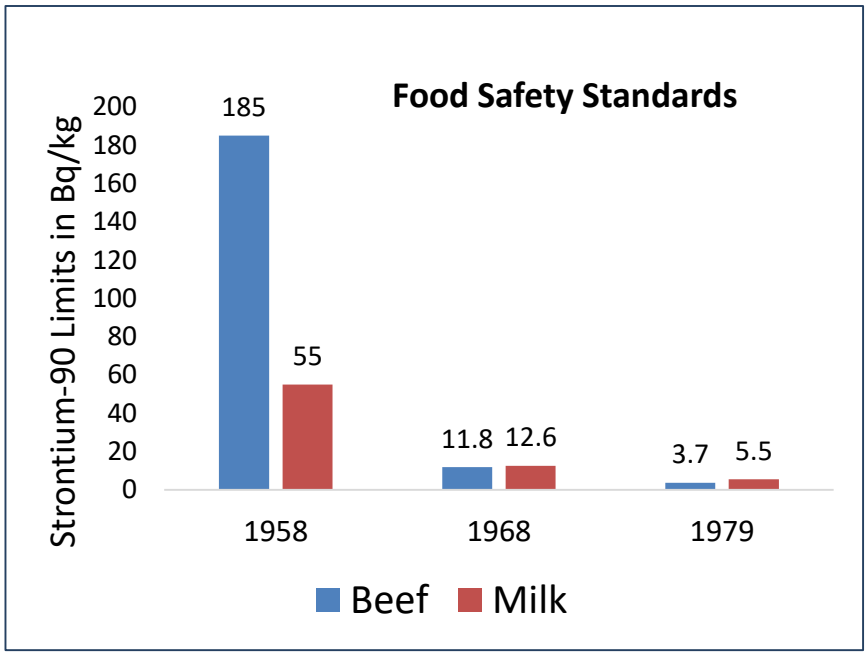
Remediation options used

- Topsoil removal
- Deep ploughing, shallow ploughing
- Turnover ploughing
- Liming and extra mineral fertilisers
- Selecting crop varieties
- Preference to pig and poultry production

Remediation reference levels







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Clean feeding

- Objective is to prevent or control the contamination of animal products by ensuring that feedstuffs which are too highly contaminated are not ingested by agricultural animals.
- one of the most highly preferred options for animal products by stakeholders (including farmers)
- one of the most effective and practically applicable measures for agricultural animals
- used extensively

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Clean feeding

- Agricultural animals given nutritionally balanced diets
  - either un- or low level contaminated feed
- Needs production of suitable, local forage

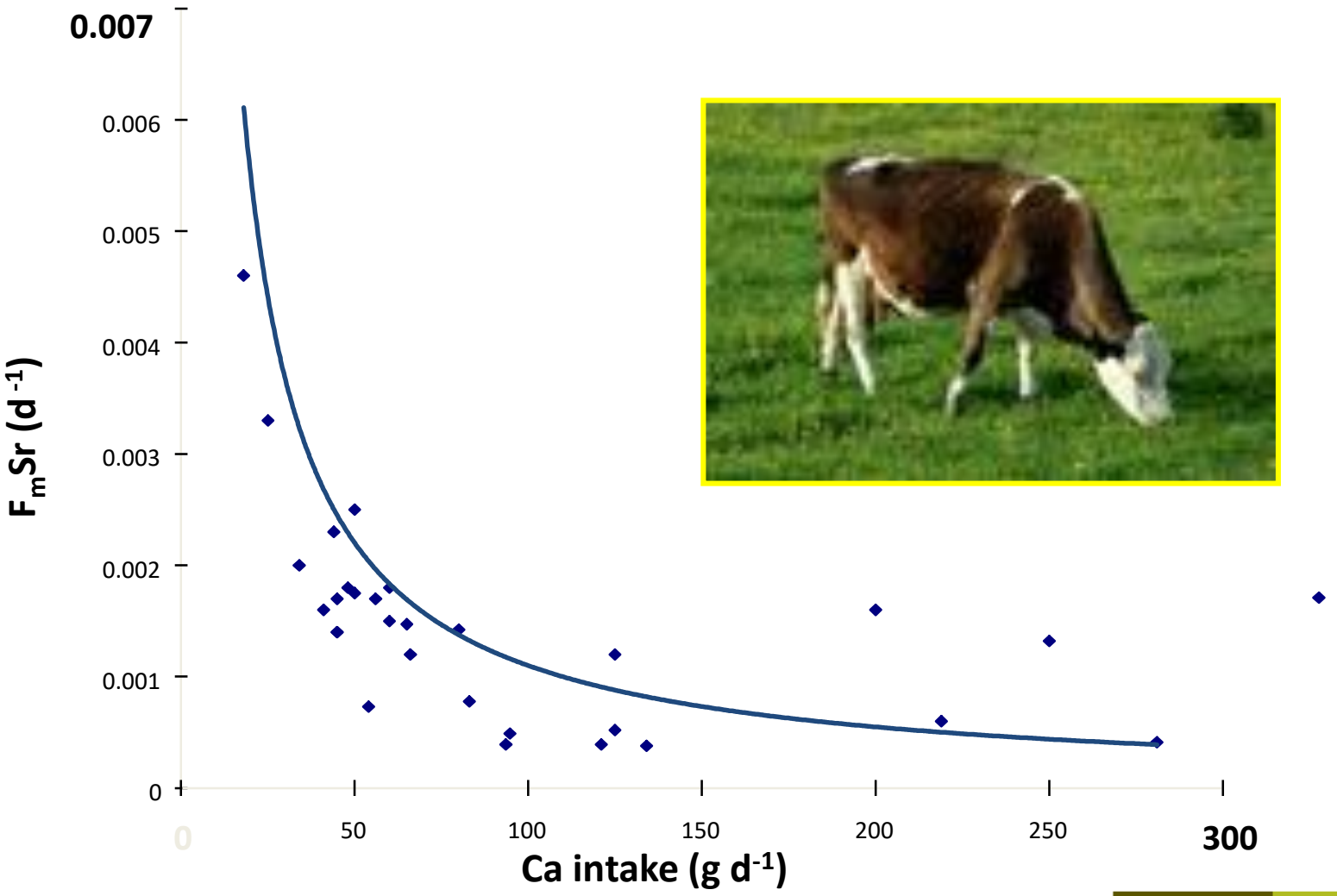
✓ Ensures animal products (normally milk or meat) have activity concentrations below the specified limit

✓ Much easier to control if animals are housed

✓ Wastes - faeces and urine do not require special disposal routes

✓ Reduces amount of waste milk and meat from otherwise contaminated animals

Effect ca intake on ^{90}Sr transfer to milk



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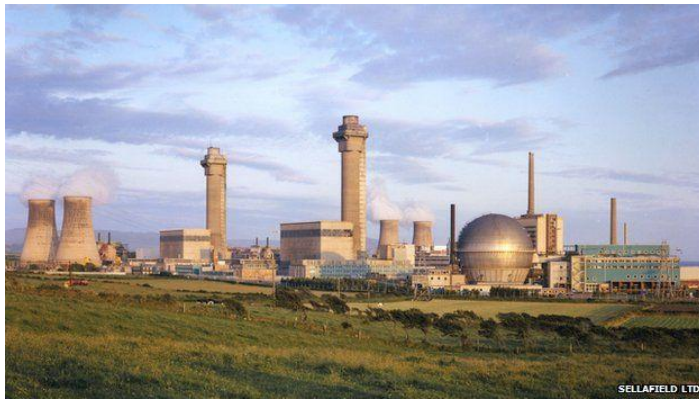
Windscale

- 10 October 1957
- Supplying Pu for British atomic bomb project and to generate other nuclides through the neutron irradiation of appropriate materials placed in channels within the core
- Stored Wigner energy lead to a fire in Unit 1 for 3 d
- INIS level 5
- Key releases - ^{131}I, ^{137}Cs, ^{210}Po
- Cow milk in coastal area



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Garland & Wakeford 2007 Atmospheric emissions from the Windscale accident of October 1957 Atmos Environ 41

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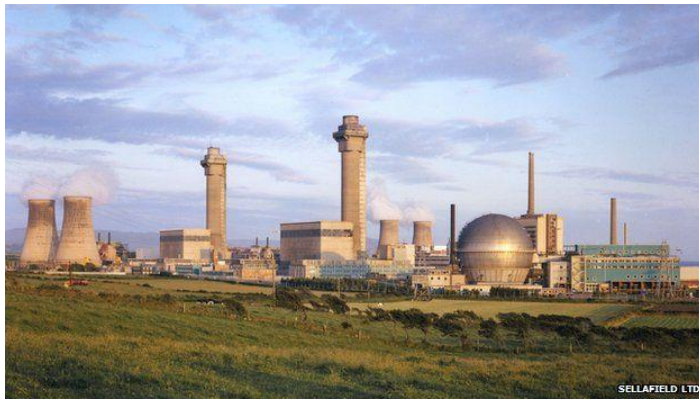

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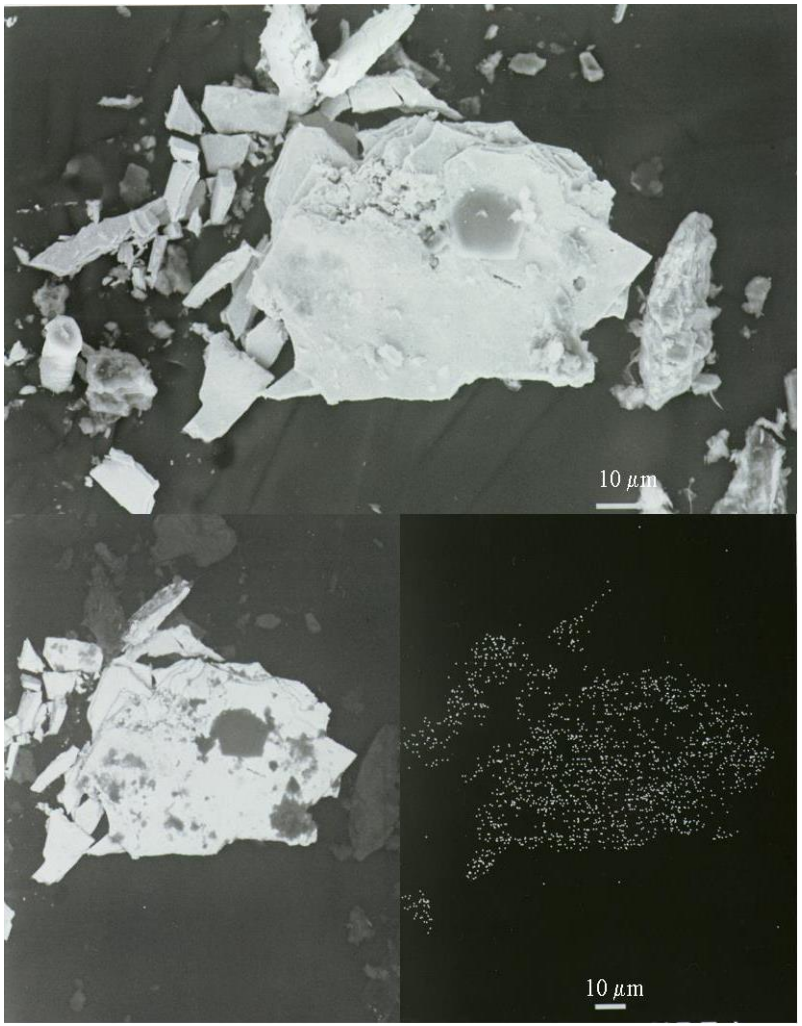
Windscale particle



- release due to corrosion

Pictures by Agricultural University of Norway

Countermeasures

- Environmental monitoring - ^{131}I was major radiological hazard
- Little guidance available on what constituted an acceptable limit for $[^{131}I]$ in milk
- Derived limit of 0.1 μCi L^{-1} (3700 Bq L^{-1}) to constrain thyroid doses
- Milk ban based on these *ad hoc* calculations
- West Cumbrian coastal strip running from 10 km north of Windscale to 20 km south.
- Cow milk diluted and dumped into Irish Sea, for c. 1 month

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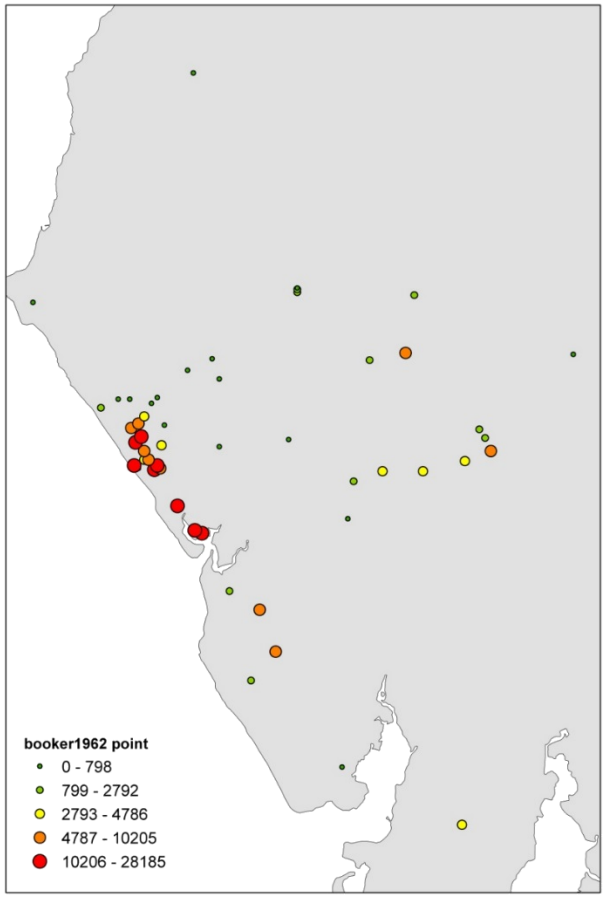
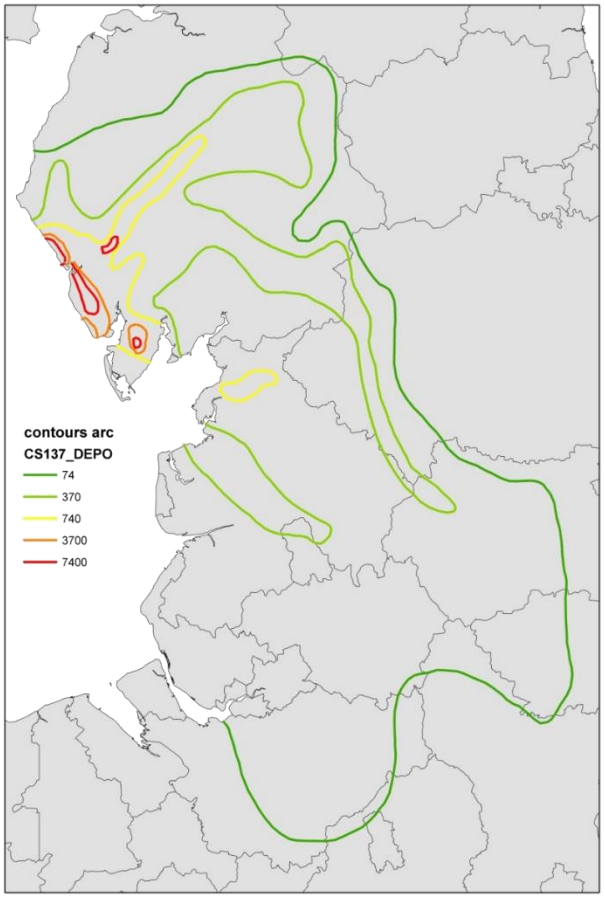
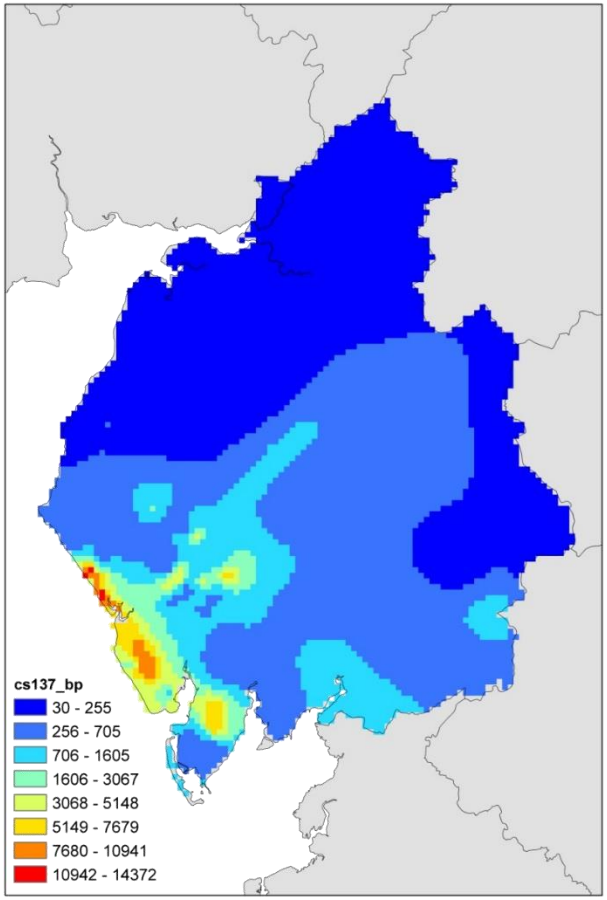
Deposition of ^{137}Cs in Cumbria



Booker (1962)



Jackson & Jones (1991)



Wright et al 1980s

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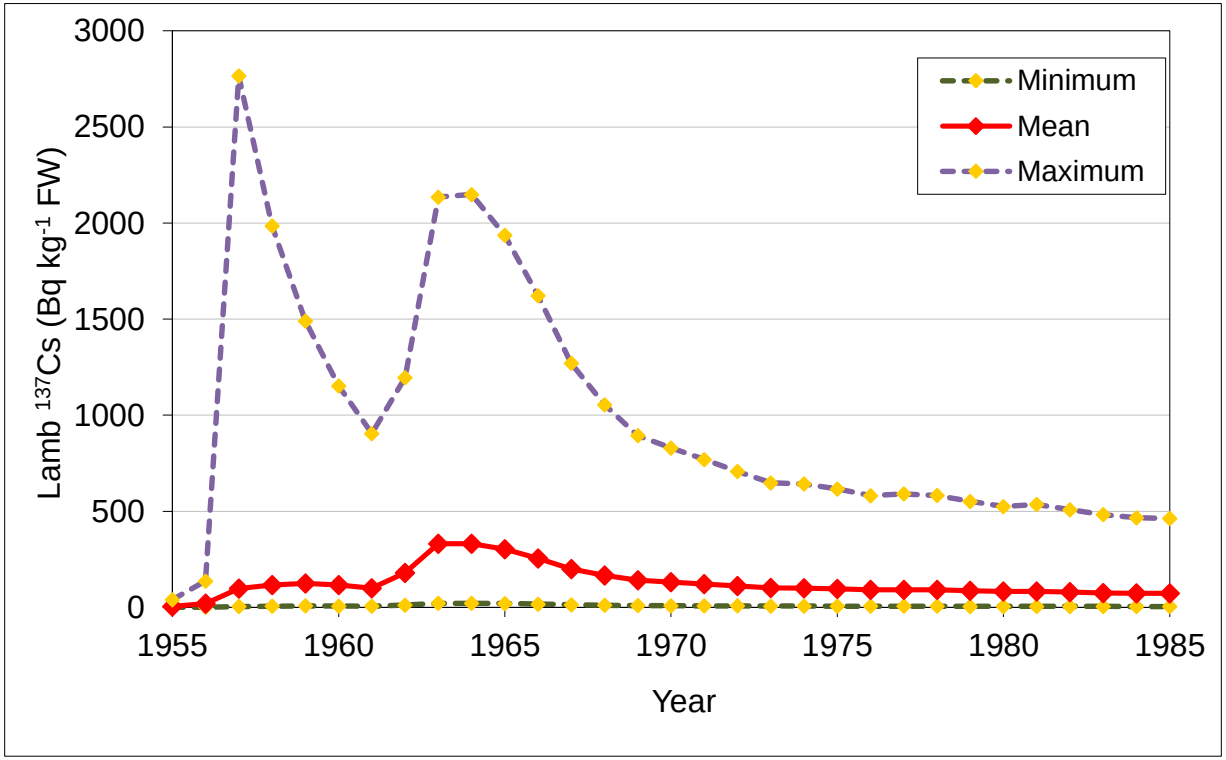
Temporal variation in lamb ^{137}cs

Global fallout + Windscale



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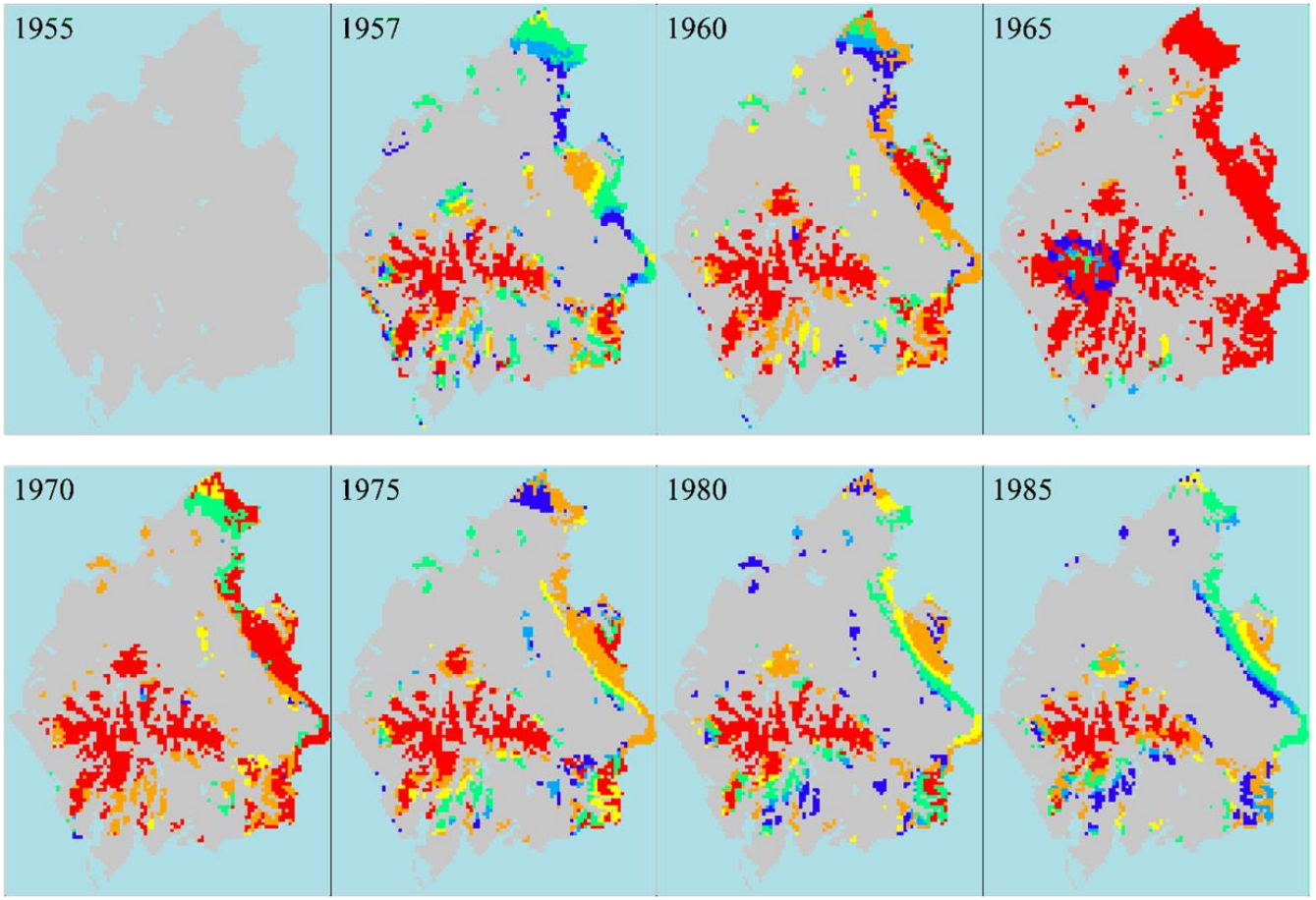
Flock restriction probability

GLOBAL FALLOUT + WINDSCALE



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Flock probability

No Data | 0.000 | 0.001 | 0.005 | 0.010 | 0.050 | 0.100 | 0.500 | 1.000

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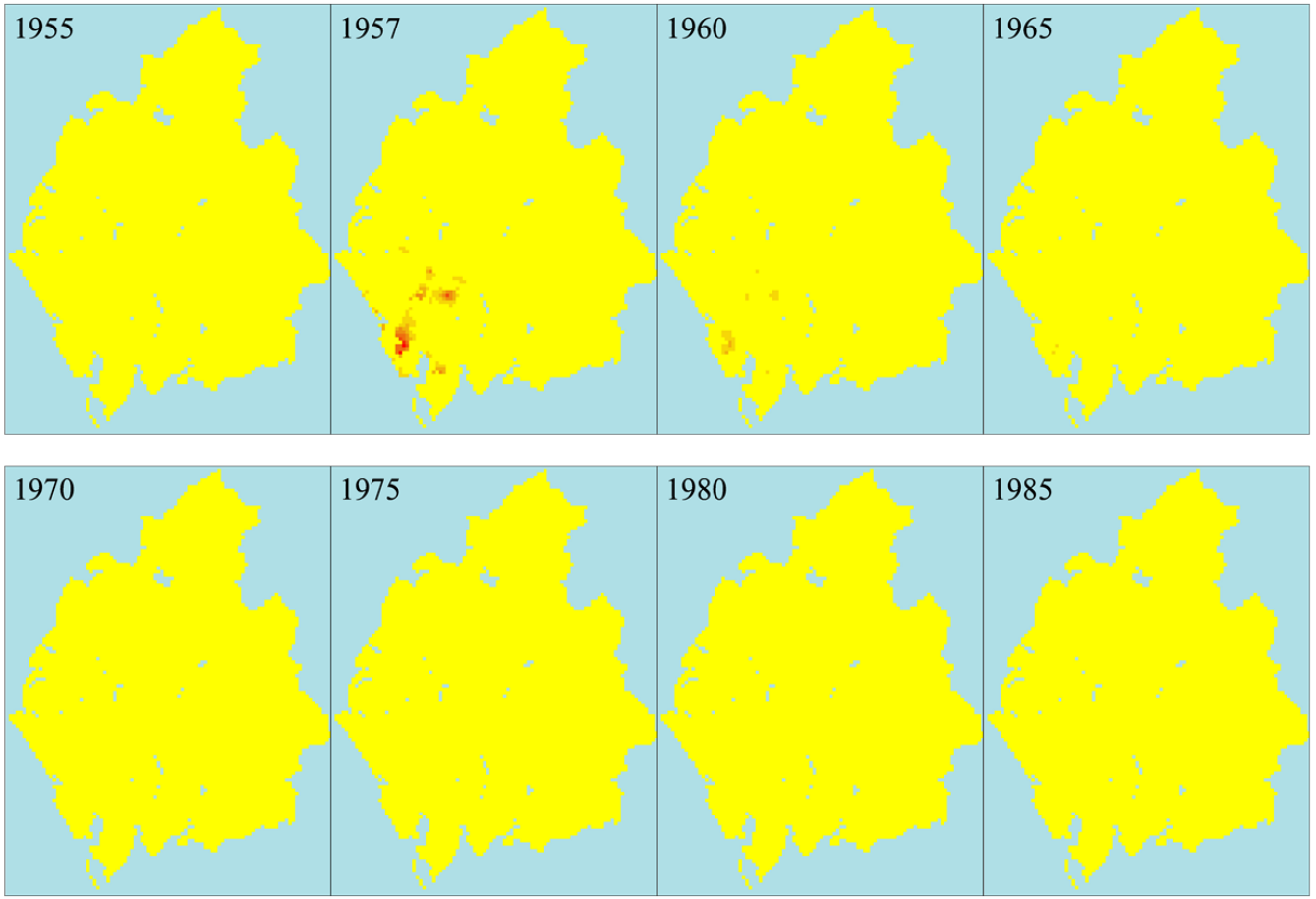
Spatial variation in lamb ^{137}Cs

WINDSCALE ONLY



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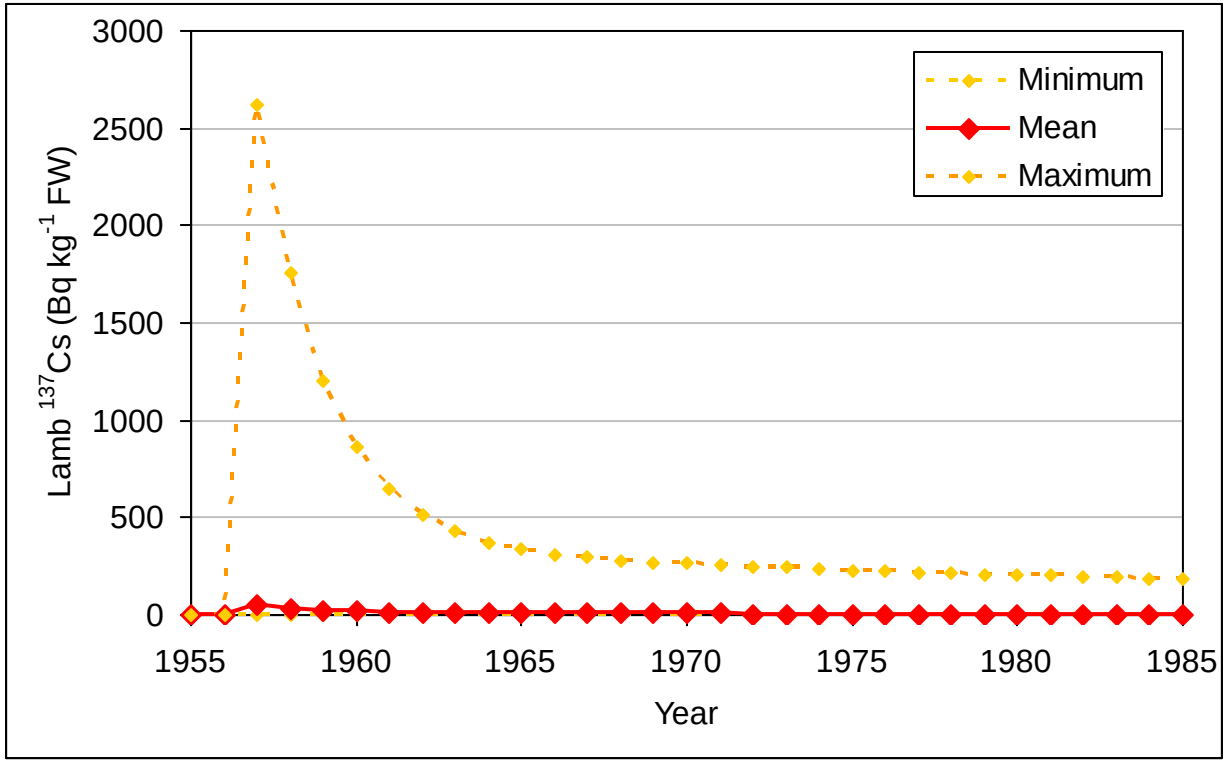
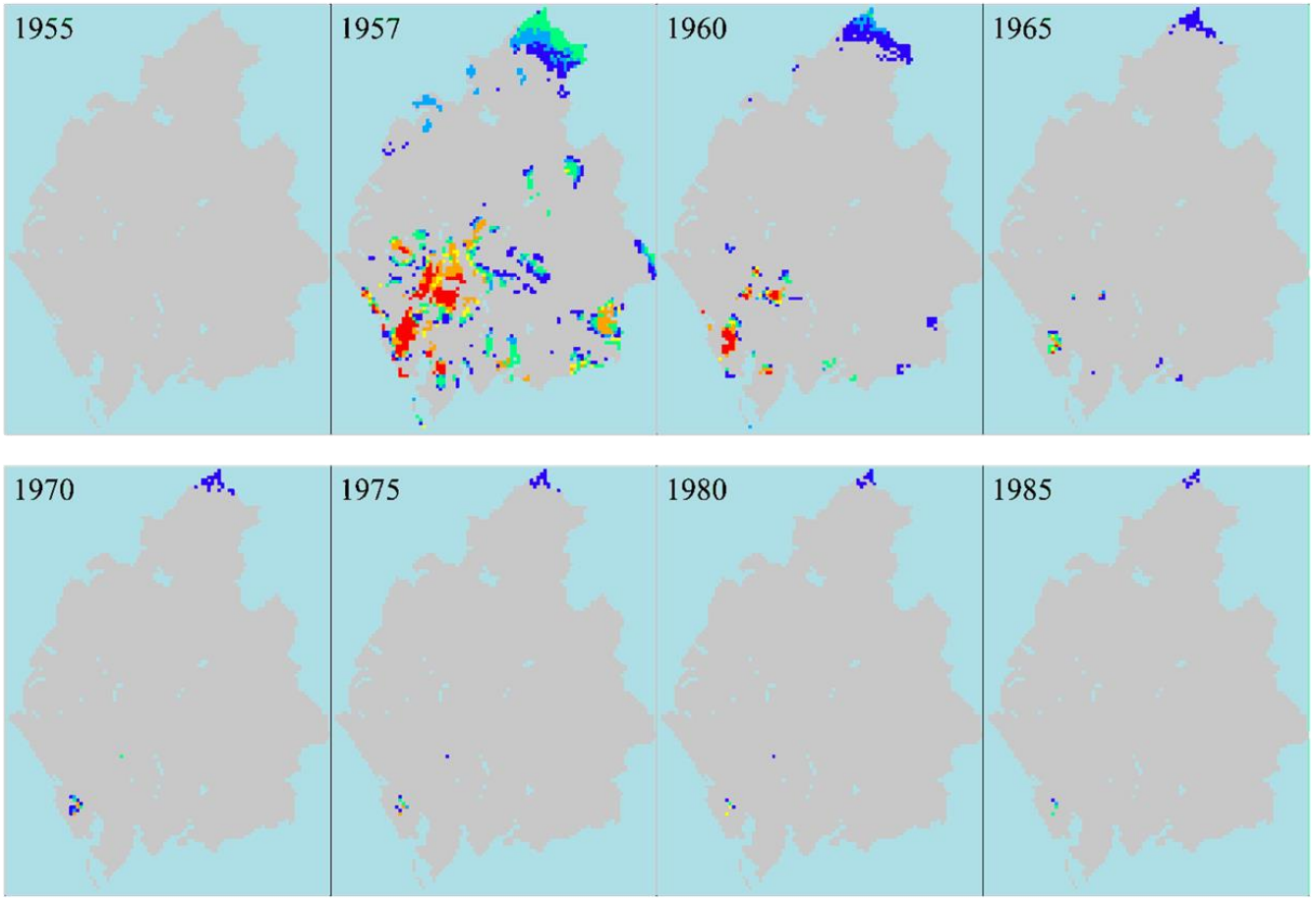
Temporal variation in lamb ^{137}Cs

Windscale ^{137}Cs only



Flock restriction probability

WINDSCALE ONLY



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Flock probability

No Data | 0.000 | 0.001 | 0.005 | 0.010 | 0.050 | 0.100 | 0.500 | 1.000

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Summary of global fallout and Windscale

- Based upon current intervention limits restrictions would have been needed
  - Global fallout + Windscale
  - Global fallout only
  - Windscale only
- Main contributor is global fallout – both in terms of level and spatial extent

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Chernobyl accident

- 26 April 1986, 10 d release
- 1040, 910, 25 and 250 PBq respectively for ^{132} I, ^{133} I, ^{134} I and ^{135} I (^{132} I in rad equilibrium with ^{132} Te)
- Many W. European countries also affected
- High [RI] in cow milk
- High [RCs] in milk and meat
  - Agricultural and semi-natural animals

Emergency phase - countermeasures

- I isotopes intercepted by plants, eaten by ruminants, high transfer to milk
- Response focused on banning milk from collective farms, not private households
- Consumption of milk from private cows caused thyroid cancers in young children

Existing situation - Radioecological sensitivity

- High RCs uptake for soils
  - Ukraine, Belarus, Russian federation
  - Western Europe

- Long term, sustained transfer of radiocaesium to animals
  - Agricultural areas with sensitive soils
  - Extensive farming in uplands with low fertiliser status and high [OM]
  - Game and semi-domesticated animals

Transfer to semi-natural animals

Reindeer

Grouse

Roe deer, wild

Moose

semi-domesticated animals

High RCs transfer,
seasonal trends
long effective half lives

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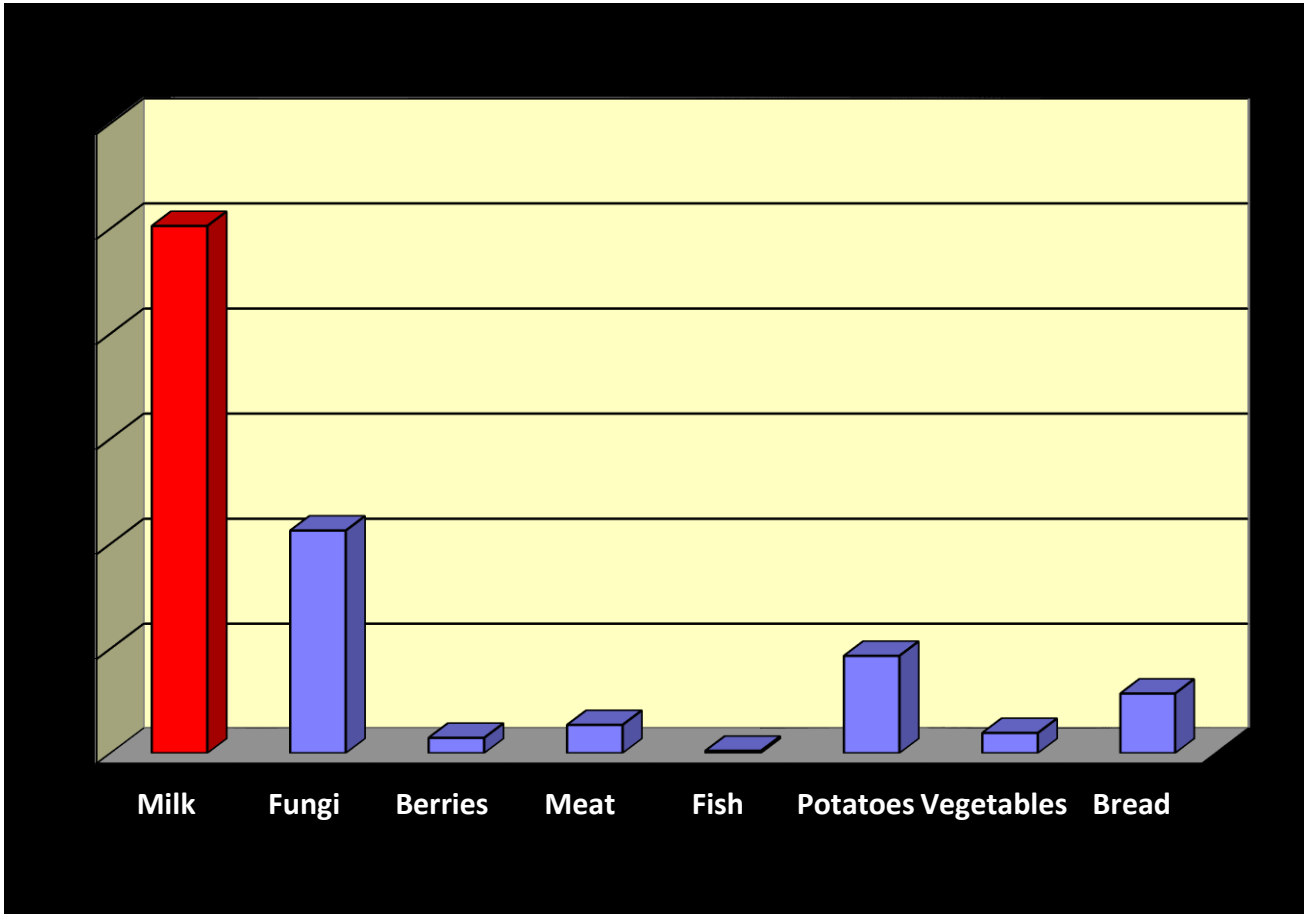
Animal products

Contamination of agricultural animal products was often a major contributor to ingestion dose

% contribution to daily Cs-137 intake by population of Milaych Ukraine



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Most relevant options for livestock

- Remediation of fodder production
- Clean feeding, in vivo monitoring
- prevent gut absorption by application of radiocaesium binding agents to animals
- changing animal feeding strategies

Radical improvement

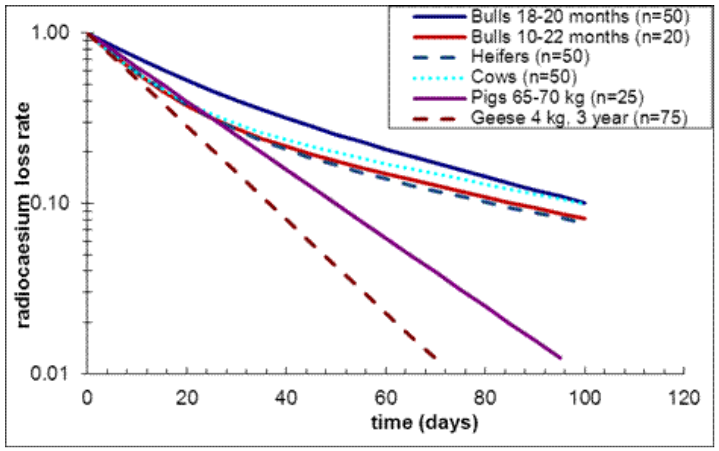
- ploughing
- improved drainage
- wide range of fertilizer mixtures
- reseeding
- Cs sorbents

One of the most effective options to:

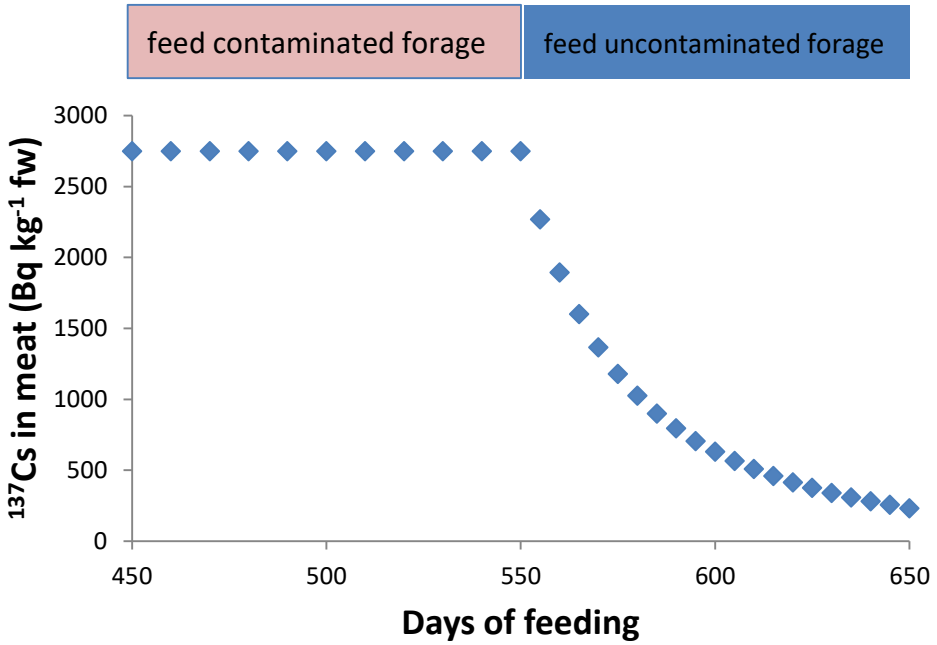
- **increase productivity** of grass stands by 3-5 fold
- **decrease the transfer** of radiocaesium to fodder by 2-10 fold
- Farmers like it

Changing animal feeding strategies

- Utilize contaminated feed for young animals
- Then decontaminate
  - Clean feeding
  - Use of Cs binders



Decontamination of an 18-20 month bull



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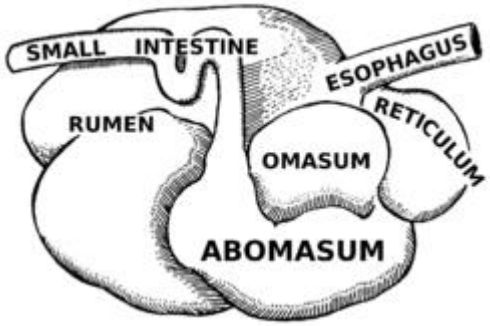
Preventing gut absorption – clay minerals

- Clay minerals used
  - bentonites vermiculites zeolites

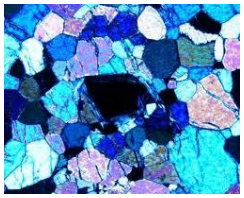


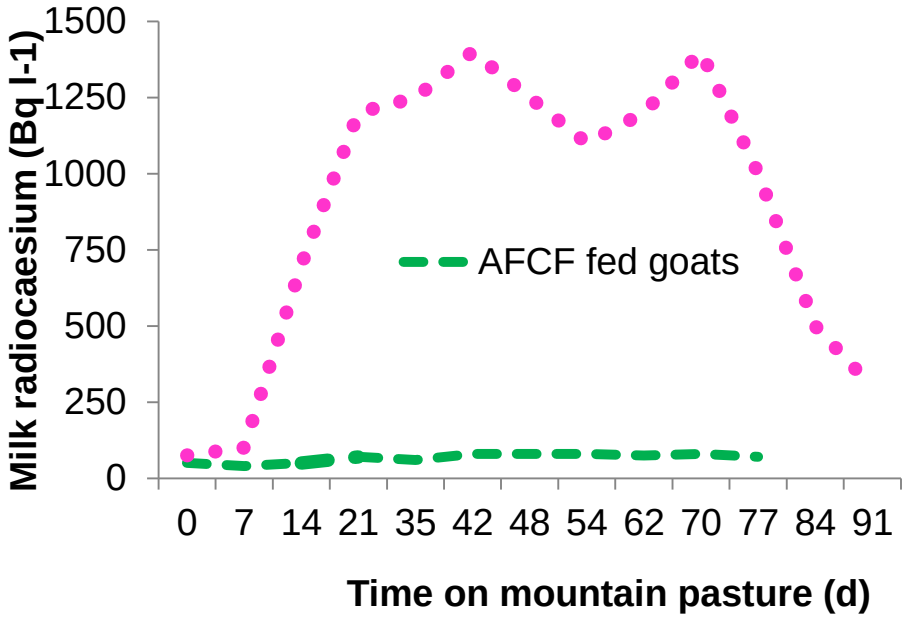
- Add to fodder, incorporate into concentrates
- Needs daily administration
- Costs depends on ease of access
- Moderate effectiveness
  - up to 5 fold reduction
- Some adverse effects if clay intake high



AFCF

- Effectiveness: v high
- Feasibility
  - size, delivery routes for free ranging animals
- Acceptability
  - **BLUE**, boli
- Constraints
  - Licensing





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Administration rates & reduction factors for AFCF

Livestock	*AFCF administration Rate (g d^{-1})*	*Reduction factor fSU*	*Reduction factor Other sources*
Dairy cows	3	3-5	5-10
Bull calf	3	4-5	
Pig	1.5-2	4-6	10
Chicken	1.5	3-5	

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Fesenko et al., 2007

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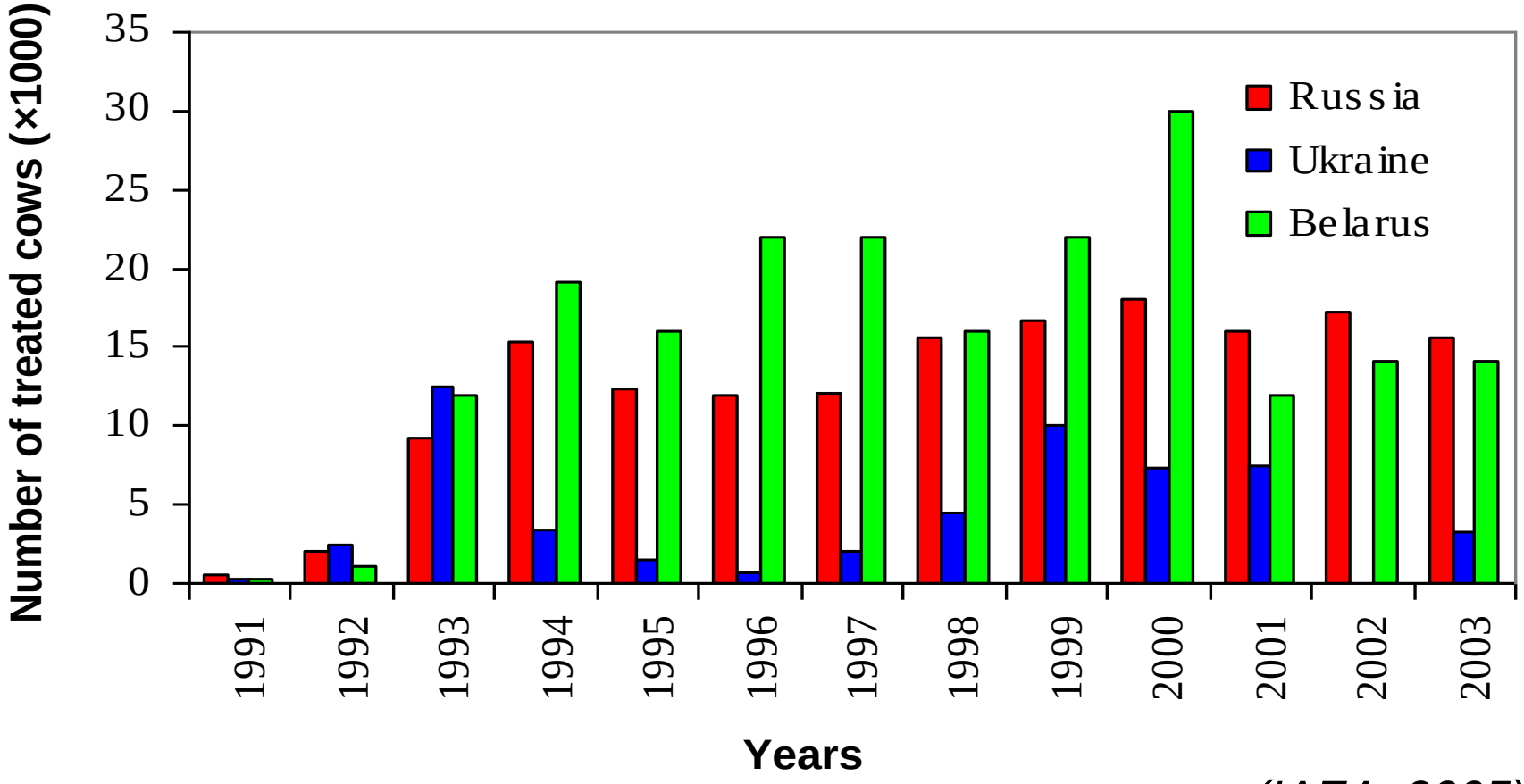
Preventing gut absorption – AFCF

Changes with time in the use of AFCF in the fSU



(IAEA, 2005)

POST CHERNOBYL INITIATIVES

Disposal of contaminated milk and meat

- Disposal routes for milk
  - disposal to sea
  - incineration,
  - landspreading
  - processing and storage

- Disposal routes for meat
  - burial
  - burning carcasses (potentially by incineration)
  - carcasses rendered down

EC Maximum Permissible Levels (MPLs) for radiocaesium in animal feeds

Following a nuclear accident or any other case of radiological emergency

Animal feed intended for:	MPL (Bq kg^{-1} as ready for consumption)
Pigs	1250
Poultry, lambs and calves	2500
Other	5000

*The regulation does not specify a DM assumption for the feedingstuffs

(CEC, 1990)

The social dimension for applying management options

- Farmers / producers concerns:
  - animal welfare
  - feeding contaminated feedstuffs
  - compensation
  - residual levels of contamination in food
  - the use of secondary products such as composted material and manure on land
  - effects on landscape
  - environmental side effects

Fukushima Daiichi accident

- 11 March 2011
- Earthquake and tsunami
- Loss of cooling capacity
- Several initial releases due to venting and hydrogen explosions;
  - Weeks of subsequent releases
- Low [RI] and [RCs] in agricultural animal products
- High [RCs] in game animals

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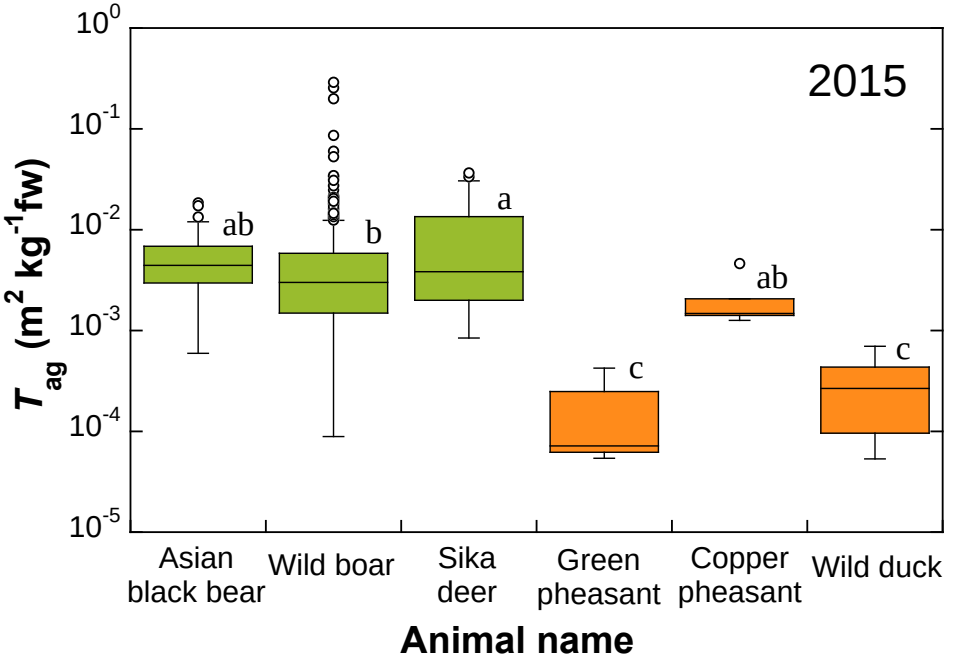
Emergency phase

- Relatively low [RI] and [RCs] in agricultural animal products
  - Dairy animals housed
  - No grazing in March 2011
  - Feeding stored feed
  - Less potential for transfer of radioiodine to milk

- Extensive, comprehensive food bans imposed quickly

Existing situation

- High [RCs] in game animals – trashing fields
- Low [RCs] in agricultural animal products
- Tendency to refer to minimum measureable [RCs] rather than the "low" food standard limits
- Limited clean feeding
- Development of v. low-level *in vivo* monitoring methods



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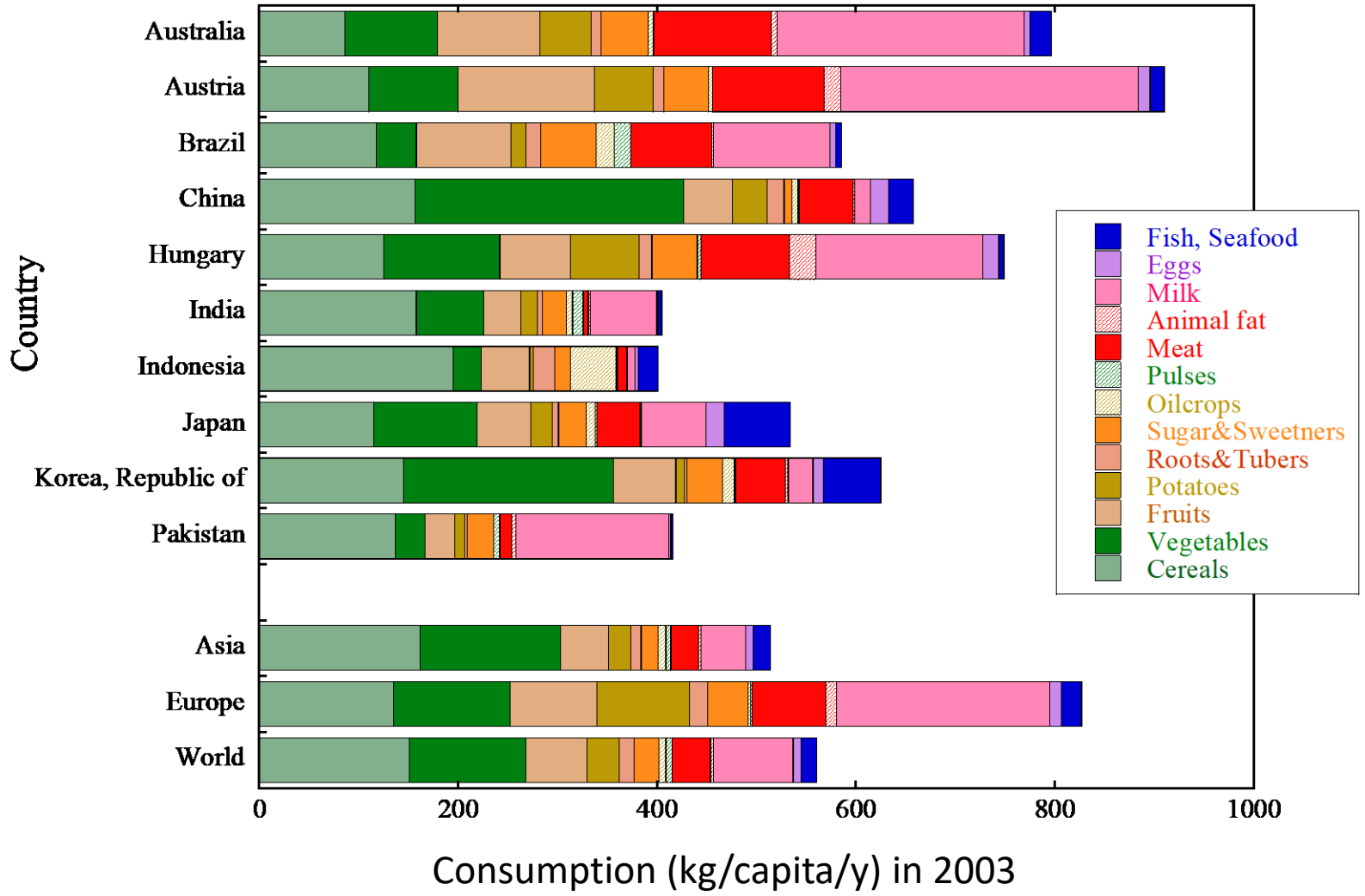
Summary

- Kyshtym
  - Wide range of rads initially, ^{90}Sr long term, first development of wide range of remediation options
- Windscale
  - Some relevant radionuclides missed, identified and dumped milk
- Chernobyl
  - Severe impact of I isotopes in private milk, high and sustained transfer of RCs to animal products, importance of soil type, extensive and game animals, Cs binders, live monitoring, social dimension
- Fukushima
  - Agricultural practices and time of deposition minimised animal contamination in emergency phase, highly conservative approach in existing situation

GLOBAL FOOD CONSUMPTION



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QST

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Data source:FAO database

With thanks to….

- Nick Beresford, Cath Barnett, Claire Wells CEH, UK
- Gerhard Proehl, Sergey Fesenko (IAEA), Mikhail Balonov, (RF), Shinichi Nakayama (JAEA, Japan)
- MODARIA participants


Questions?