The Management of Contaminated Land - Challenges in Belarus following the Chernobyl Accident

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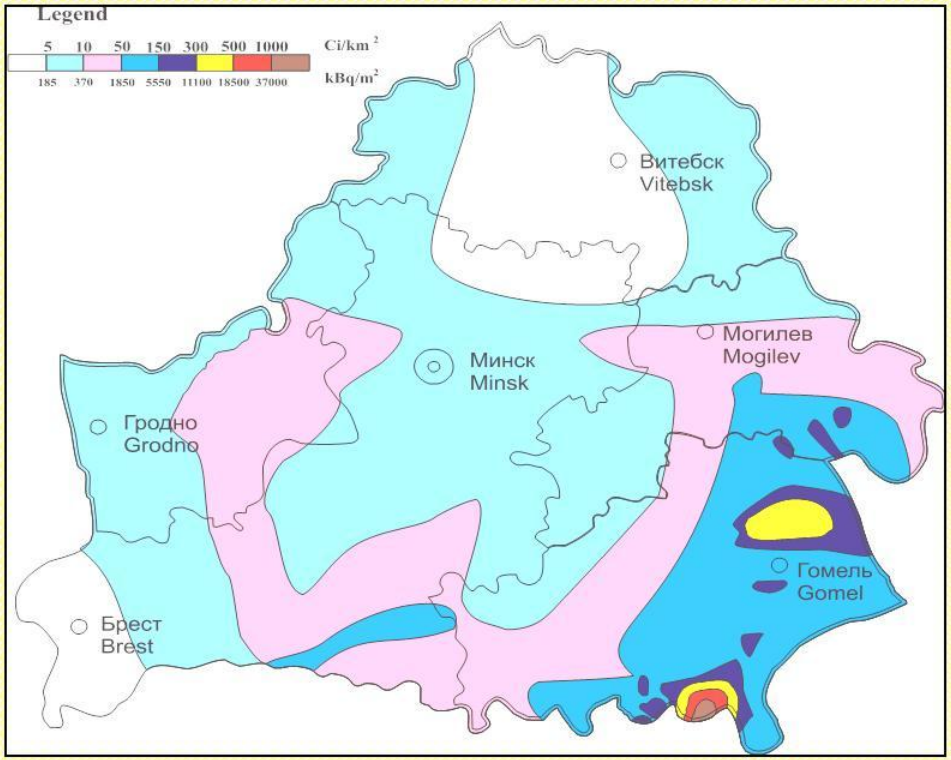
Chernobyl accident: challenges for agriculture

- ✓ The accident occurred 28.04.1986 in an vulnerable period, end of sowing campaign and start of cattle grazing.
- ✓ Belarus had the highest share of contaminated territory: 23 % (46 thousand km^2) including 1.8 million ha agricultural land was contaminated with ^{137}Cs (>37 kBq/m2),simultenasly 10% of territory - with ^{90}Sr (>5.5 kBq/m2) and 2%of territory - with Pu isotopes (>0.37 kBq/m2).
- ✓ Population on contaminated territory in 1986 - 2.2 million. 25 thousand of citizens were evacuated from 30 km zone in 1986 . 113 thousands - relocated in 1991-2000 years. About 200 thousand - left contaminated territory voluntary.
- ✓ After 27 years the contaminated territory reduced on 37% (30 thousand km^2) population – to 1.0 million of inhabitants. Agriculture is conducted on area of1 million ha of land contaminated with ^{137}Cs including 0.37 million ha simultaneously contaminated with ^{90}Sr.

Countermeasures in an early period of emergency (spring – autumn 1986)

Iodine-131 deposition in Belarus 10.05.1986



27- 28.04.1986. The lowest concentrations of ^{131}I in air on North of Belarus were 150-200 Bq/m^3. Safety limit is 7.3 Bq/m^3.

Monitoring of radionuclide content in soil, water, food stuff (deficit of measurement devices. Soil maps of Cs and ^{90}Sr deposition were prepared in August 1986).

- Feeding the milky cows with "clean" fodder (restricted use).
- Rejection of milk with ^{131}I content > PL and further processing for butter.
- Information & recommendations for population on the contaminated territory (luck of experienced experts and reliable information, recommendations directed mainly to public sector of agriculture).

Regulatory actions

The main goal - to reduce the external and internal doses of irradiation of population to prevent the deterministic effects and provide production of foodstuff with radionuclide content below TPL.

TPL (Bq/kg) of radionuclide content in food in USSR after Chernobyl (1986-1991)

Date of adoption	6.05.1986	30.05.1986	15.12. 1987	22.01. 1991	
Radionuclide	^{131}I	Beta emitters	^{134}Cs & ^{137}Cs	^{134}Cs & ^{137}Cs	^{90}Sr
Drinking water	3700	370	18.5	18.5	3.7
Milk	370-3700	370-3700	370	370	37
Meat and products	—	3700	1850-3000	740	—
Fish	37 000	3700	1850	740	—
Vegetables, fruit,	—	3700	740	600	37
Bread, flour, cereals	—	370	370	370	37
Expected internal dose, mSv		<50	<8	<5	

Permanent resettlement zone (after 22 May 1986) - exposure >0.2 mGy/h, Dose>100mSv.
Temporary resettlement zone if exposure 0.05 - 0.2 mGy/h, Dose >25 mSv.
Maximal doses of rural dwellers during 1986-1990 ≤ 175mSv/

Countermeasures related to land management in the late emergency period (1987-1989)

- Exclusion of heavily contaminated agriculture land from use – 265 000 ha (1986-1991).
- Deep ploughing of meadows on peat soil (limited use).
- Exclusion of crops with high accumulation of radionuclides (legumes, buckwheat, etc).
- Liming 682 000 ha & fertilization with higher doses of K (1.2 million t) and P(0.6 million t) fertilizer.
- Restriction on the consumption of milk produced in the personal farmstead and milk processing.
- Two stage cattle clean feeding was routinely used for meat production on land with deposition of $^{137}Cs > 185$ kBq m^{-2}. Clean feed of animals for 1.5 months before slaughter was combined with live monitoring. Animals exceeding PLs were returned to the farm for further clean feeding

Decontamination of houses and soil

Decontamination of rural houses with dose monitoring were well accepted:

- Washing the roof, walls and pavement with high pressure water. Removing contaminated dust with vacuum cleaners

- Removing topsoil from a 1 m strip around house. Removing topsoil in garden (400-500 m^2 per house). Dose reduction -DRF= 0.3-0.5 (80% of reduction due to decontamination of soil).
Deep ploughing 50 cm DRF=0.1-0.3
Typical ploughing 20-30 cm DRF= 0.3-0.5

Removal of 10-15cm top soil (Bobcat)
DR=0.3 cost 1.0 USD per 1 m^2 (without disposal wastes)
Volume of disposed soil 1000-1500 tons/ha

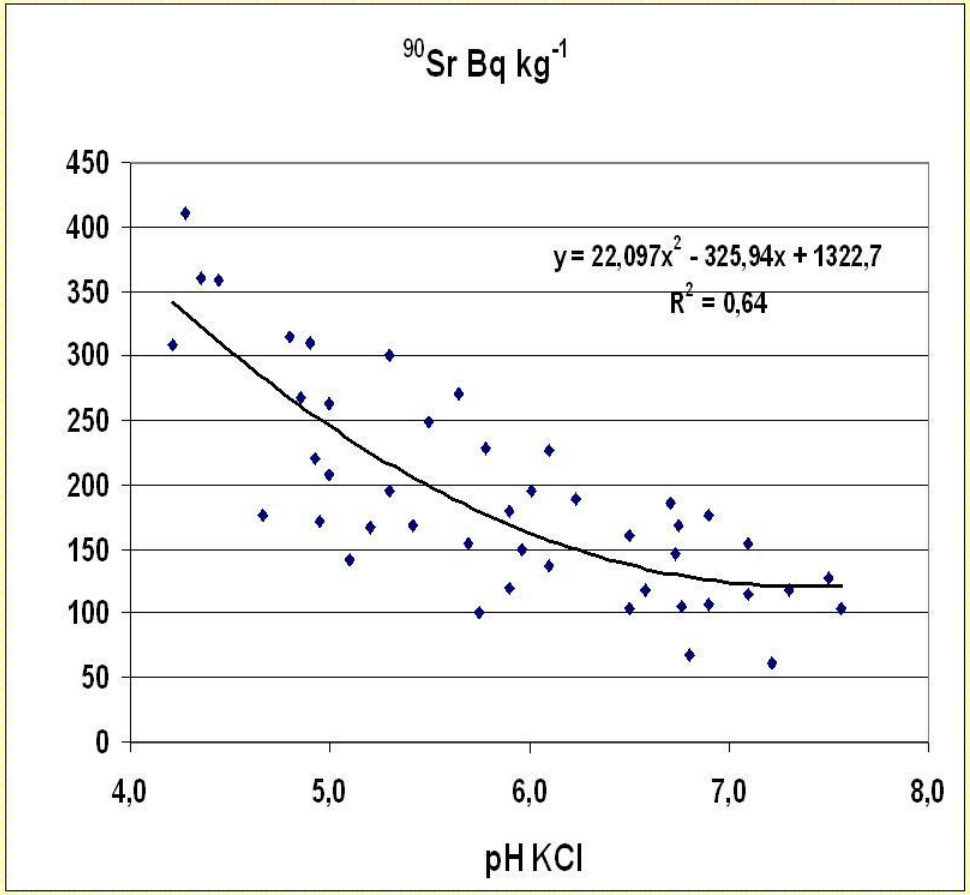
Top soil removal could be accepted only to small affected areas around public buildings.

It is not acceptable and affordable to agricultural land

Site specific remediation: Liming

- Liming only efficient on acid soils (pH "Low to optimal" related to different soils and crops)
- RF for ^{137}Cs and ^{90}Sr activities in plants 1.5-3.0.
- Cost of liming on such soils covered by increased yield
- Minimal uptake by plants at pH levels at 0.2-0.3 higher than maximum yield is achieved
- Over liming provide the reduction of availability of micronutrients Mn, Zn, Cu in soil to plants

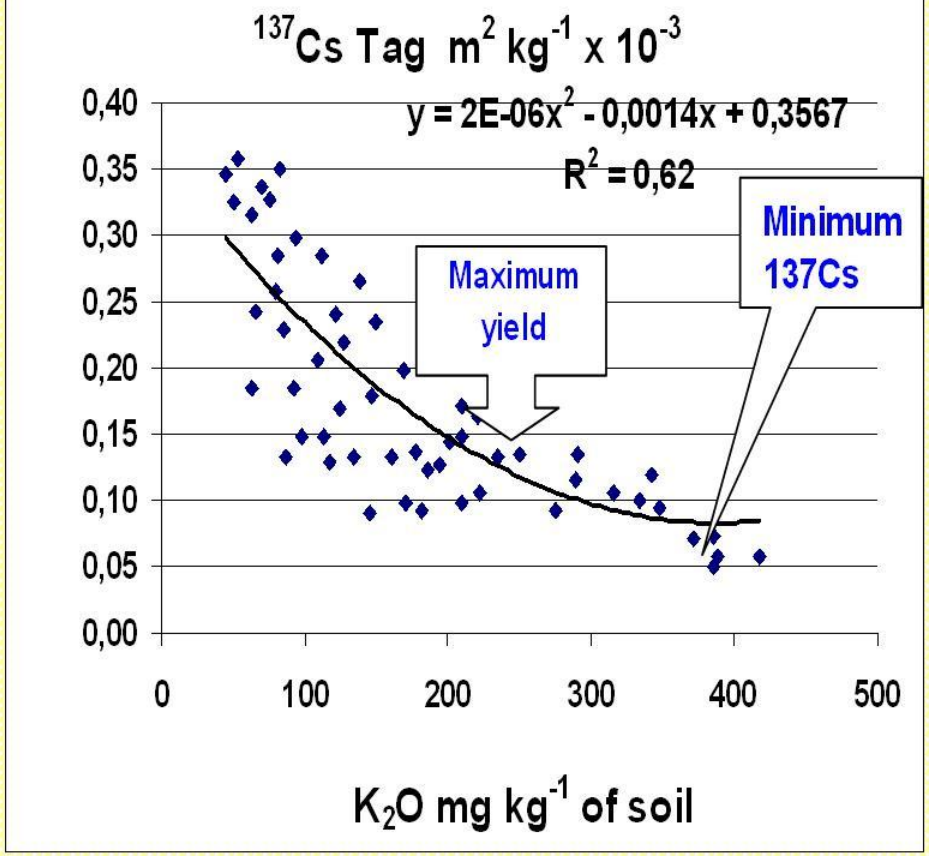
Accumulation of ^{90}Sr in clover green mass in relation to reaction of Podzoluvisol loamy sand soil



Site specific remediation: K-fertilizer

- K fertilizer could effectively inhibit the transfer of ^{137}Cs (and ^{90}Sr in lesser extension) from soil to plants only in soils with "Low to Optimal" K status.
- Minimal accumulation of radionuclides in plant production is found on soil with higher K content than needed for maximum yield.
- Only moderate potash fertilizer rates are needed for medium and rich K-supplied soils (K 5.3-7.4 mmol kg^{-1}) to replace of the crop K-removal.
- Expenses for averted 1 man Sv =40-60 k Euro if deposition of ^{137}Cs ≥370 kBq/m^2.
- Expenses for averted expose are covered by extra crop yields with sufficient net return on soils with low to optimal content of exchangeable K.

^{137}Cs transfer to clover green mass in relation to K status of Luvisol loamy sand soil



Recommended annual doses of K-fertilizer on Podzoluvisol soils contaminated with radionuclides ^{137}Cs and ^{90}Sr

Land	Mobile K_2O, mg kg^{-1}	Basic doses K_2O, kg ha-1	Additional doses of K2O (kg ha-1) according to deposition, kBq m-2		
			^{137}Cs 37-184	^{137}Cs 185-554	^{137}Cs 555-1480
			^{90}Sr 6-10	^{90}Sr 11-73	90Sr 74-111
Arable land	< 80	100	50	100	150
	81-140	90	30	60	90
	141-200	80	20	40	60
	201-300	55	15	30	45
	> 300	25	-	-	-
Meadows and pastures	< 80	80	40	80	120
	81-140	70	30	60	90
	141-200	60	20	40	60
	201-300	45	15	30	45
	> 300	20	-	-	-

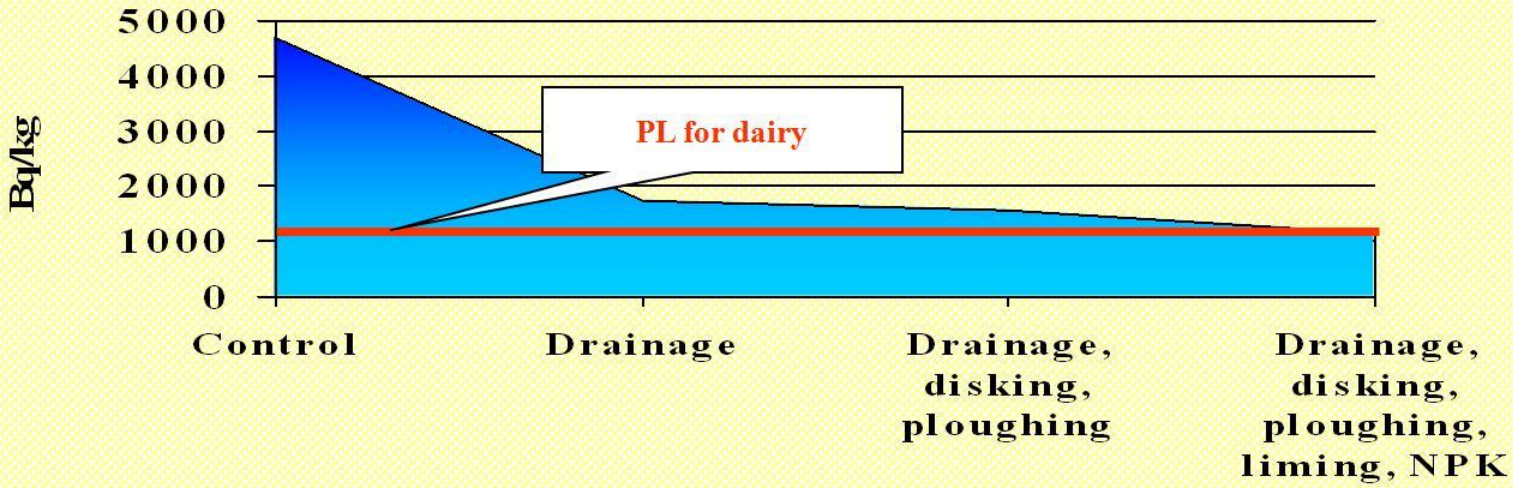
Radical improvement of pastures & meadows

The most efficient and acceptable by farmers remedial action.

- **Liming of acid soils, fertilization, destruction old grass mat, sowing of new grass stand, and the regulation of soil water (drainage), if needed.**
- **Reduction of grass activity 2-10 times (depending on intensity)**
- **Usually, the expenses for pasture improvement are covered by extra yield of milk.**

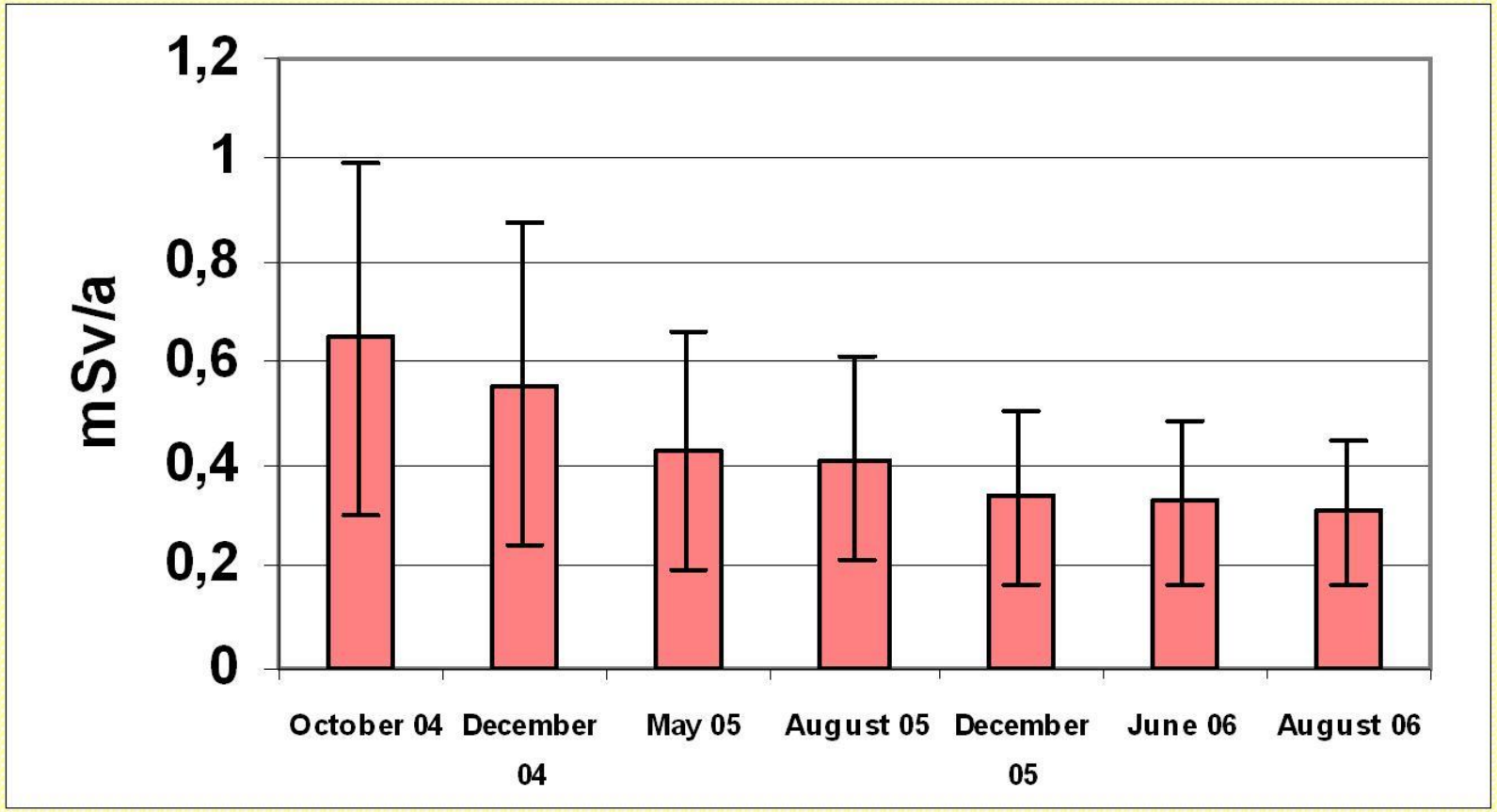
^{137}Cs concentration in hay depends on type of meadow improvement

(deposition by ^{137}Cs - 370 kBq.m^{-2})



Application of Prussian Blue to cows is an effective alternative for short period to the more expensive radical improvement.

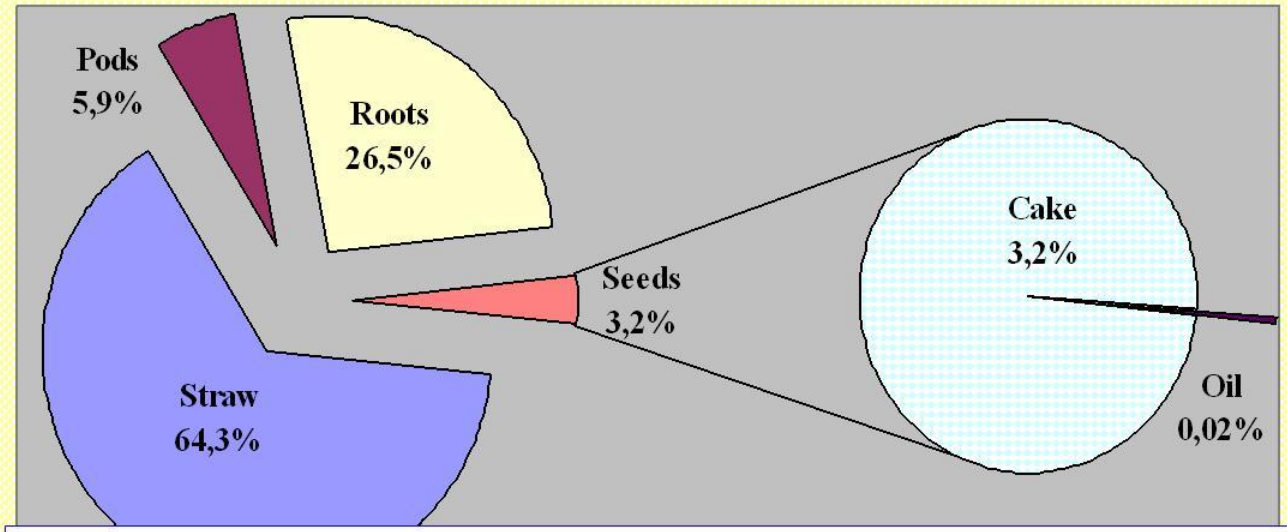
Effect of remediation actions (PB+RI) on the internal dose reduction in Svetilovichi (IAEA RER 9074 2004 - 2006)



The whole body measurements were undertaken for dynamics estimation of internal doses irradiation of people RF=2 during 1.5y

Modified Use of Land
Growing & Processing of Rapeseed
IAEA TC Project BYE 5/004

Only about 3% of the total ^{137}Cs and 6 % of the total ^{90}Sr taken up by rape plant are involved in the chain soil-plant-fodder-animal-man.



^{137}Cs allocation in spring rapeseed biomass

During 1996-2012 the production of rape seed increased from 18 to 700 thousand tons. Net return for growing 1 tone of rape seed - 30 Euro, for processing - 34 Euro.

Remedial actions in rehabilitation period, since 2001

The main goal – Rehabilitation of contaminated territories, providing the safe food and living condition, economic and social development of rural settlements

- **Returning the abandoned land to agricultural use (15000 ha).**
- **Liming for optimization (pH – Ca^{++} -- Mg^{++}).**
- **Soil fertility optimization and maintenance. Site specific fertilization P and K, slow release N and compound fertilizers**
- **Radical and surface improvement of pastures and hayfields for personal households**
- **Clean two stage feeding diets for animals (on alluvial and boggy soil)**
- **Modernization and re-specialization of farms**

Recommendation to farmers on personal fields

International projects /ETHOS - CORE 1999-2007

Involvement of stakeholders in process of rehabilitation

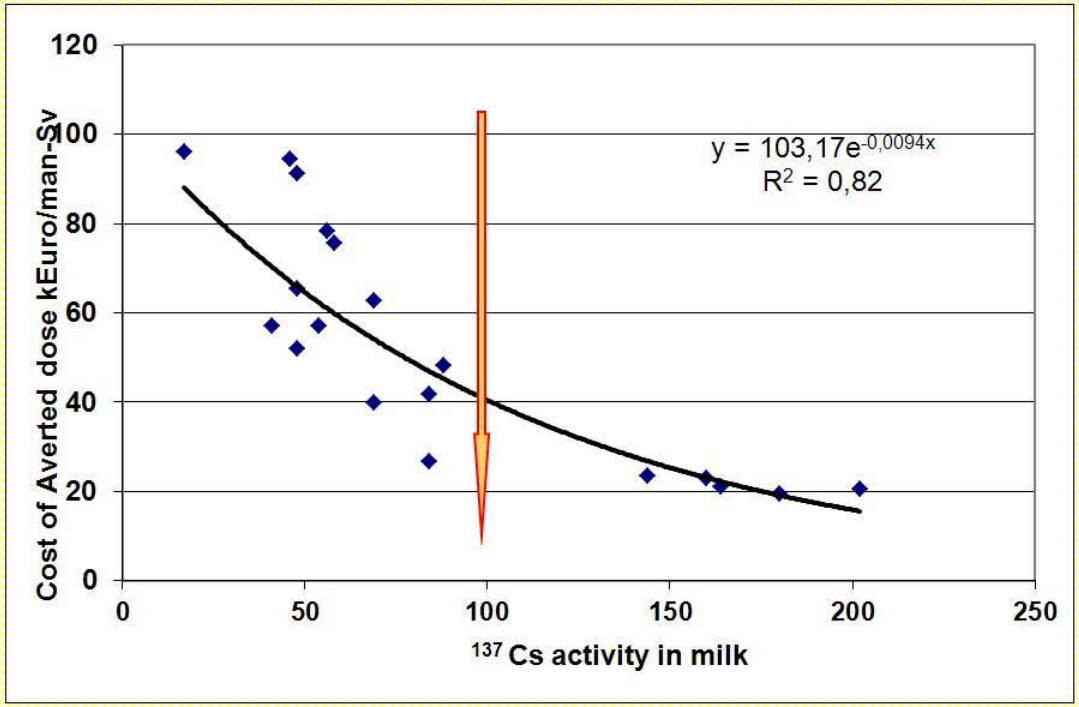
Measurements of radioactive contamination and processing of milk, vegetables, berries, mushrooms

Modern technologies:

- ✓ *increase the potato & vegetable yields in 1.6-1.8 times*
- ✓ *reduction on 20-30% of ^{137}Cs and ^{90}Sr concentration in products*
- ✓ *1 EURO invested (430-9400 € ha^{-1}) has made 1.5-2.5 € of net return*
- ✓ *Transition from personal field to farmer's production*

Optimizing remediation measures. Decision support for remediation planning – ReSCA

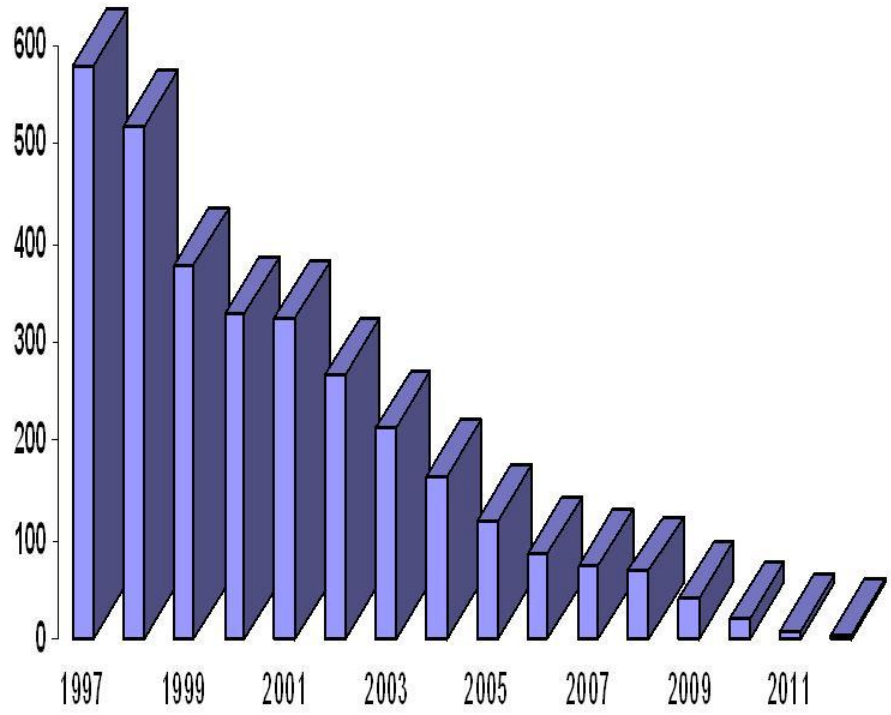
Cost of averted dose related to initial ^{137}Cs activity of milk for radical improvement of pastures



Agriculture – 28 years after Chernobyl

- After 2006 99,9% of milk produced with activity ^{137}Cs <50 Bq/l; 99,7 % of beef - <100 Bq/l .
- Unsolved problems on 17% contaminated land with poor sandy and boggy soils (deposition of 137 Cs > 185 kBq/m^2, ^{90}Sr 11-111 kBq/m^2.
- Demographic situation and economic status of farmers should be improved.

Number of settlements with samples of milk exceeded the PL of ^{137}Cs activity (> 100 Bq l^{-1})



Chernobyl consequences –long term problem

Forecast for number of settlements situated on contaminated land of Belarus (in1986 – 3668 settlements)

Year	Deposition, kBq/m^2				
	Cesium-137			Strontium-90	
	555–1480	185–555	37–185	18,5–74	5,55–18,5
2010	22	506	1 915	116	554
2015	13	361	1 817	96	526
2020	8	294	1 748	66	462
2025	6	228	1 664	51	414
2030	2	174	1 593	36	351
2040	-	95	1 312	15	259
2050	-	57	1 161	5	212
2090	-	1	428	-	36

Lessons learned

- The team of experts and the comprehensive plan for the protection of affected people in emergency period should be prepared in the long time before the possible nuclear accident.
- Permissible levels of radionuclide content in food products are important target instruments for selection and optimizing appropriate countermeasures and remedial actions.
- Countermeasures in the early phase of the Chernobyl accident were only partially effective. Little reduction of ^{131}I intake with milk due the lack of timely information on the accident and appropriate countermeasures.
- Agricultural countermeasures and remedial actions applied in Belarus proved to be highly efficient averting about 40%of collective internal dose.
- Radical improvement of pastures & medows was the most efficient and acceptable by farmers remedial action. Application of Prussian Blue to cows started only 6 years after the accident: its an effective alternative for short period to the more expensive radical improvement. However in normal practice the expenses for pasture improvement are covered by extra yield of milk.

Lessons learned

- Soil fertility improvements through liming and fertilizer application resulted in optimization of soil properties in Belarus on 70-85% of cultivated area. These are the basic guarantee for minimization of radionuclide accumulation in farm products in the long-term period after accident. Ca, K and P amendments are efficient only in the range of "Low to Optimal" related Ca, K and P status of soil. The expenses for fertilization are covered by extra crop yields.
- Modified Use of Land by growing and processing of rapeseed strongly reduced inflow of radionuclides ^{137}Cs and ^{90}Sr into food chain. It was profitable.
- Until today, agricultural remedial actions are still effective. To identify priorities in remediation strategies the involvement of all interested parties in planning is necessary.
- International cooperation and assistance are very important in mitigation of consequences of radiation accidents. There are many examples of effective International projects implemented in Belarus: IAEA projects and training courses 1986-2012; EC projects; French-German initiative; ETHOS-CORE etc.