MAIN HIGHLIGHTS ON CHERNOBYL OVER 30 YEARS AND CURRENT SITUATION

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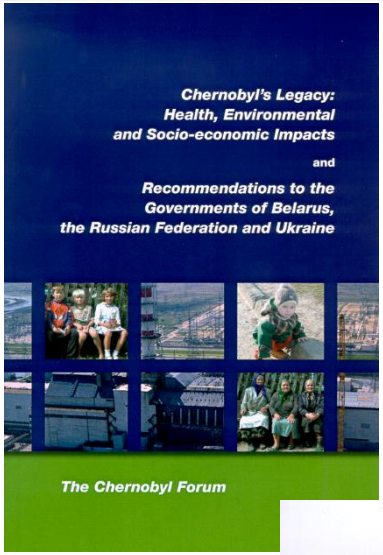
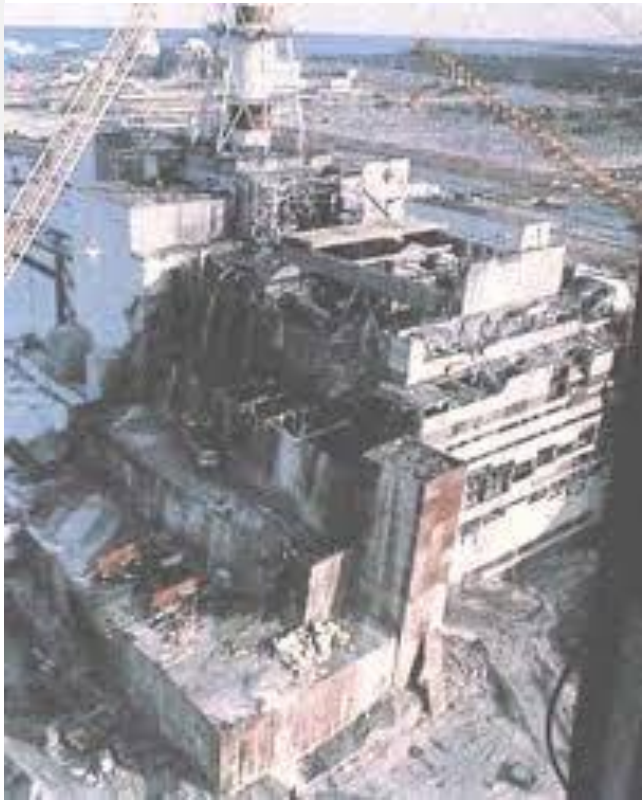
Chernobyl USSR, 1986

- Unit 4
- Atmospheric release (PBq)
  - ^{131}I - 1760; ^{134}Cs ~ 47, ^{137}Cs ~ 85; ^{90}Sr – 10





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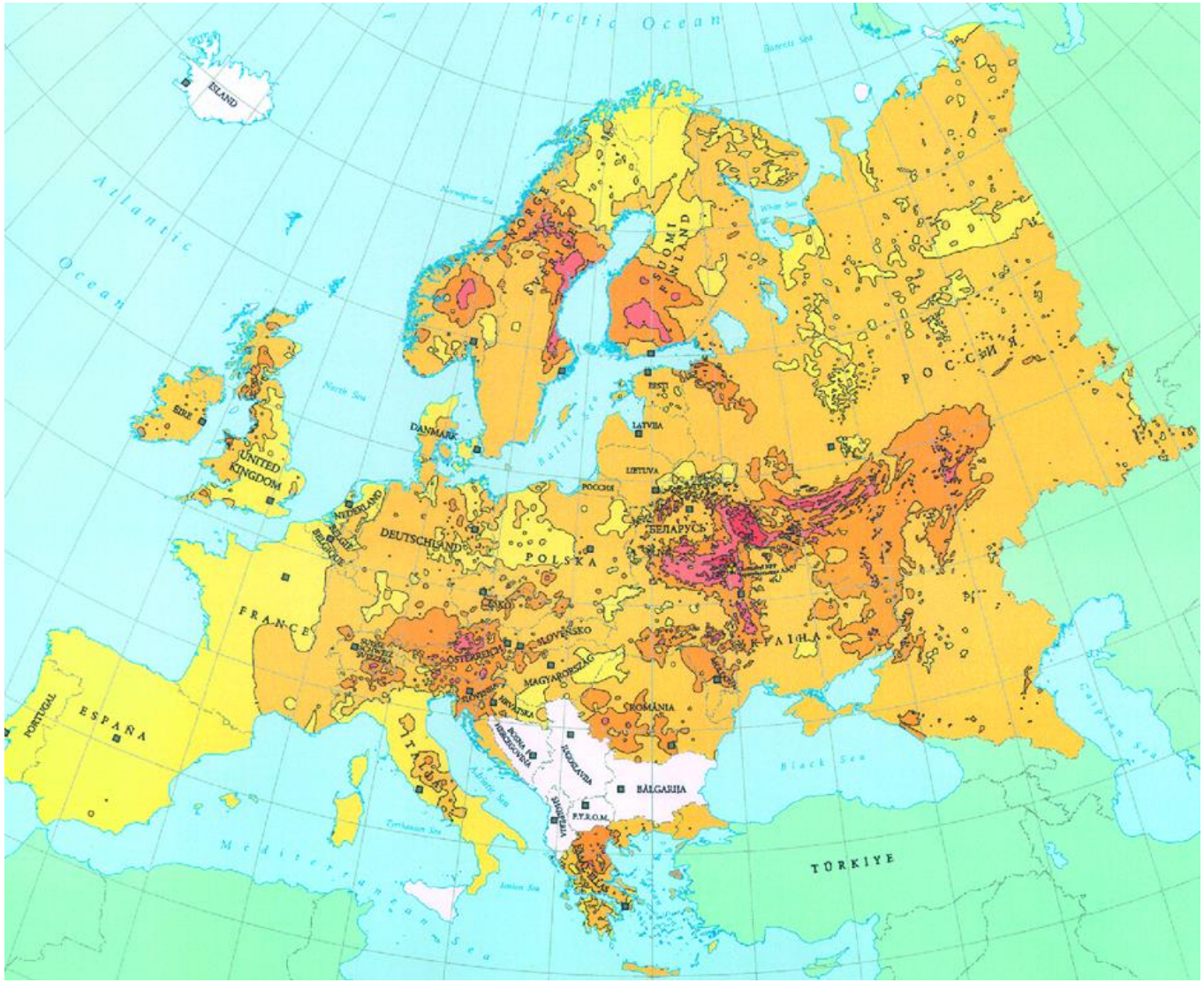
Radioactive Iodine Food Chain

Start of growing season – cows on pasture

In spring 1986, children and adolescents in surrounding areas of USSR received substantial radiation doses to the thyroid due to the consumption of milk contaminated with radioiodine.

Deposition of ^{137}Cs in Europe



- More than 200,000 km^2 of Europe 'contaminated' with ^{137}Cs, mostly in FSU countries
- More than 5 million people live in 'contaminated' areas

Agricultural countermeasures – early phase

Partially effective in reducing radioiodine intake via milk

- lack of timely information about the accident and countermeasures, particularly for private farmers

Most effective countermeasures in the early phase

- exclusion of contaminated pasture grasses from animal's diet
- exclusion of milk (with further processing) based on radiation monitoring data
- Feeding animals with "clean" fodder in some affected countries, but not in USSR due to lack of supply

Slaughtering of cattle was unjustified from a radiological point of view

- hygienic, practical and economic problems (wastes)

Existing situation - features of contaminated USSR

Population intensity	Moderate, no pressure to use land
Terrain	Flat, forested and agricultural
Intensity of agriculture	Low - medium
	- Collective farms
	- Private subsistence farmers
Key products	Milk, meat, grain, potatoes
Lateral movement across landscape	Low

Changes with time

Initial reduction in transfer due to weathering, physical decay, vertical migration of radionuclides down the soil and reductions in bioavailability in soil

↓

Soil to plant transfer important with strong time dependence - ^{137}Cs and ^{134}Cs

↓

Long term ^{137}Cs in meat and milk - important contributors to internal dose

Characteristics of the contaminated landscapes -

Internal exposure pathways

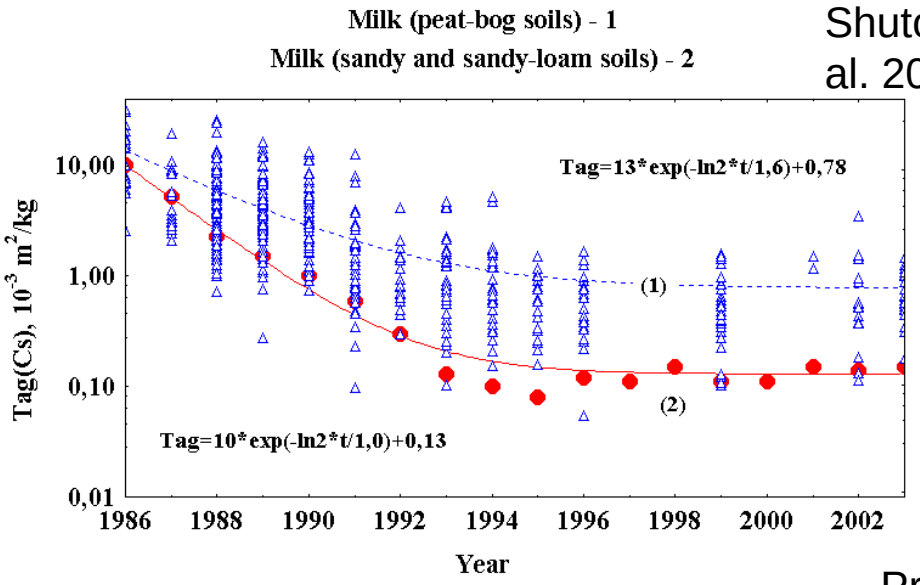
Fraction of soils with high organic matter or sandy content	Moderate to High
K fertiliser usage	Very low to moderate
Radiocaesium availability for root uptake	Moderate to very high
Transfer to animal products	Moderate to High
Intake of local food	High to very high
Intake of wild food	Moderate to very high

Agricultural Environment - RCs

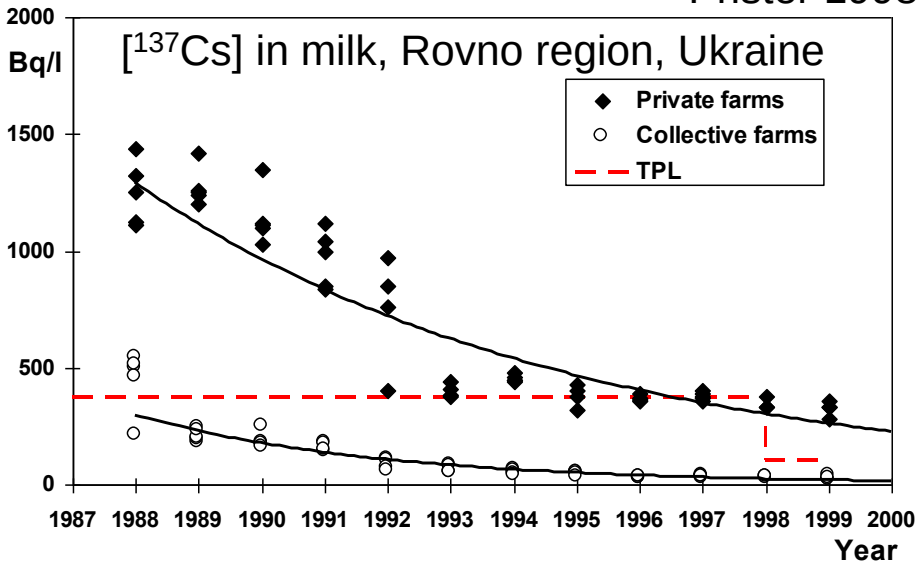
Cs-137 in foodstuffs affected by:

- deposition density
- chemical form
- soil types
- management practices
- type of ecosystem

Russia - Shutov et al. 2004



Prister 1998

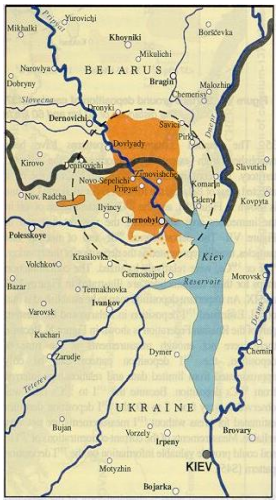


Major persistent problems

- extensive systems with high organic or sand content soils
- subsistence farmers with privately owned dairy cows grazing in unimproved pastures

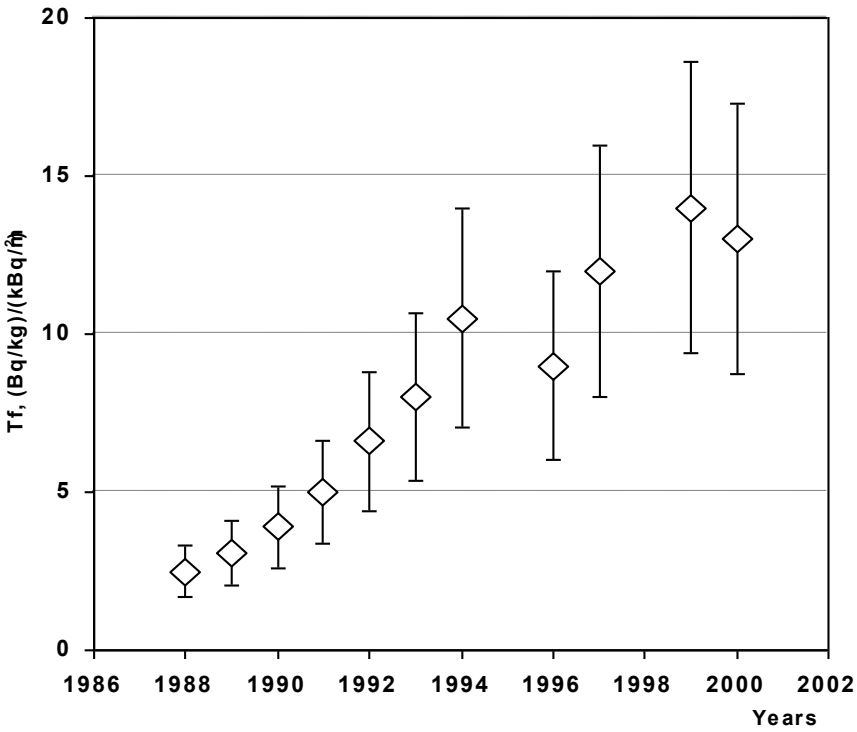
Agricultural environment - other radionuclides

- ^{90}Sr, plutonium isotopes and ^{241}Am, mostly insignificant in terms of human dose
- Sr-90 could contribute to internal dose mainly in the exclusion zone
  - increase with time



$^{239/240}Pu$ > 3.7 KBq/m^2

^{90}Sr



Dynamics of ^{90}Sr transfer factor into grass in the 30-km zone

(Kashparov et al., 2004).

Extensive systems – “wild” animals

Reindeer

Grouse

Roe deer, wild

Moose

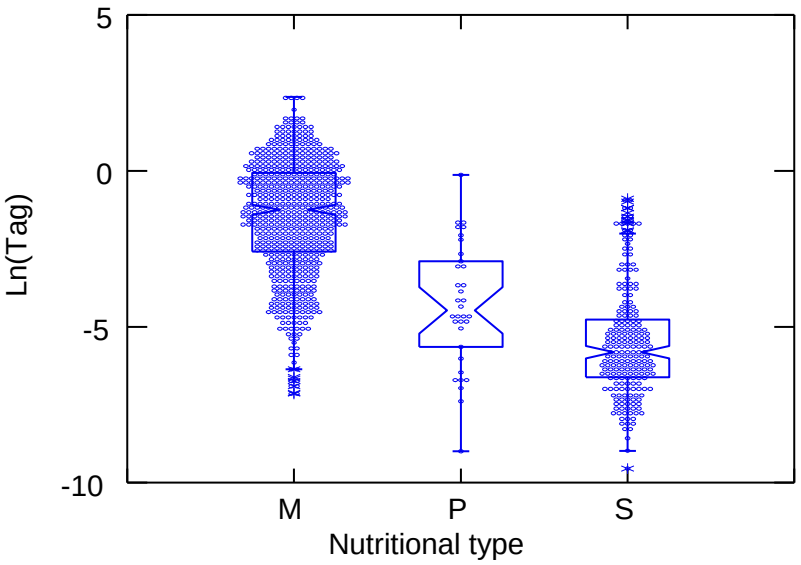
Semi-domesticated, free-ranging animals

USSR
fSU
Western Europe

High RCs transfer,
seasonal trends
long effective half lives

Forests

- high RCs uptake by mushrooms, berries
- persistent recycling of RCs for several decades
- wood ash can contain high amounts of RCs
- External doses to workers needs to be considered
- importance of forests contribution to radiological exposures of population increased with time



Cs uptake into mycorrhizal, parasitic, saprophytic mushrooms
Barnett et al 1992

- timber etc. gives only small contribution to exposure
- radiological consequences of forest fires unlikely to be high except possibly close to the fire

Aquatic bodies

- Rapid reduction in [RCs] due to dilution, reduction in bioavailability in catchment and settling to sediments
- Lower weathering rate of fuel particles than in terrestrial ecosystems
- The most contaminated lakes have no inflowing and outflowing streams and an organic soil catchment
  - ➢ long ecological half lives and potential significant source of dose to local population

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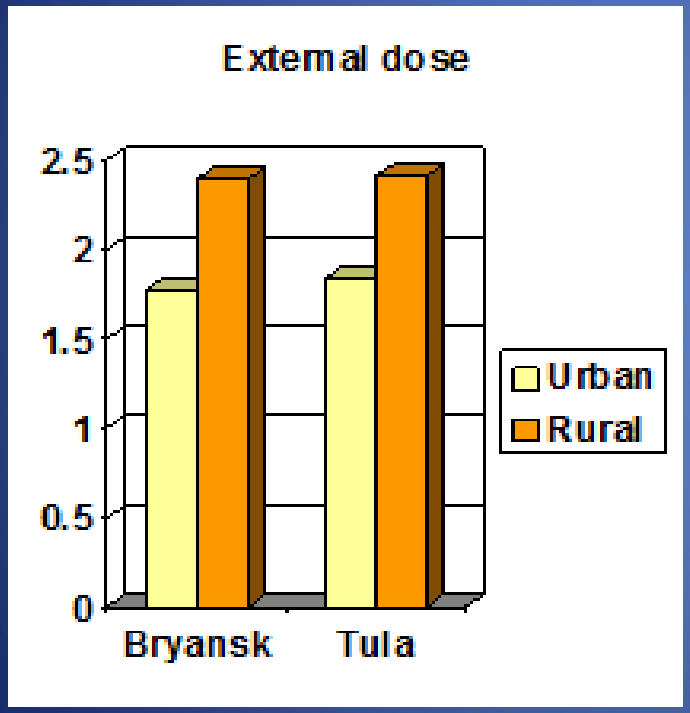
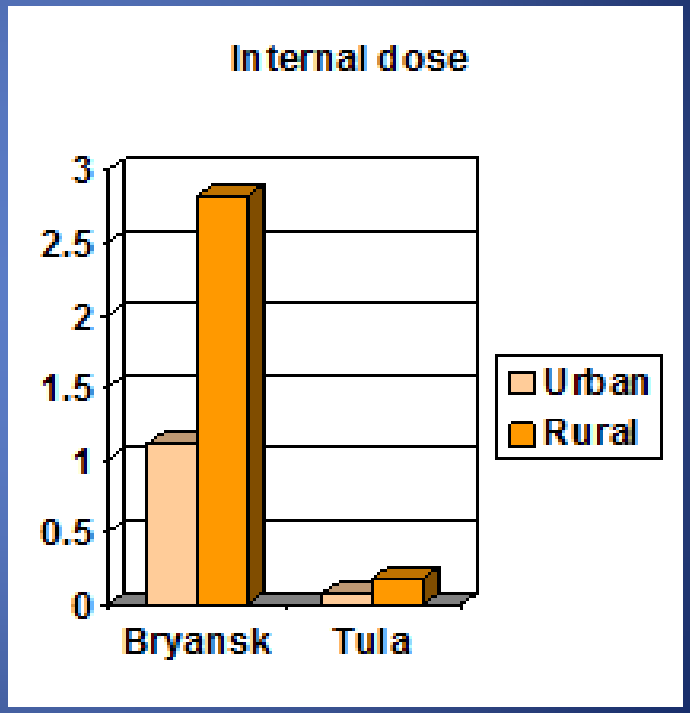
PATHWAYS LESSONS LEARNED

- Severe impact of I isotopes in private milk
- High and sustained transfer of RCs to animal products in some areas close and far from the NPP
- Importance of soil type, extensive systems and wild food identified
- Deposition density plus soil type both critical
- Models giving site-specific spatial and temporal predictions are invaluable

Variation in relative internal and external doses

Internal and external doses in some areas affected by the Chernobyl accident normalized to ^{137}Cs contamination density, 1996-2000, MBq m^{-2} (Fesenko et al., 2000)

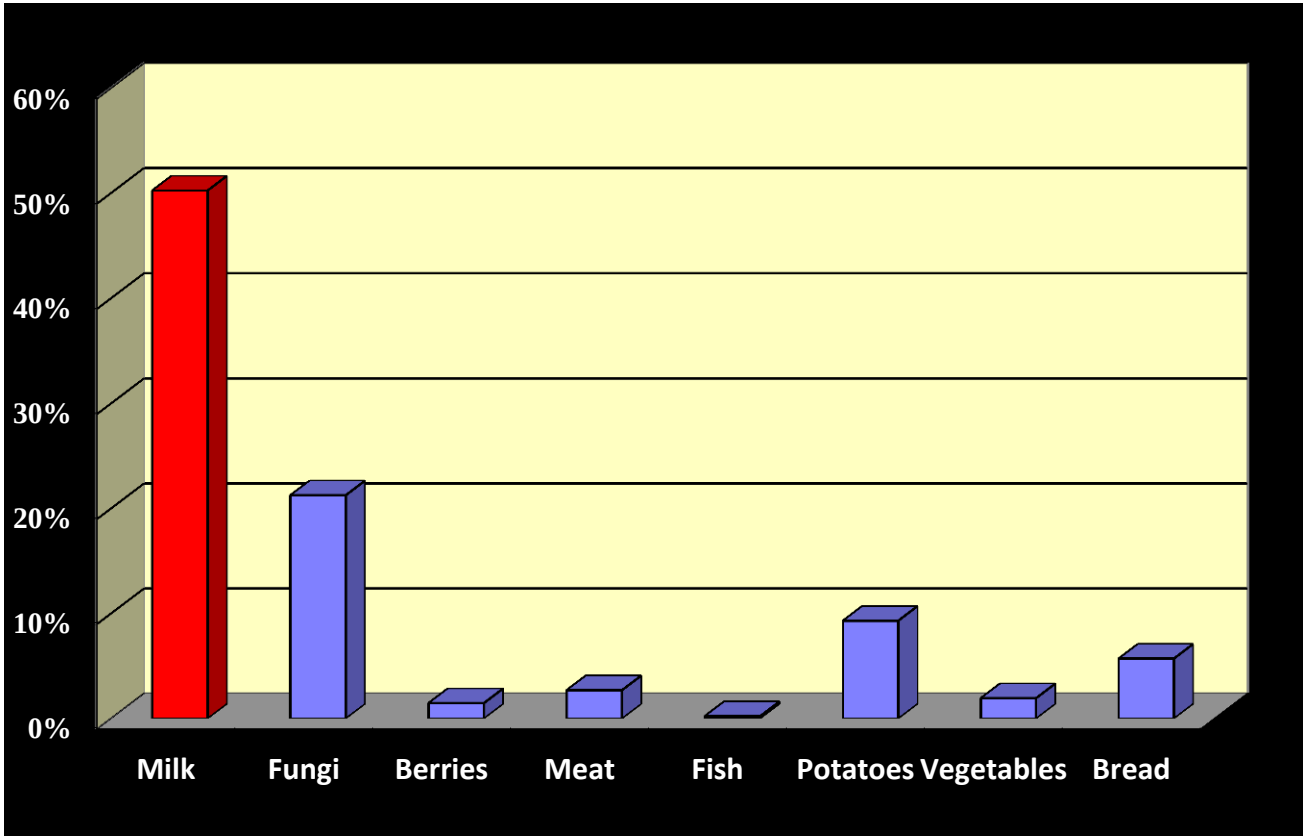




Animal products and internal dose

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

% contribution to daily ^{137}Cs intake by population of Milaych, Ukraine (ECP9)



Remediation strategy

- Some hundred of thousands of people were living in areas with > 1 mSv/y
  - Need to remediate to reduce their effective dose rate - long term goal <1mSv/y
  - To enable residents of contaminated areas to return to a normal life
  - Secondary concern to return people to evacuated areas
- **weighting of averted dose versus remediation costs** was an important part of the remediation strategy

Chernobyl designation of remediation areas

Temporary permissible levels for effective annual dose	1986 – 100mSv 1987 – 30 mSv 1988- 1989 – 25 mSv 1991- 1mSv
Ambient dose rate µSv/h	2.2 corresponding to lifetime additional dose of 350 mSv (applied in 1989)

Set definition of contaminated land at 37 kBq/m^2

Identified settlements where annual dose rate was > 1 mSv. Izrael 1990

^{137}Cs kBq/m^2	Designation
Below 37	Not contaminated
37 - 185	Remediation for areas with “sensitive soils” (eg. wet peat, acid sandy)
185 - 555	Remediation applied for sandy soils and light loam soils
555 - 1480	Full scale remediation
>1480	No economic activity

Permissible levels in food – changes with time

TPL	4104-88	129-252	TPL-88	TPL-91	
Date of adoption	06.05.1986	30.05.1986	15.12.1987	22.01.1991	
Nuclide	^{131}I	β-emitters	$^{134}Cs + ^{137}Cs$	$^{134}Cs + ^{137}Cs$	^{90}Sr
Milk	370–3700	370–3700	370	370	37
Dairy products	18500–74000	3700–18500	370–1850	370–1850	37–185
Meat and meat products	–	3700	1850-3000	740	–
Fish	37000	3700	1850	740	–
Eggs	–	37000	1850	740	–
Vegetables, fruits, potato, root-crops	–	3700	740	600	37
Bread, flour, cereals	-	370	370	370	37

Country, International body	EU	Belarus	Russia	Ukraine
Year of adoption	1986	1999	2001	1997
Milk	370	100	100	100
Infant food		37	40–60	40
Dairy products	600	50–200	100–500	100
Meat and meat products		180–500	160	200
Fish		150	130	150
Eggs		–	80	6 Bq/egg
Vegetables, fruits, potato, root-crops		40–100	40–120	40–70
Bread, flour, cereals		40	40–60	20

Agriculture remediation measures

Remediation for animal products
Clean feeding
Live monitoring of domestic animals
Prussian Blue binder to animals
Remediation of agricultural land
Radical improvement – ploughing, reseeding, additional fertilisation
Soil treatment with additional K and P
Soil amendment with liming
Application of sorbents and organic fertilisers
Drainage of wet peats

LL – combined highly effective and practical measure

Avoided measures which generated large amounts of waste (eg top soil removal)

Extensive agriculture remediation measures

- Free ranging animals
- New binder delivery systems
- Increase food action levels
- Live monitoring

Amounts of milk and meat exceeding action levels

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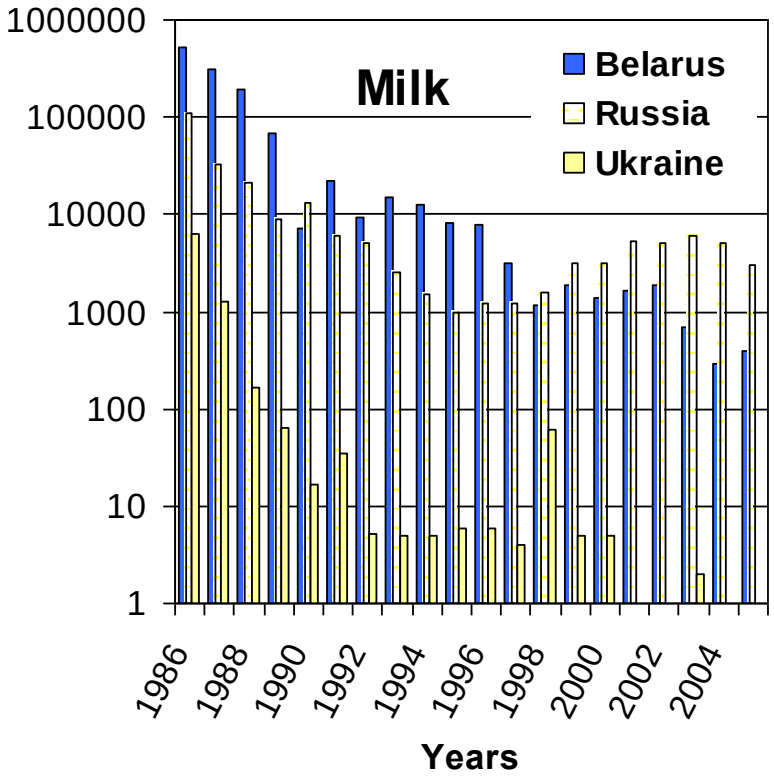

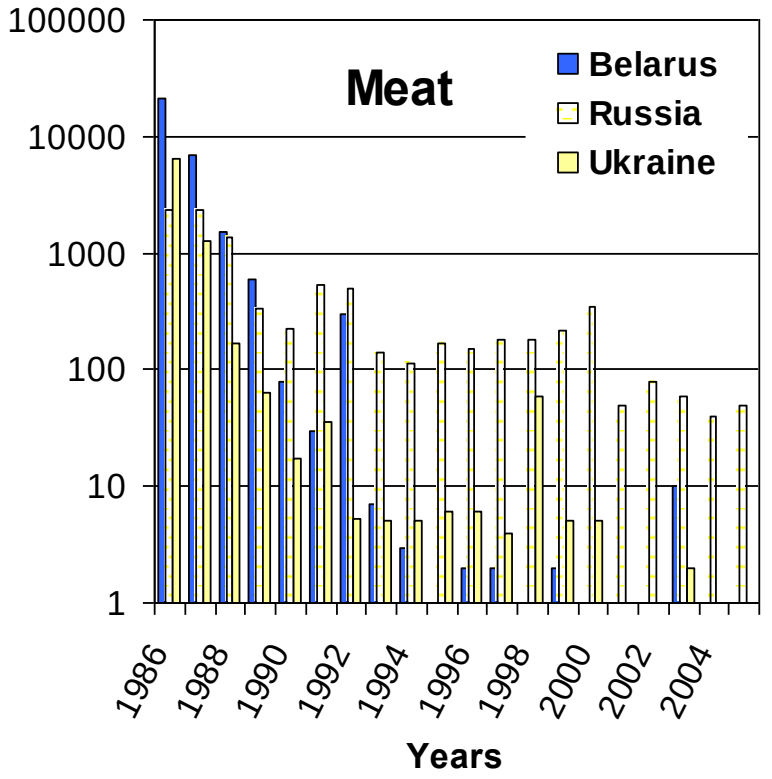

NB Russia includes private produce

Forest remediation

Restrictions on

- Access, harvesting of food products, collection of firewood

Local monitoring

Fire prevention

Optimisation approach

Site specific settlement information on:

- Spatial variation in contamination
- Which mushroom species to avoid
- Where and when to collect wood, wild products and hunt game animals
- Tree felling schedules

AQUATIC BODIES - LESSONS LEARNED

- Restrictions on consumption of fish remain, in a few cases for several decades (closed lakes)
  - but such restrictions not always adhered to

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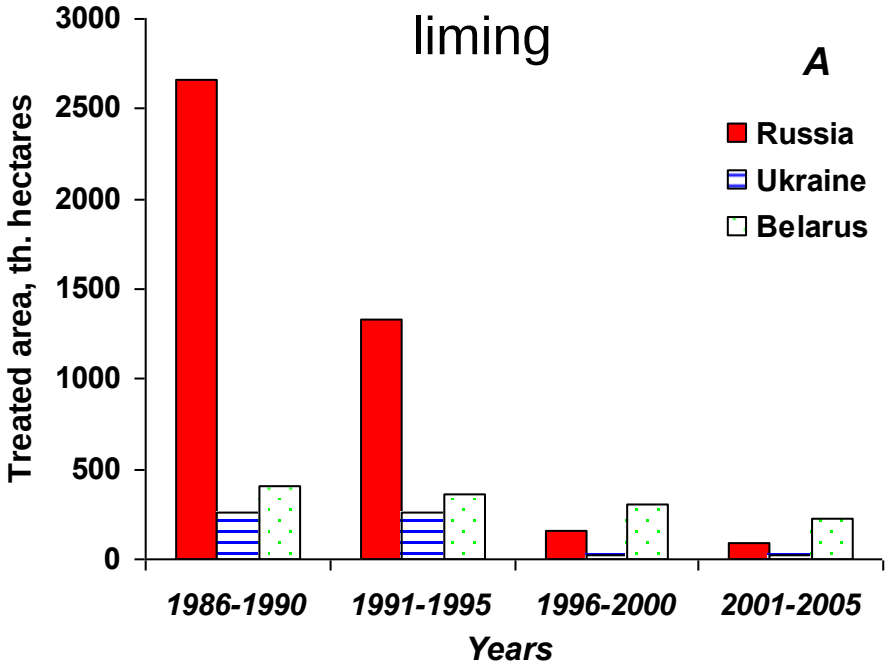
- measures generally ineffective and expensive and relatively high exposures to implementing workers.
- Restrictions on consumption of freshwater fish
- Public information important

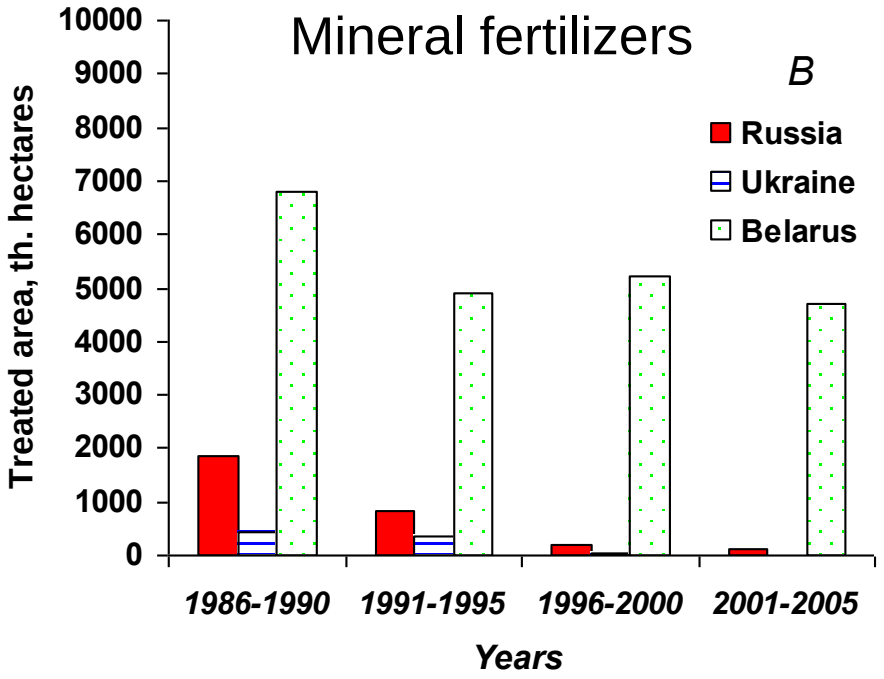
CURRENT SITUATION

- Since 1991, the proportion of animal products with [^{137}Cs] exceeding action levels has been <10% of the gross output from contaminated areas.
- Technologically based remediation measures applied to forests and surface waters not practicable on a large scale
- Since mid-1990s, use of agricultural measures considerably reduced. Application rates inadequate for both conventional food production and remediation so some increase in ^{137}Cs transfer occurred.
- Remediation ongoing in some areas with still high radiocaesium transfer from soil to vegetation

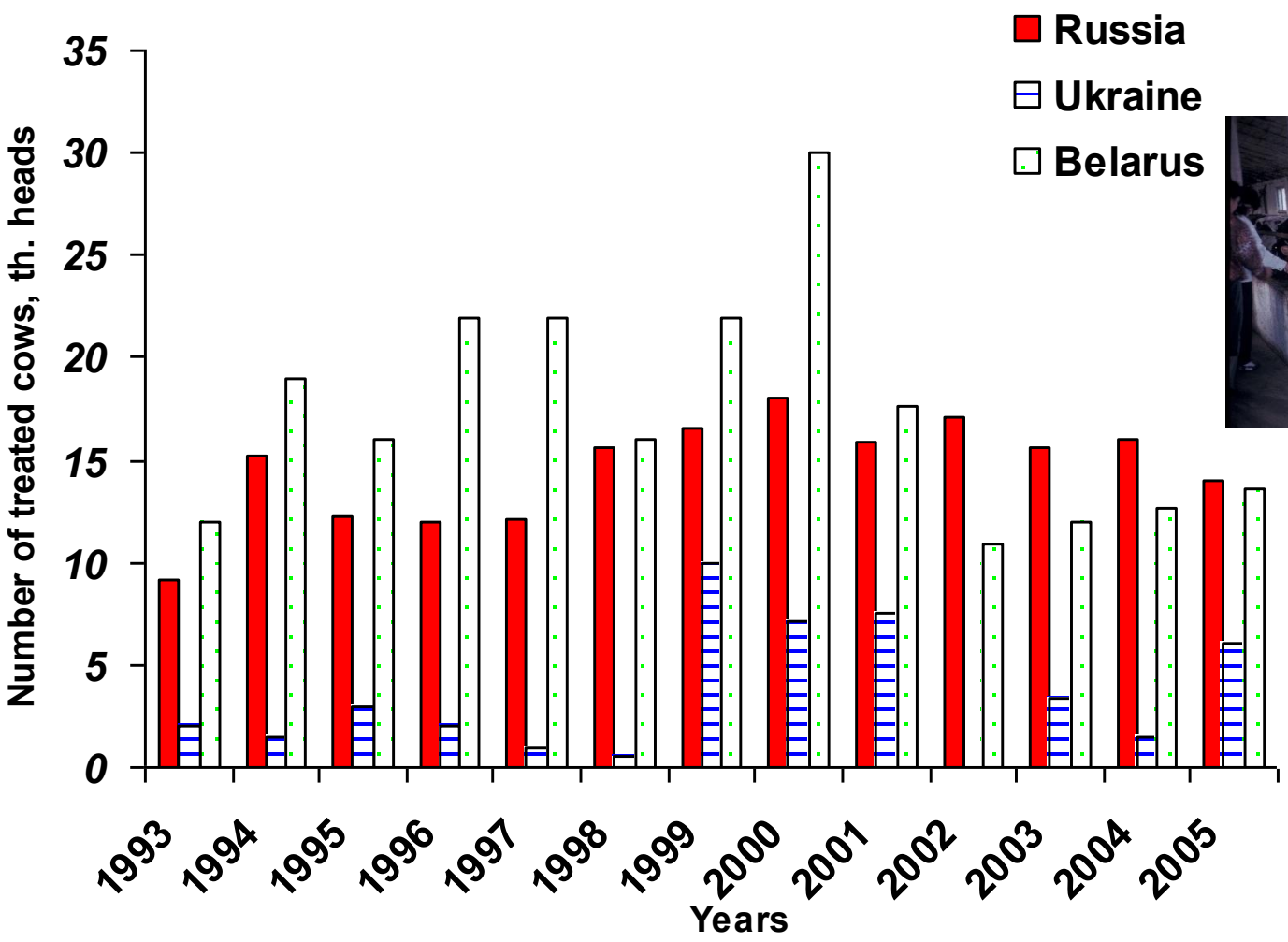
Soil amendments – decline with time

- Since mid-1990s, use of agricultural measures considerably reduced.
- Application rates inadequate for both conventional food production and remediation
  - ➢ **some increase in ^{137}Cs transfer**



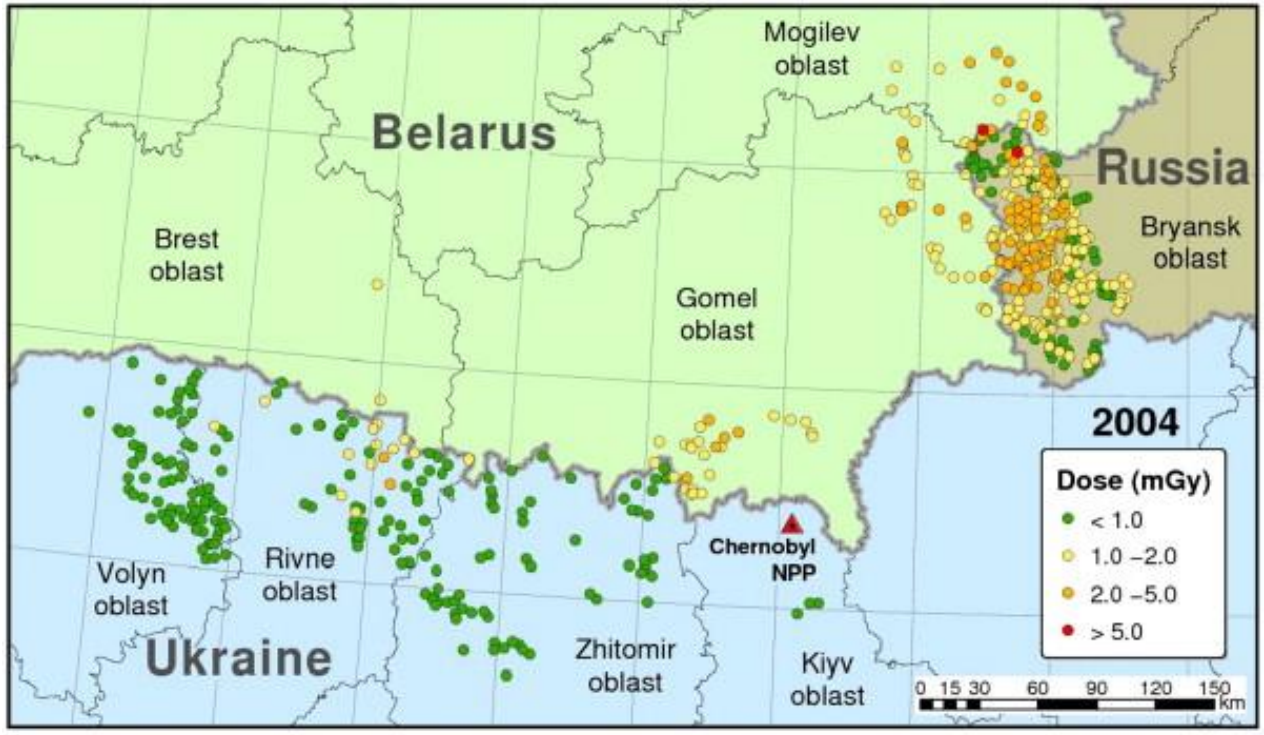


Use of Prussian Blue



Settlement based information

The three fSU countries have developed “catalogues” for each remediated settlement – compiles annual effective doses due to both external radiation and ingestion of radiocesium, -strontium and plutonium



Map of the 541 study settlements, with dose of the representative person from ^{137}Cs as calculated with *ReSCA* for 2004 (Jacob et al 2009 STOTEN 408)

REMEDIATION CURRENT SITUATION

- Most land previously contaminated with radionuclides is now safe for habitation and economic activities
- Still many people in settlements in Belarus and Ukraine with annual effective dose > 1 mSv
- However, in Chernobyl Exclusion Zone and isome limited areas of fSU some restrictions on land-use likely to be retained for decades
- In some areas with still high ^{137}Cs transfer from poor sandy/peaty soils to vegetation remediation measures remain efficient

Changing emphasis with time

- Whilst cost benefit analysis was key factor during first decade, importance of considering social aspects increased thereafter.
- Long term adherence to banning the collection and/or consumption of products has reduced.
- Focus on providing readily understandable information and guidance on how people can themselves reduce their radiological risk

Ranking of practicability

Countermeasure	Belarus	Russia	Ukraine
Radical improvement	High	High	High
Drainage (for wet peat only)	Low	Low	High
Prussian blue	High	High	Moderate
Supply clean milk	Low	Low	Low
Clean feed for animals	Moderate	Moderate	Moderate
Mineral fertiliser for potatoes	Moderate	Moderate	High
Restrict mushroom consumption	Low	Low	Low
Food monitors	Moderate	Moderate	Moderate
Removal of soil	Low	Low	Low

Fesenko et al, 2006

REMEDIATION LESSONS LEARNED

- Remediation planning and identification of priorities for implementation essential
  - **facilitated by available expertise in USSR**
- Early application of previously identified suitable measures can substantially reduced internal doses to the population
- Implementation of effective measures may depend on availability of pasture and fodder – seasonally dependent
- Remediation may be required for many years after contamination occurs, depending on the soil types and agricultural production characteristics of the contaminated area
- Benefit of models which include effect of remediation measures (eg. ReSCA)

REMEDIATION LESSONS LEARNED

- Optimizing requires consideration of technical (e.g. effectiveness, cost, feasibility), environmental and social (e.g. acceptability, opportunities for self help) factors
  - **varies between countries**
- Importance of local monitoring and information, trusted professionals
- Success of remediation in private sector of subsistence rural farmers dependent on compliance of rural population - can only be achieved by:
  - **involvement in decision making process**
  - **providing good information**
  - **opportunity to discuss the implications of their decisions**
- Best measures depend on agricultural, environmental conditions and social/cultural perspectives

One solution does not fit all