National experience in remediation of contaminated farmlands after the Chernobyl accident

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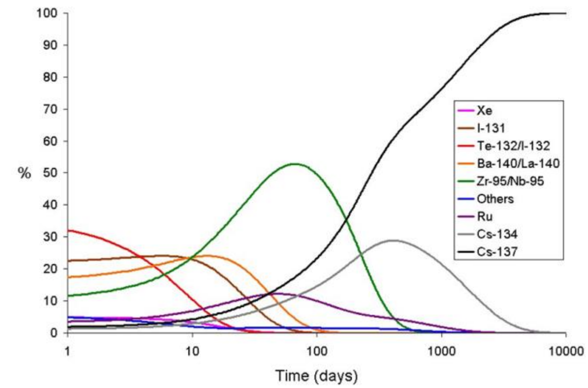
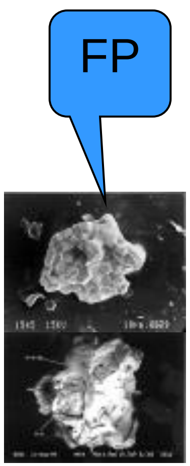
Environmental Contamination After the Chernobyl Accident

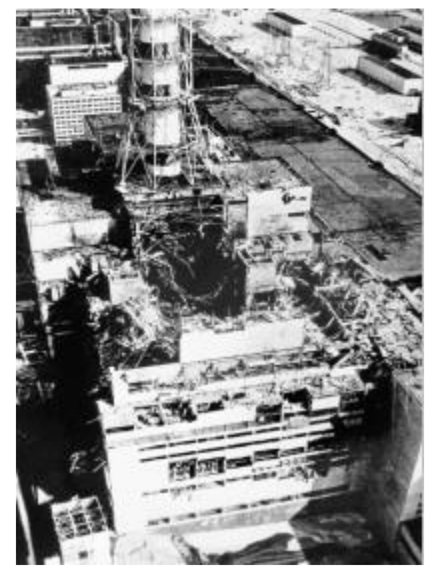


April 26, 1986 at 01:23 two explosions destroyed unit 4 of the Chernobyl nuclear power plant (ChNPP).

The Chernobyl accident released a mixture of radionuclides into the air over a period of about 10 days:



Radionuclide	$T_{1/2}$	Release of radionuclides from the reactor during the accident		
		Activity, Bq	Weight, kg	Part of the content in the reactor,%
^{131}I	8.04 d	$1,7*10^{18}$	0.04	50÷60
^{137}Cs	30.2 y	$8,6*10^{16}$	27	33±10
^{90}Sr	29.1 y	$4*10^{15}$	0.8	1.8
^{238}Pu	87.7 y	$1.8*10^{13}$	0.03	1.4
$^{239+240}$Pu	24100 & 6563 y	$3.4*10^{13}$	8.1	1.4
^{241}Am	433 y	$2.2*10^{12}$	0.02	1.4



The external dose

For open spaces	For residents of villages	For small towns	For urban residents (cities)
1	0.29	0.2	0.13

Children under 7 years: **0.13 in winter and 0.18 in summer**

For agricultural workers: **0.33 in winter and 0.43 in summer (**for employees and retirees**: 0.24 0.28-0.3 winter and summer).**

The effectiveness of decontamination:

villages <25%

agricultural land and forests <5%

Ukrainian Institute of Agricultural Radiology (UIAR) of

National University of Life and Environmental Sciences of Ukraine (NUBiP of Ukraine) is a leading institution in Ukraine in the field of agricultural radiology.
Since our foundation in 3 June 1986 we have accumulated a large experience in elimination of the Chernobyl accident consequences.

Main activities in the past:

- evaluation of the radiological situation in agriculture (at the levels regions, districts and farms) and development of recommendations for agricultural production at the radioactive contaminated lands;
- application of agricultural countermeasures and evaluation of their efficiency for rehabilitation of the radioactive contaminated lands and their return to economical activity;
- characterization of the physical-chemical forms of the radioactive fallout;
- determination of the fuel particles types and dissolution rates in the Environment and various media;
- experimental studies and modeling of the radionuclides resuspension, transportation and deposition in various natural conditions (normal weather, strong winds, wildland fires etc) and during the agricultural practice and evaluation of the radionuclides inhalation and doses to workers/population;
- mapping the 30-km Chornobyl zone contamination with ^{90}Sr and the fuel component radionuclides;
- experimental studies and modeling of the radionuclides migration in the soil (unsaturated zone and aquifer), revealing the phenomenon the fast migration of Pu isotopes;
- studies of the radionuclides root and foliar transfer into agricultural crops;
- studies of the radionuclides fluxes in the forest ecosystems;
- studies of the radionuclides transfer into fish;
- studies of radiation effects to biota

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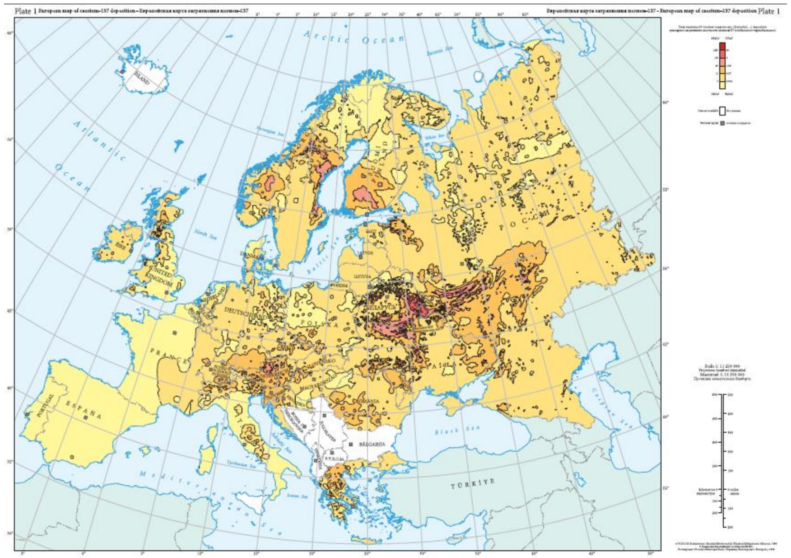
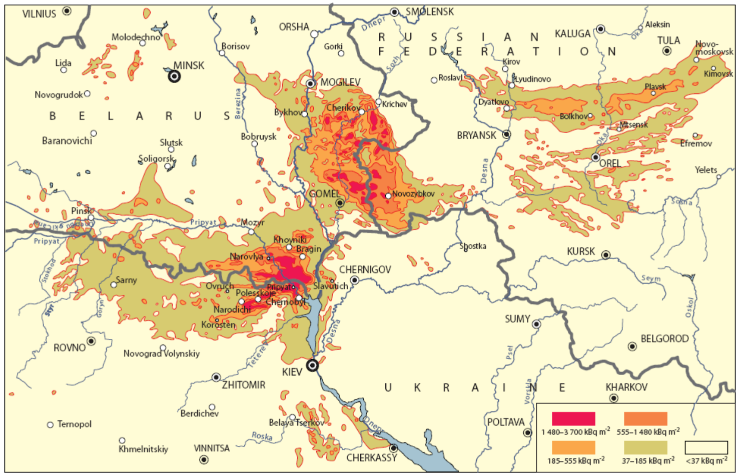
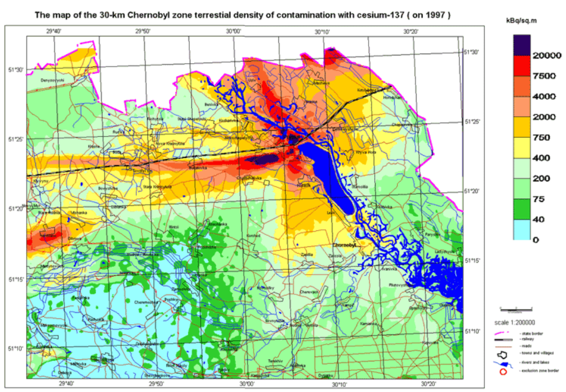
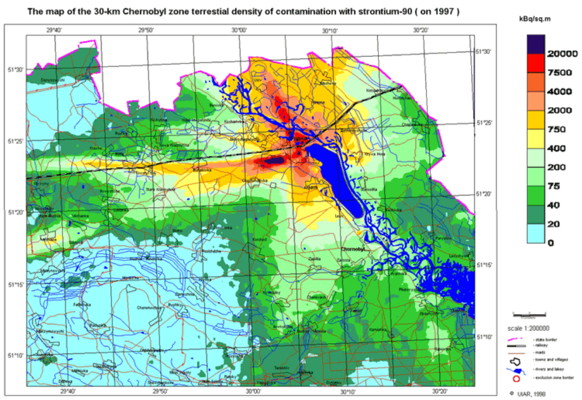
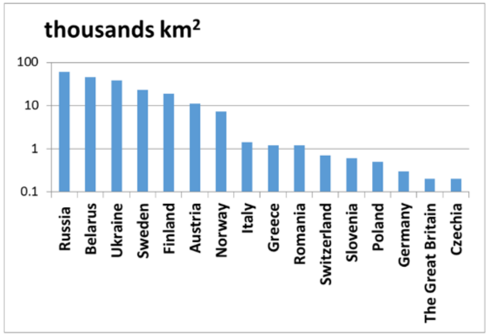
Large area of contamination of different radionuclides









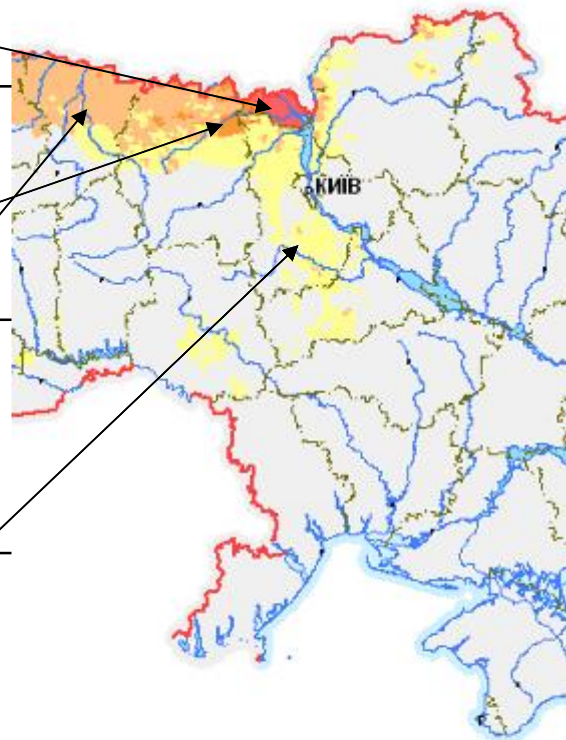


Contamination of agricultural land and forest area of Ukraine (01.01.95), thousands of hectares

Area	^{137}Cs density of contamination, kBq/m^2		
	37-185	185-555	>555
Agricultural land	1034.9	98.9	27.1
Forest	*1087.0*	*106.0*	*40.8*

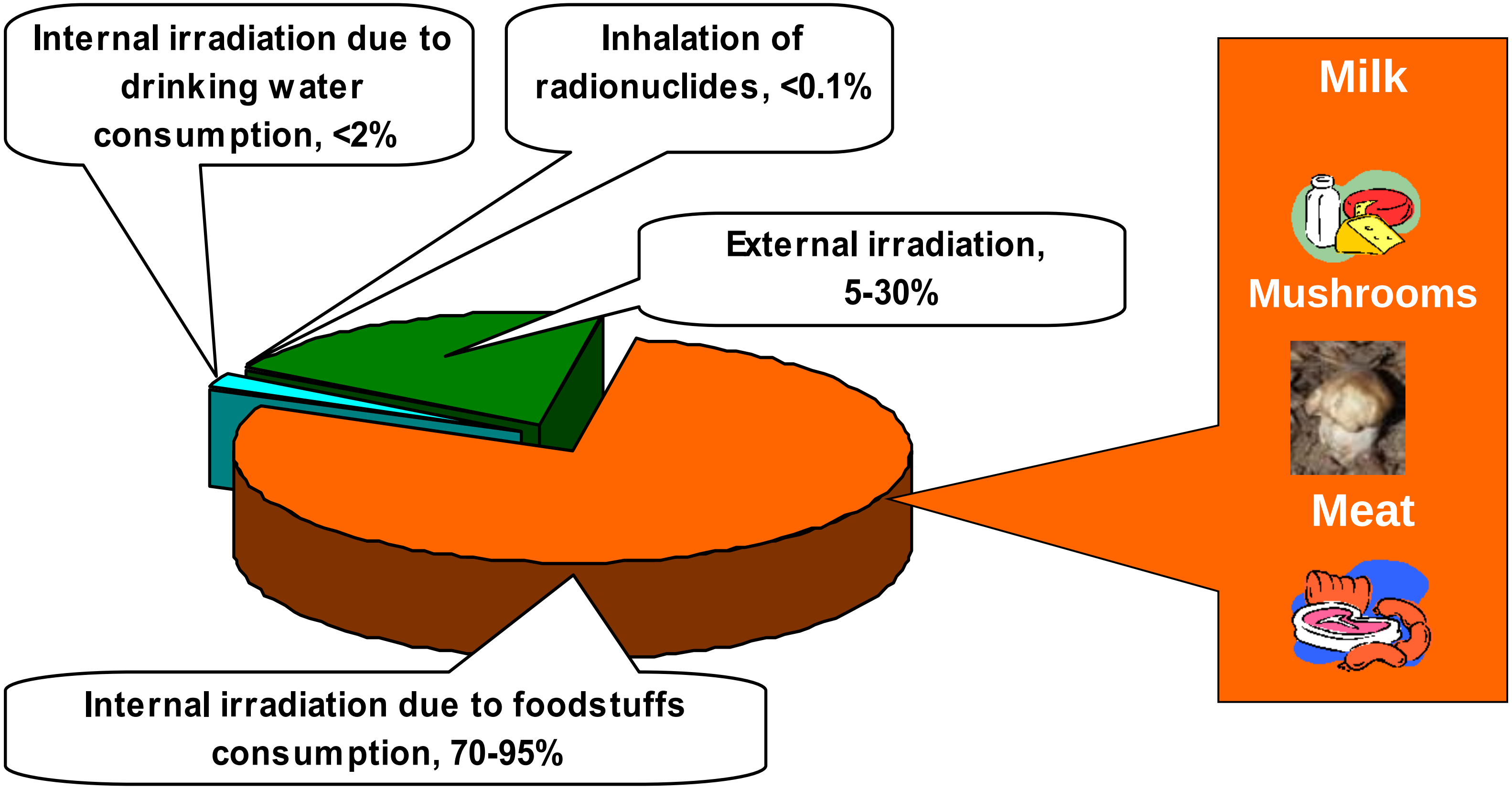
Criteria to establish the zones of radioactive contamination in Ukraine *(Laws of Ukraine, 1991)*

Zones	Criteria to establish the zones
1. Exclusion zone	Area where the population was evacuated in 1986 (includes 30 km zone around ChNPP)
2. Zone of an unconditional (obligatory) resettlement	Where $D_{eff}>5$ mSv/yr *$^{137}Cs > 555$ kBq/m² or* *$^{90}Sr > 111$ kBq/m² or* *Pu> 3.7 kBq/m²*
3. The zone of a guaranteed voluntary resettlement	Where $D_{eff}>1$ mSv/yr *$185 < {}^{137}Cs < 555$ kBq/m²,* *$5.5 < {}^{90}Sr < 111$ kBq/m²,* *0.37 < Pu < 3.7 kBq/m²*
4. The zone of an enhanced radioecological monitoring	Where D_{eff} >O.5 mSv/yr *$37 < {}^{137}Cs < 185$ kBq/m²,* *$0.74 < {}^{90}Sr < 5.5$ kBq/m²,* *0.185 <Pu< 0.37 kBq/m²*



Characteristics for 01.01.2007	1 zone	2 zone	3 zone	4 zone	Total
Number of settlements	76	86	841	1290	2293
Area, km²	2122	2003	22619	26710	53454
Population	120	9040	637230	1645540	2291930
including children under 14 years	*0*	*1870*	*150160*	*336660*	*488690*

Effective doses to Ukrainian population in the present period after Chernobyl accident



70-95% of the effective population dose in the most suffered regions of Ukraine is formed due to consumption of the foodstuffs containing Chernobyl radionuclides

Temporary permissible levels (action levels, Bq/kg) for radionuclides in foodstuff after the Chernobyl accident in the USSR, Ukraine and Japan

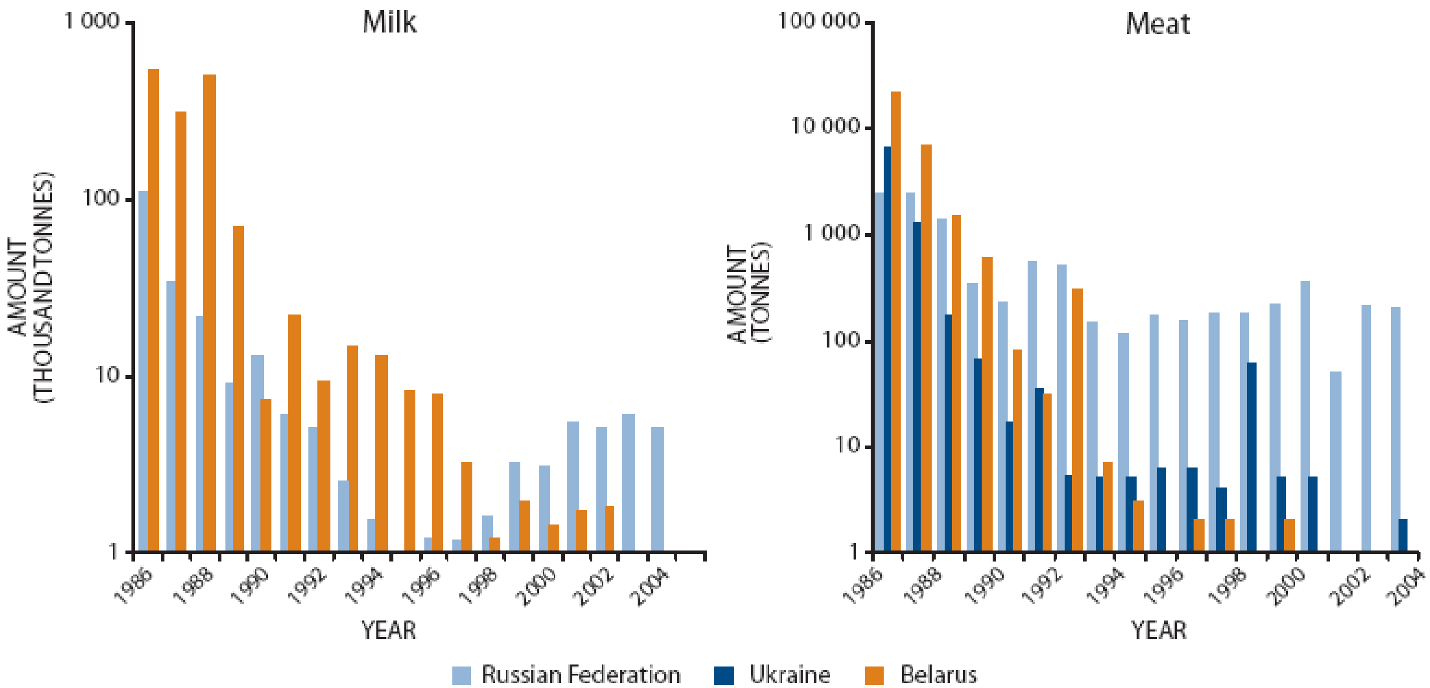
FOODSTUFF	Date						
	06.05.86[1]	30.05.86[2]	15.12.87[3]	06.10.88[3]	22.01.91[3]	Ukraine PL-97	Japan 2012
Drinking water	3700	370	20	20	20	2	10
Bread and bakery products, cereals		370	370	370	370	20	100
Milk	3700	370	370	370	370	100	50
Condensed milk		18500	1110	1110	1110	300	100
Sour cream	18500	3700	370	370	370	100	100
Cheese	74000	7400	370	370	370	200	100
Butter	74000	7400	1110	1110	370	200	100
Meat and meat products		3700	1850	1850	740	200	100
Fish	37000	3700	1850		740	150	100
Vegetables		3700	740	740	600	40-60	100
Leaf vegetables	37000	3700	740	740	600	40	100
Fresh fruit and berries		3700	740	740	600	70	100
Dried fruits and berries		3700	11100	1110	2900	280	100
Fresh mushrooms and wild berries		18500	1850		1480	500	100
Dried mushrooms			11100		7400	2500	100
Baby food			370	370	185	40	50

1 – for ^{131}I, 2- for total beta activity, 3- for $^{134+137}$Cs

ACTION LEVELS (Bq/kg) FOR CAESIUM RADIONUCLIDES IN FOOD PRODUCTS ESTABLISHED AFTER THE CHERNOBYL ACCIDENT

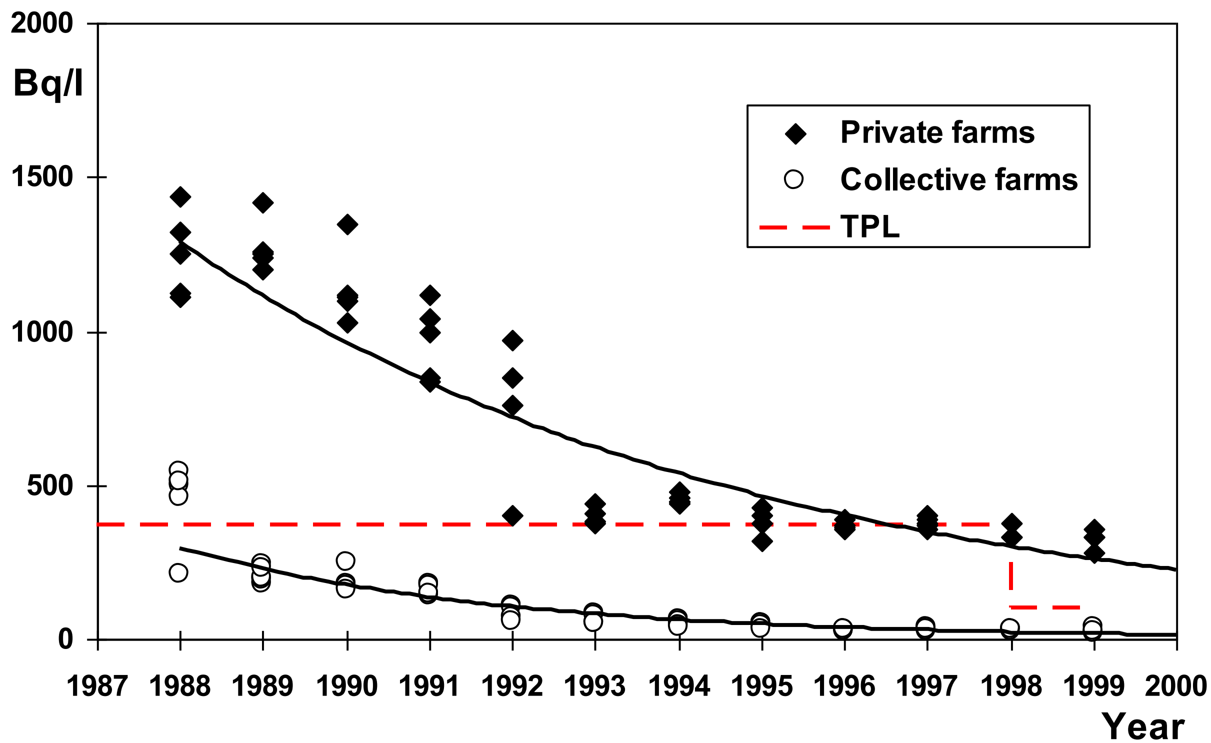
	Codex Alimentarius Commission	EU	Belarus	Russian Federation	Ukraine	Japan
Year of adoption	1989	1986	1999	2001	2006	2012
Milk	1000	370	100	100	100	50
Infant food	1000	370	37	40-60	40	50
Dairy products	1000	600	50–200	100–500	100	100
Meat and meat products	1000	600	180–500	160	200	100
Fish	1000	600	150	130	150	100
Eggs	1000	600	-	80	6 Bq/egg	100
Vegetables, fruit, potato, root crops	1000	600	40–100	40–120	40–70	100
Bread, flour, cereals	1000	600	40	40–60	20	100

Large scale application of countermeasures made it possible to achieve a sharp decrease of the volume of animal products with radiocaesium activity concentrations above the action levels



- Amounts of milk and meat exceeding action levels in Russia (all milk and meat - collective and private), Ukraine and Belarus (only milk and meat entering processing plants) after the Chernobyl accident

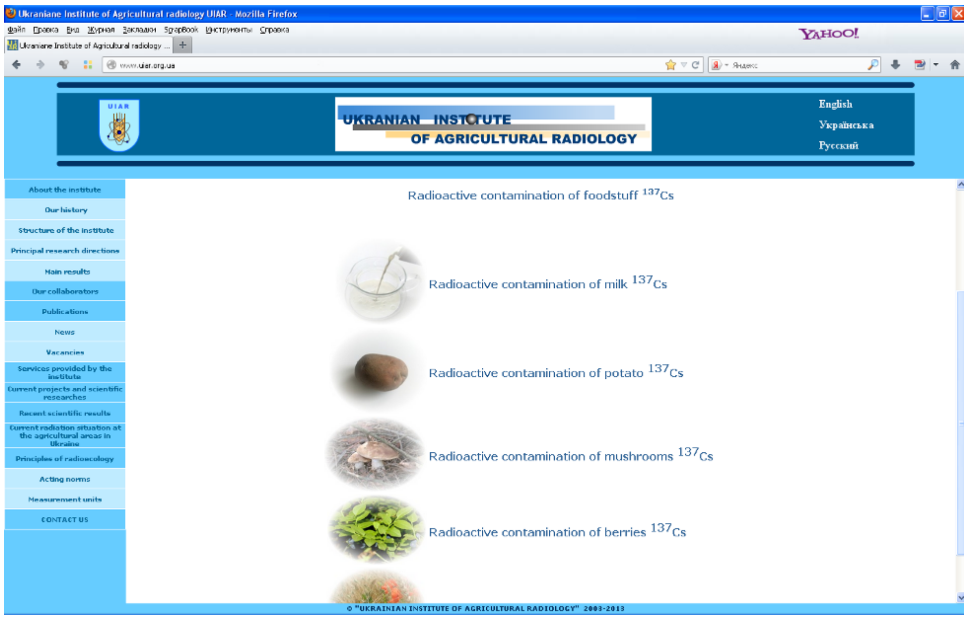
Agricultural production

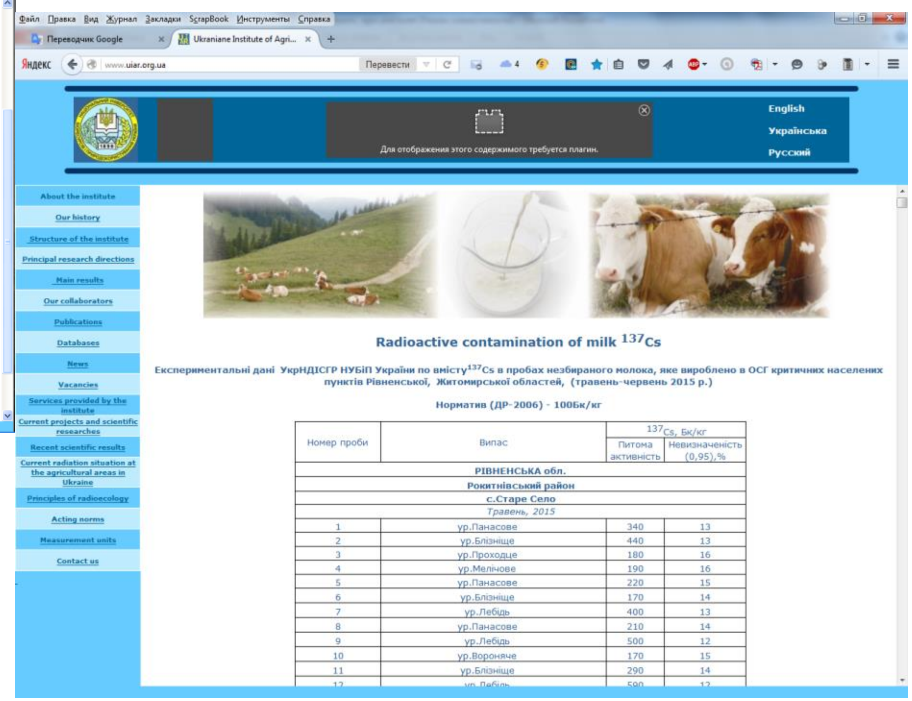


Typical dynamics of activity concentrations of ^{137}Cs in milk produced in private and collective farms in Rovno region, Ukraine, compared to the national temporary permissible level (TPL)

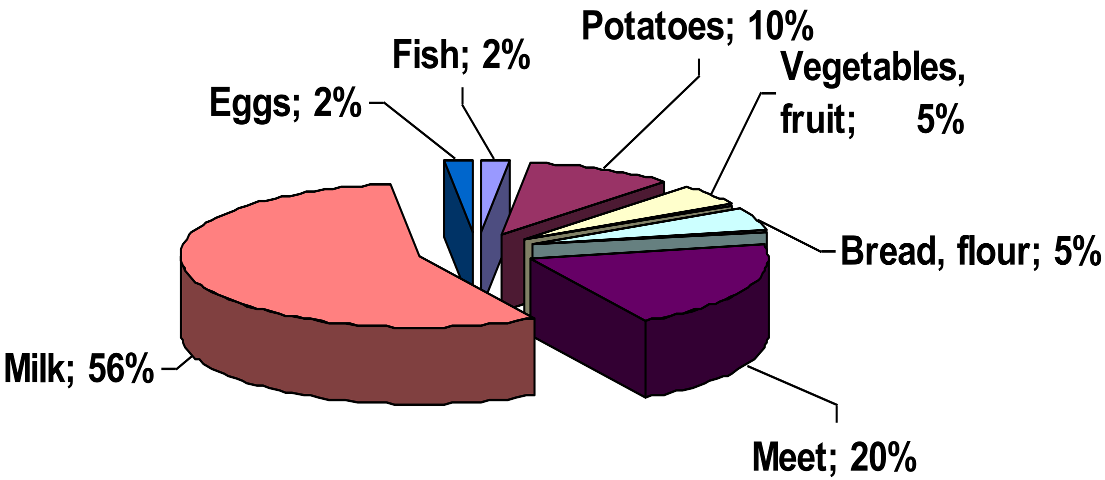
Monitoring of radioactive contamination of agricultural products

Ukrainian Institute of Agricultural Radiology NUBiP of Ukraine http://www.uiar.org.ua/



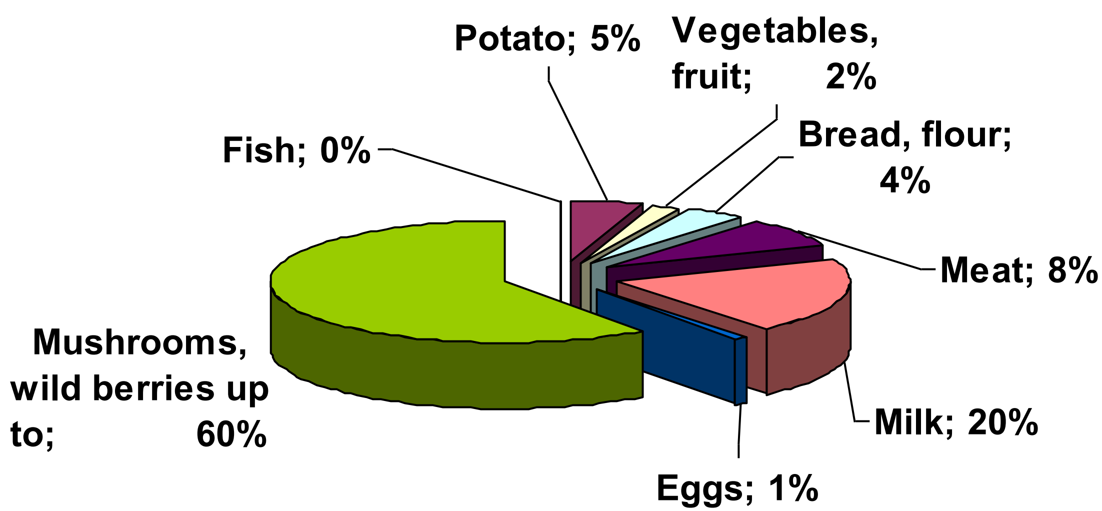


Averaged contribution of different products to the peroral ^{137}Cs uptake by the rural population

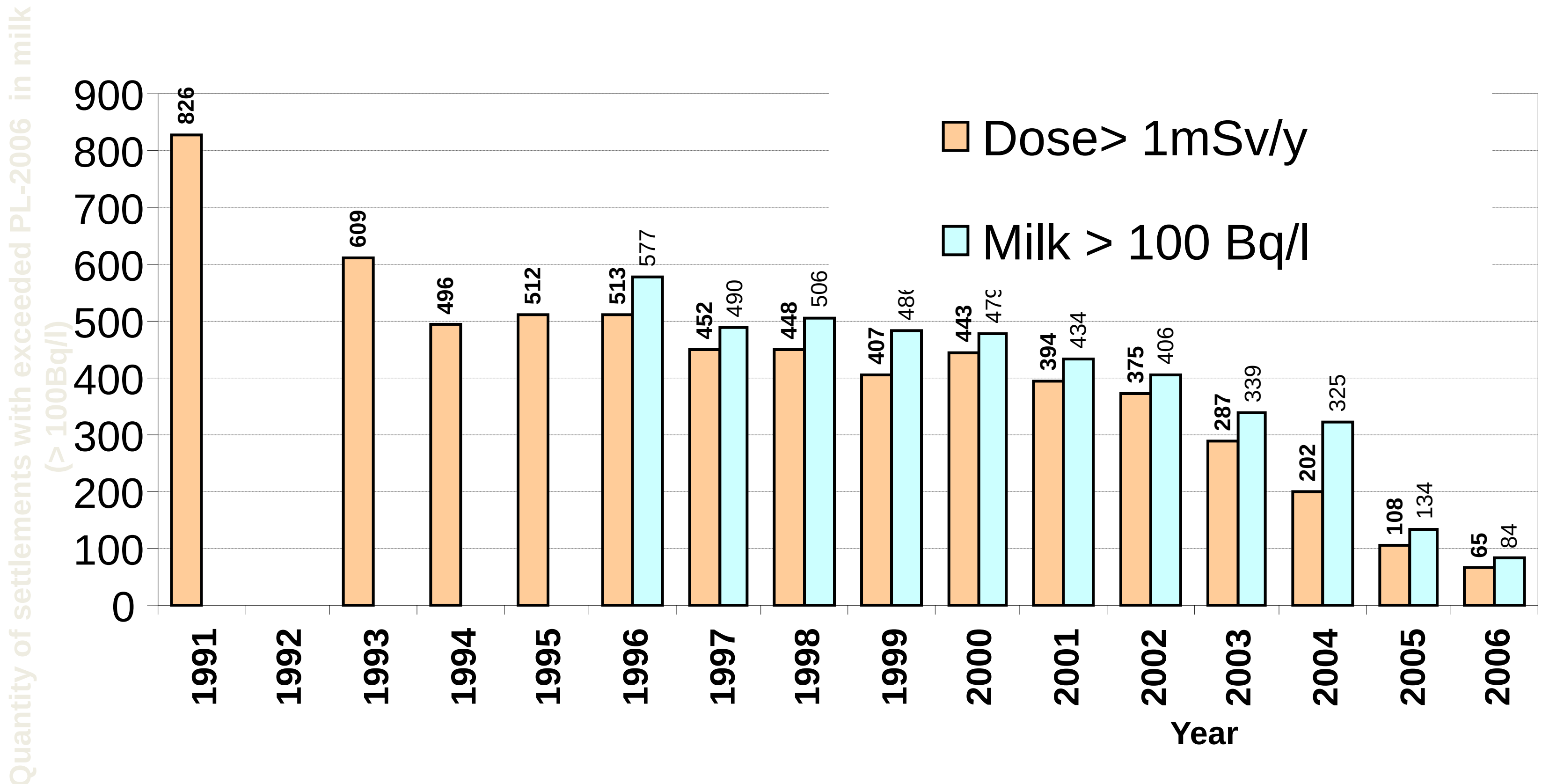


human diet with forest gifts

human diet without forest gifts



Distribution of settlements where ^{137}Cs activity in milk exceeds PL – 100 Bq/l



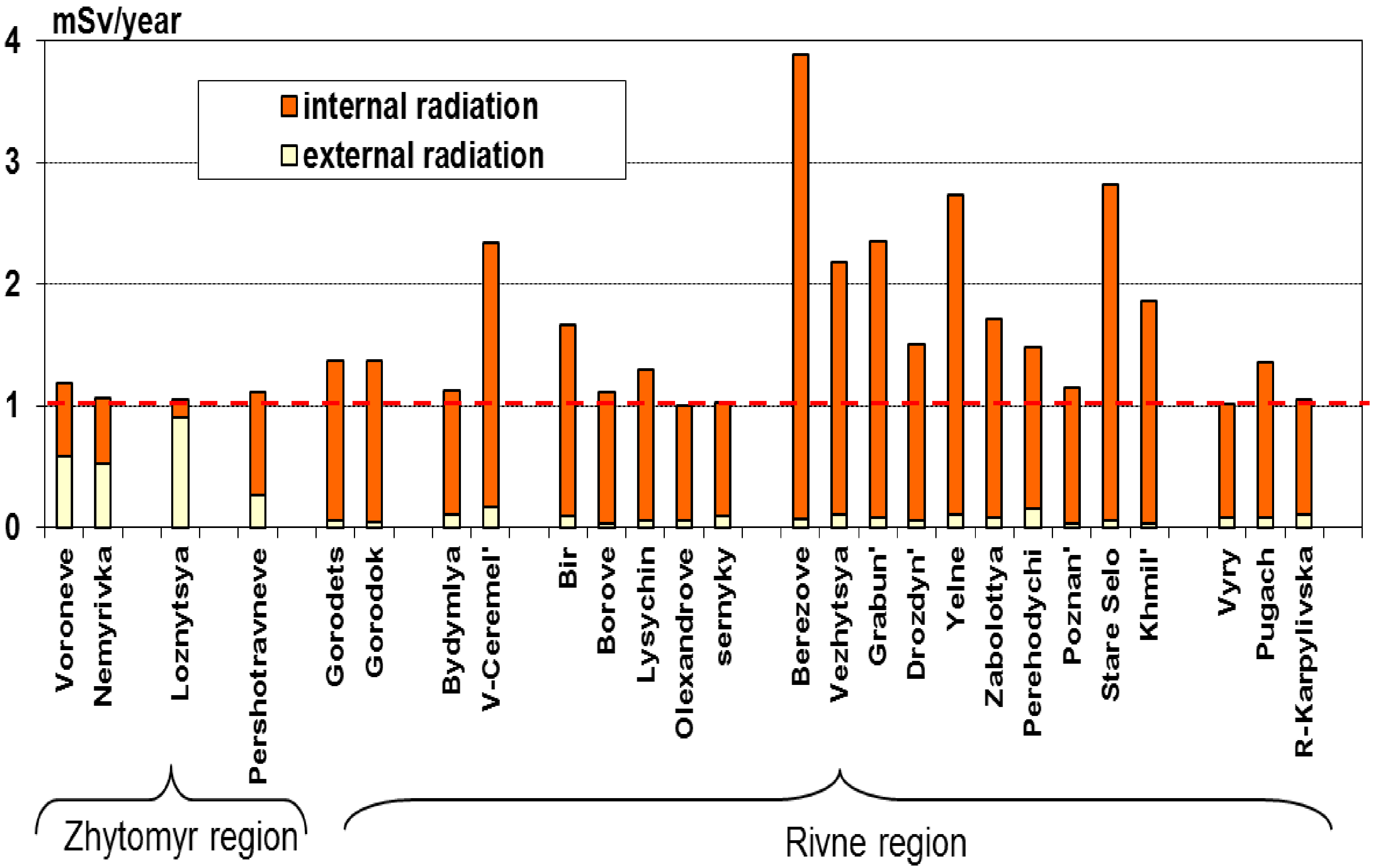
Physical decay will reduce concentrations by about 2% per year for ^{137}Cs and ^{90}Sr compared to actual values.

Distribution of number of settlements by passport doses

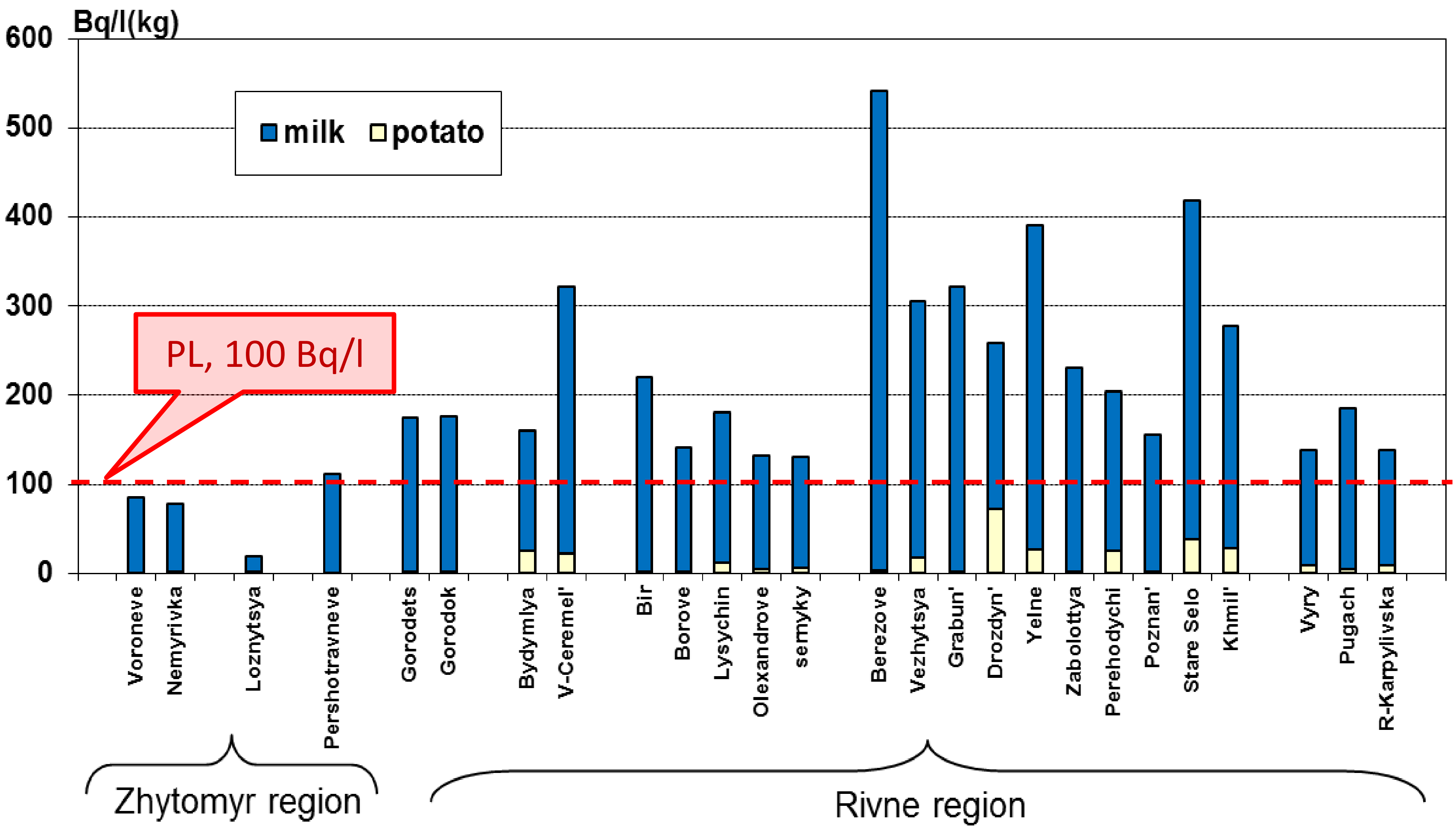
Year	Passport doses, mSv/y				
	$0,5 \le D_{eff} < 1$	$1 \le D_{eff} < 2$	$2 \le D_{eff} < 3$	$3 \le D_{eff} < 5$	$D_{eff} \ge 5$
2001	314	389	17	*12*	*5*
2002	317	351	7	*14*	*3*
2003	338	268	*8*	*9*	*2*
2004	410	187	*3*	*12*	*0*
2005	297	86	*10*	*12*	*0*
2006	285	52	*6*	*6*	*1*
2007		29	*5*	*7*	*1*
2011	101	**22**	**2**	**1**	**0**
2012	61	**26**			

Rivne oblast

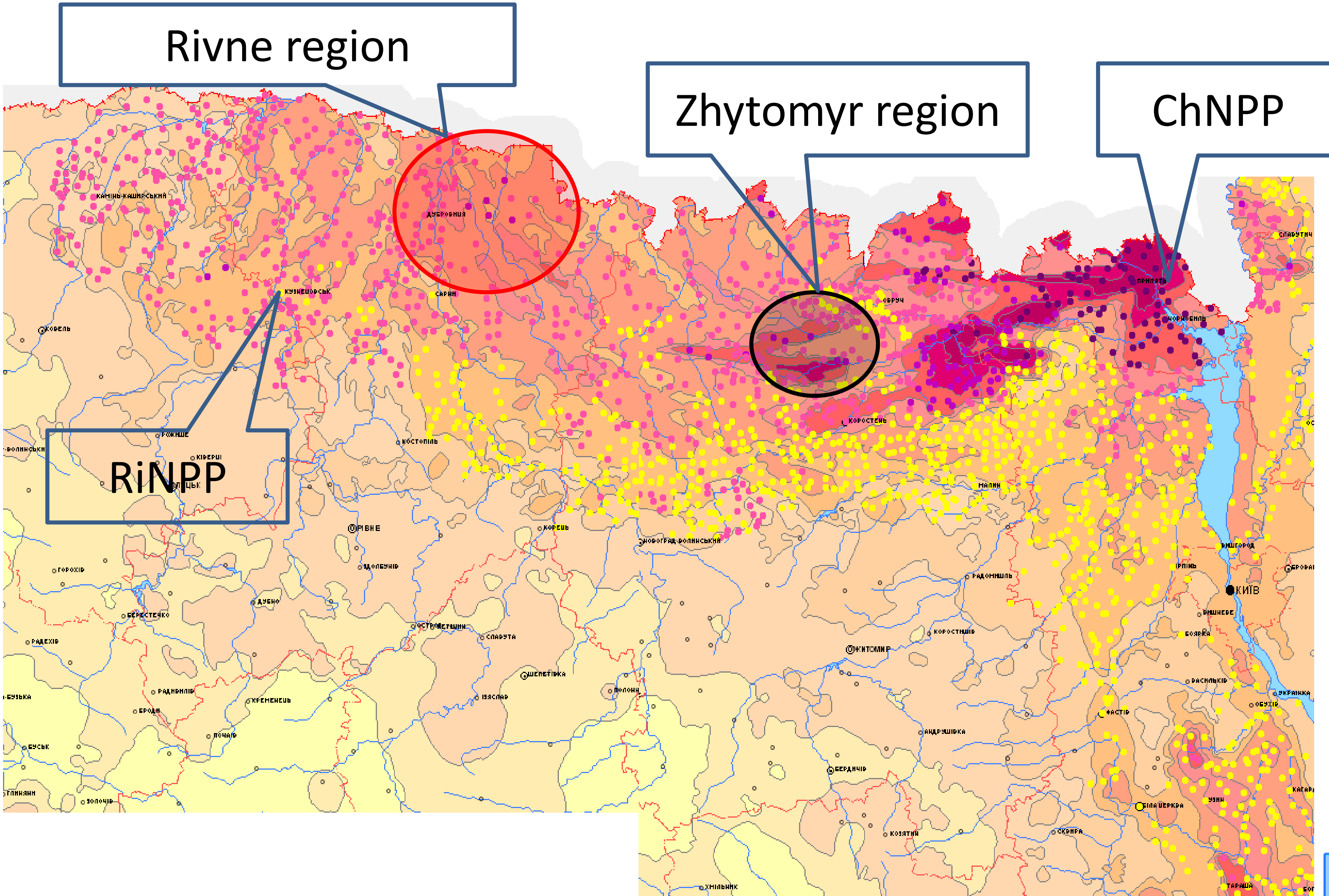
Values of the average annual effective dose to population (mSv) in the critical settlements of Zhytomyr and Rivne region



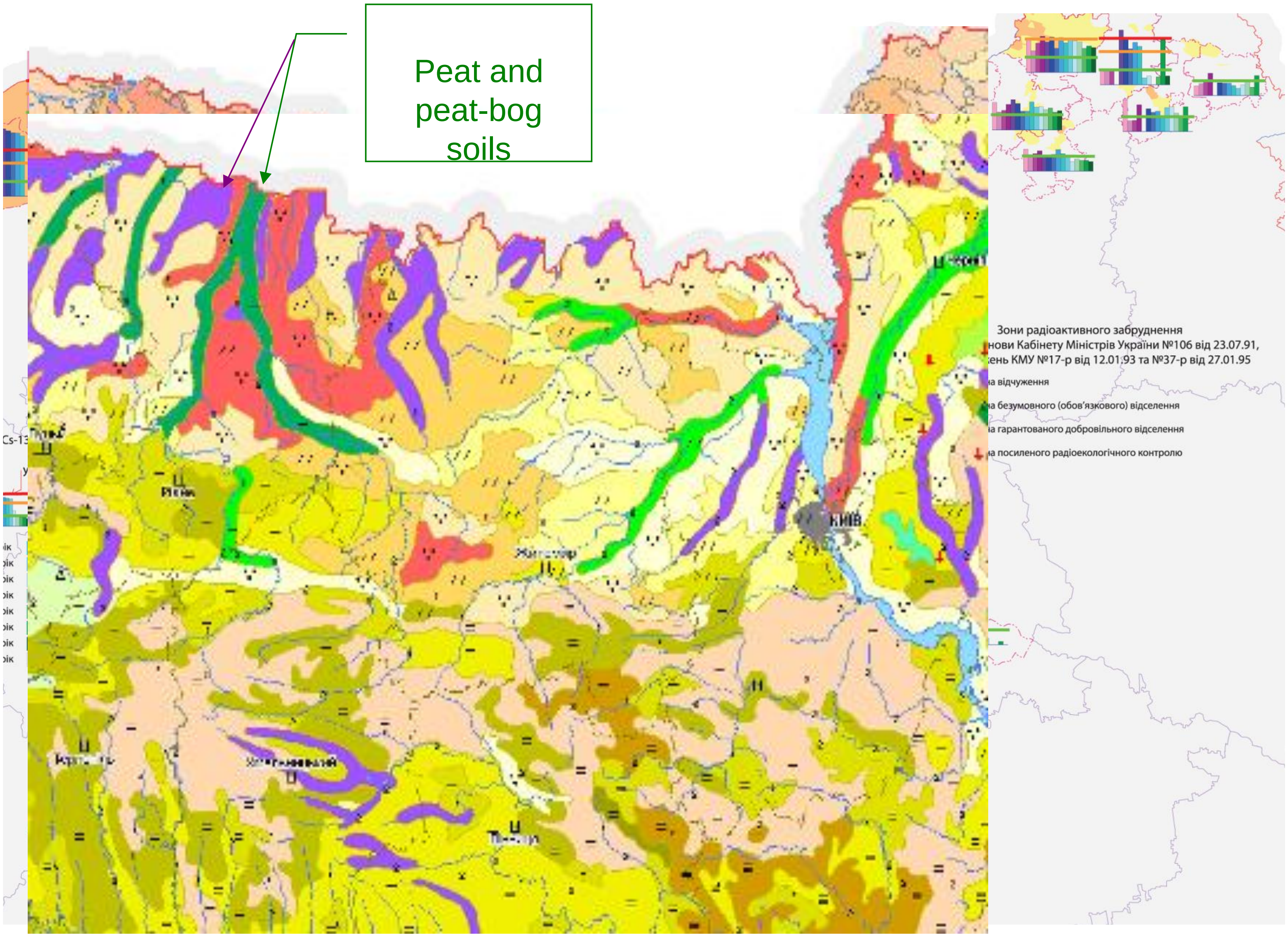
Average specific activities of ^{137}Cs in milk and potato (Bq L^{-1} and Bq kg^{-1}), in the critical settlements of Zhytomyr and Rivne region



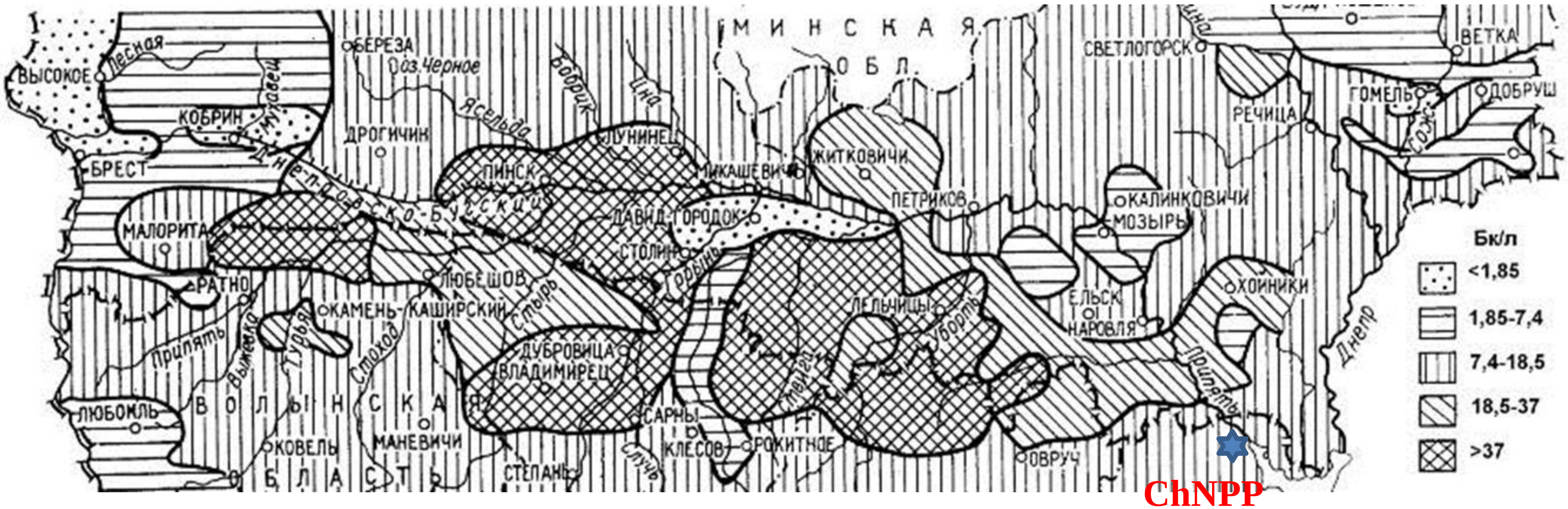
The critical settlements of Zhytomyr and Rivne region



Contamination of milk with ^{137}Cs 1991-2005



^{137}Cs activity concentrations (Bq/l) in the milk of cows in the region of the Ukrainian-Belarusian Polissya (1967-1970) before the Chernobyl accident (*Marey et al, 1974*)



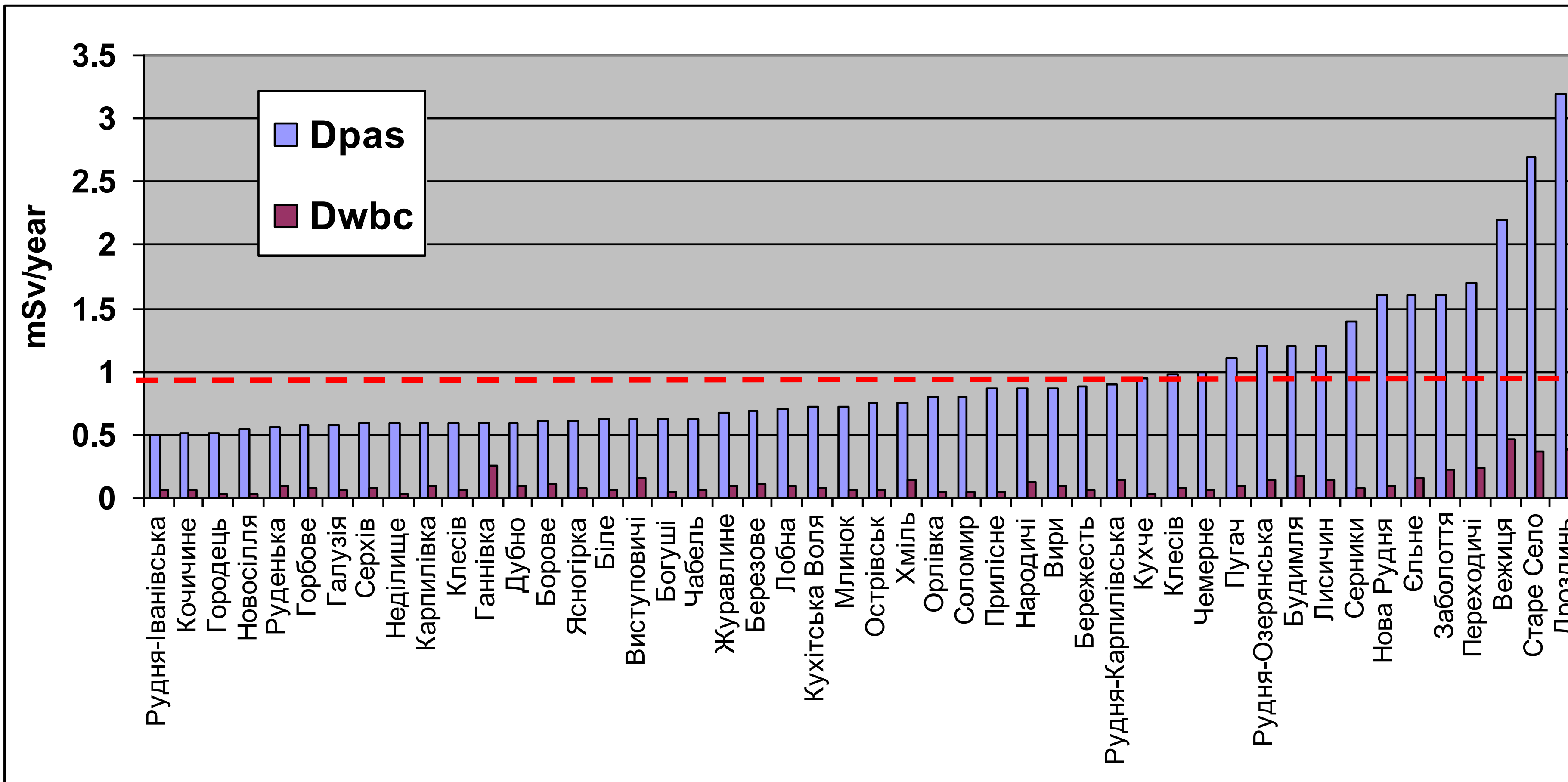
^{137}Cs content in milk exceeds 40 Bq/l in 1967-1970!

Classification of radiocaesium and radiostrontium TFs values for typical properties of contaminated soil in Ukraine.

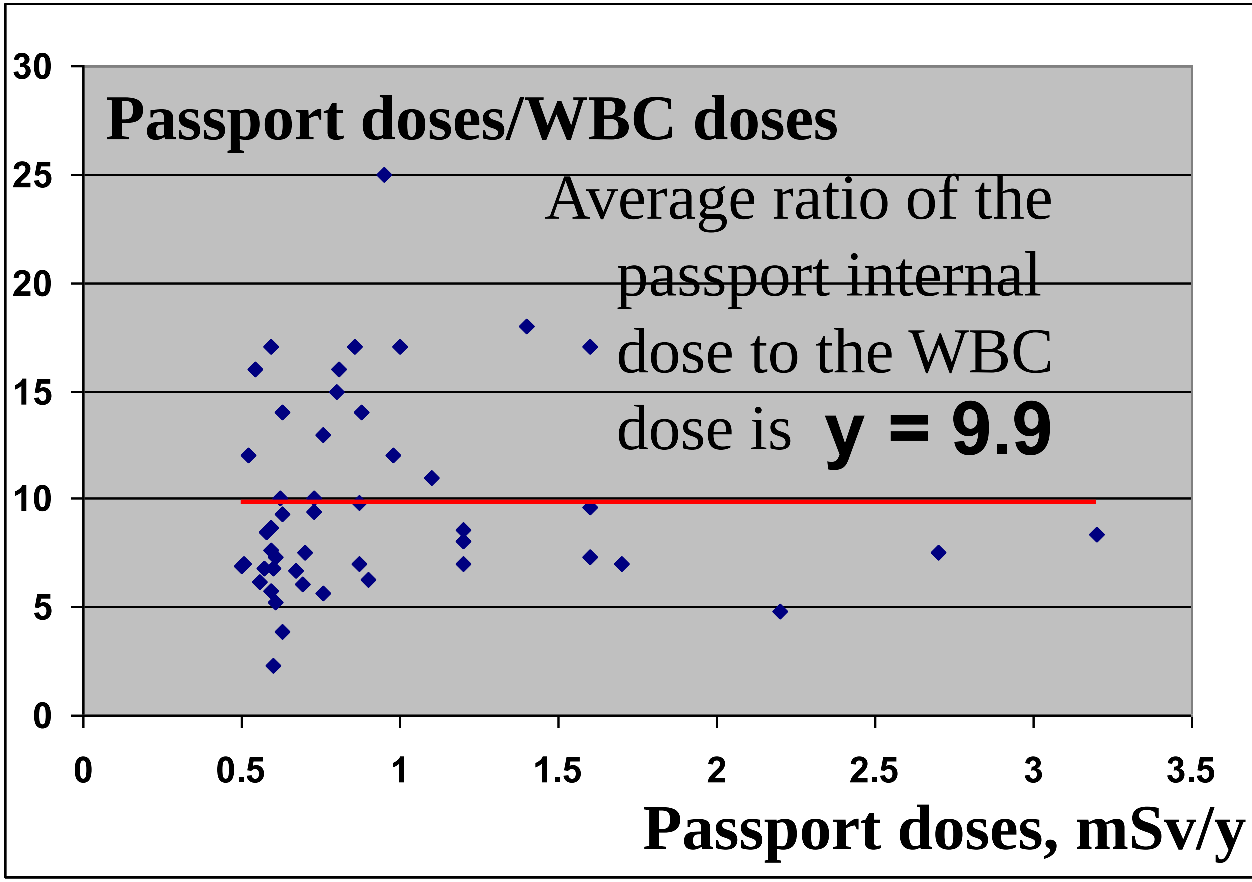
TFs values
>1
0.1-1
<1

Type of soil (CIS countries classification)	Peat- and Peaty-bog soils	Soddy-podzolic sandy soils	Grey forest	Chernozem
FAO-UNESCO	Histosols	Podzoluvisol	Greyzem	Phaeozems
Soil groups (IAEA TRS 472)	Organic	Sand	Loam	Clay
pH	3.0–5.0	3.5–6.5	4.0–6.0	5.0–8.0
Organic matter, %	≥20	0.5–3.0	2.0–6.5	3.5–10.0
Clay, %	-	<18	18–35	≥35
Typical **radiocaesium** aggregated transfer factor TF_{ag}, ((Bq/kg)/(kBq/m^2))				
Mushrooms	10-30	5-20	2-8	1-2
Forest berries	10-20	2-20	1-6	<1
Meat (beef)	1-15	0.3-1	0.2-0.4	0.02-0.2
Cow's milk	0.3-10	0.1-0.3	0.04-0.1	0.01-0.05
Leafy and non-leafy vegetables	0.004-2	0.002-1	0.001-0.7	0.001-0.7
Potatoes	0.1-1	0.04-0.08	0.02-0.06	0.01-0.02
Grain	0.01-1	0.002-0.7	0.001-0.2	0.0002-0.1
Typical **radiostrontium** aggregated transfer factor TF_{ag}, ((Bq/kg)/(kBq/m^2))				
Grain	0.01-0.4	0.01-7	0.02-0.7	0.005-0.7
Leafy and non-leafy vegetables	0.1-0.3	0.02-5	0.1-1	0.01-1
Cow's milk and beef	0.003-0.1	0.01-0.5	0.03-0.2	0.01-0.2

In all 47 settlements in which the internal passport dose (Dpas) exceed 0.5 mSv/year D_{WBC} was less then 0.5 mSv/year



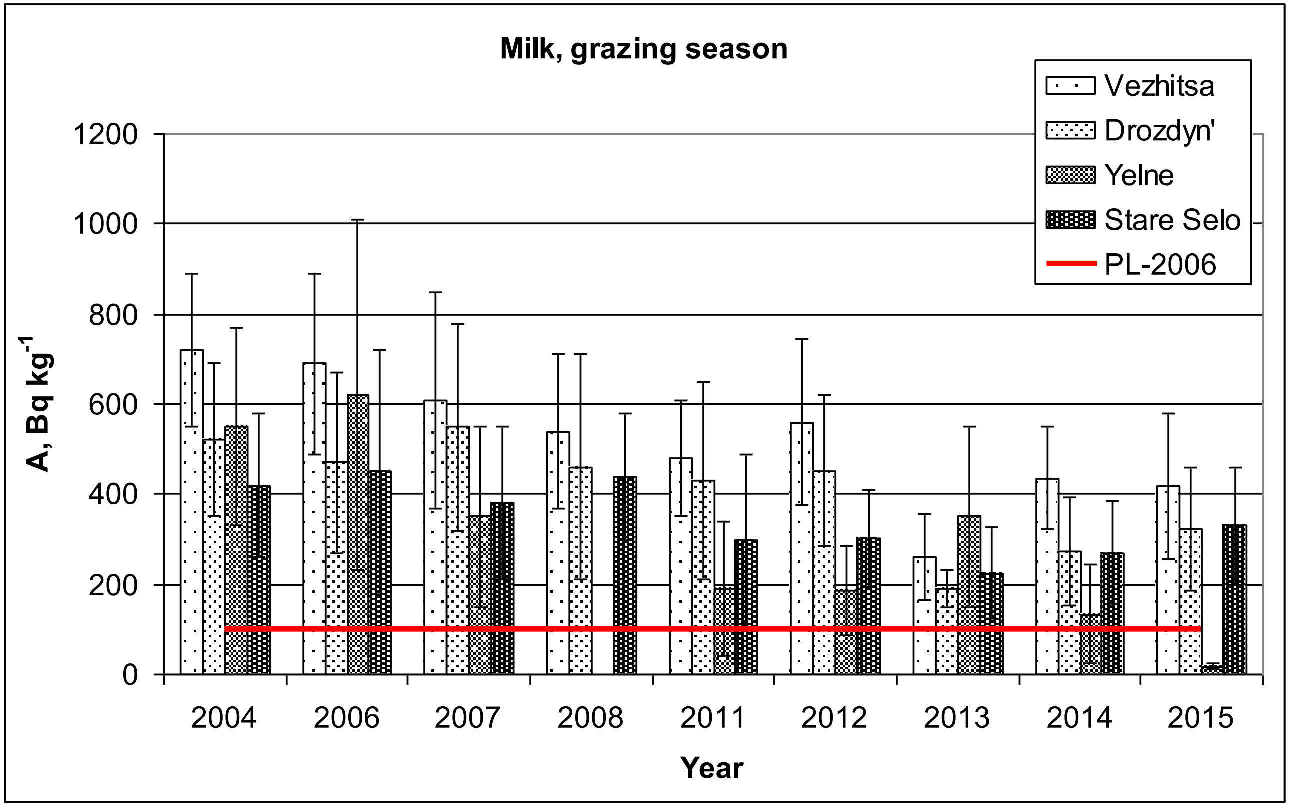
High conservatism of estimations of doses leads to high economic expenses and social consequences



Different between passport internal and WBC doses are:

- High conservatism of calculation method of passport doses (milk consumption is 390 l milk per year);
- Self-restriction of milk consumption by population;
- Sometimes levels of milk ^{137}Cs contamination do not correspond to the averages for settlements.

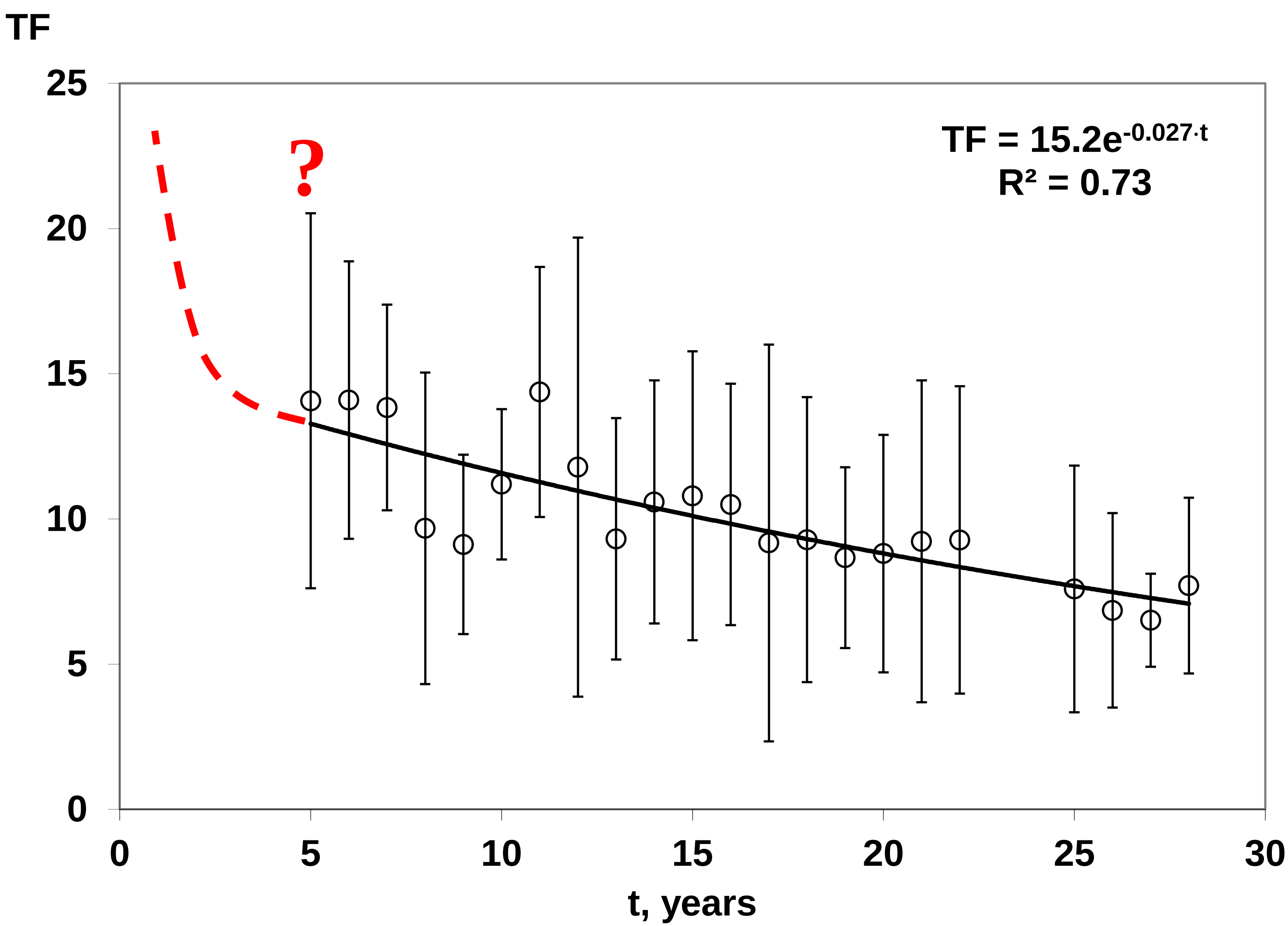
The dynamics of the milk contamination by ^{137}Cs which is produced in the private farms of the most critical settlements during the grazing period (arithmetic mean, standard deviation, n> 20) (UIAR, 2015)



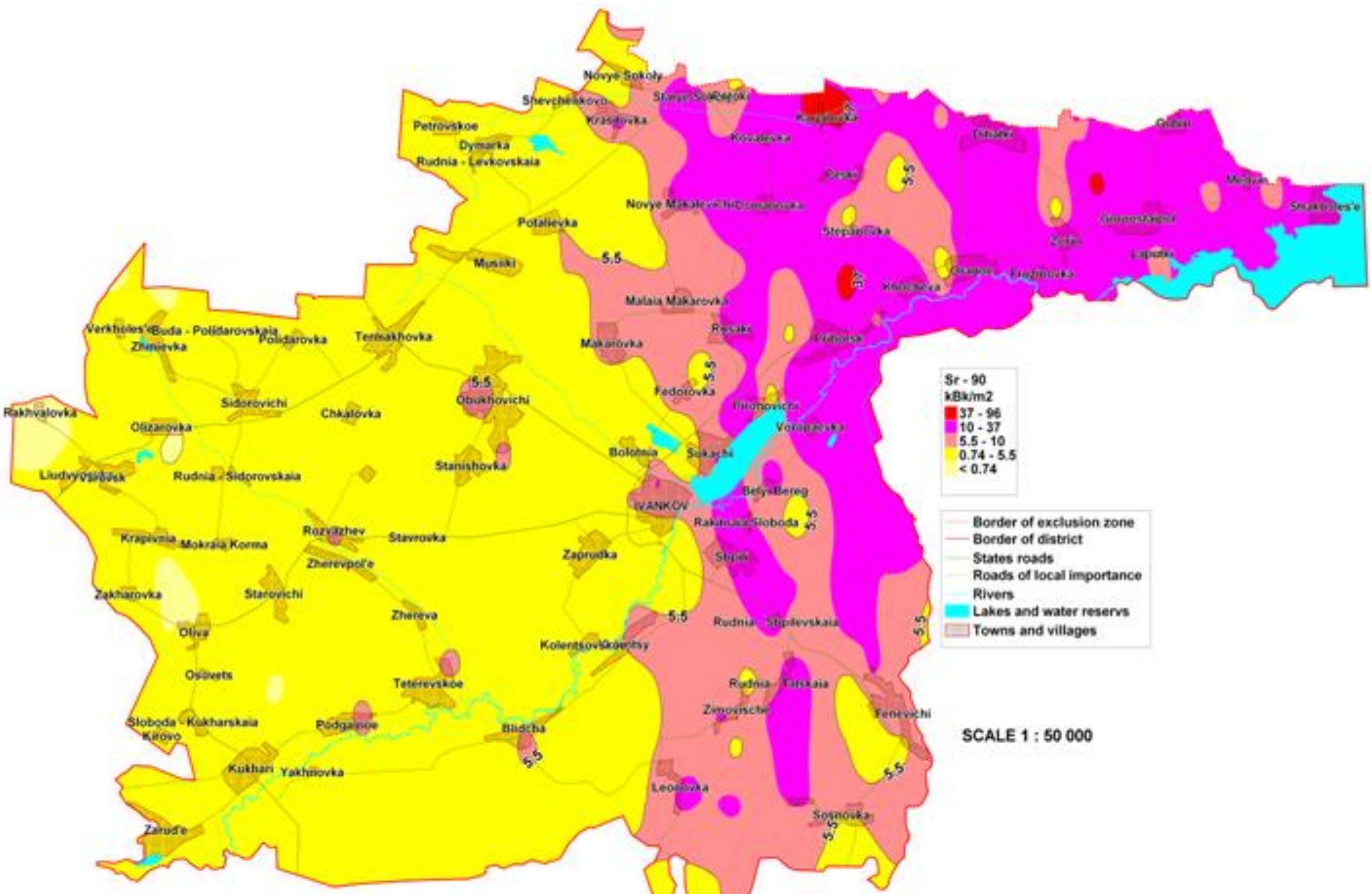
^{137}Cs, Bq/l, Drozdyn' 2015 Sep
620
390
310
310
280
280
330
260
510
360
470
300
270
640
290

Settlement	Population	Children (% of population)	The number of cows in the village
Drozdyn’	2419	1077 (44%)	565
Stare Silo	3847	1627 (42%)	800
Vezhitsa	1131	460 (41%)	330

Dynamics of with abnormally high ^{137}Cs TF, (Bq L^{-1}) (kBq m^{-2})$^{-1}$, in cow milk in the critical settlements of the north-western Polissya of Ukraine (Vezhytsya, Grabun', Drozdyn', Yelne, Zabolottya, Perekhodychi, Stare Selo)



On the eastern part of Ivankov district of Kyiv region with ^{90}Sr density of contamination higher than 5.5 $kBq \cdot m^{-2}$ there is a risk of grain production with the content of ^{90}Sr above the permissible level PL-2006 (20 $Bq \cdot kg^{-1}$).



Cartogram for density of soil contamination with ^{90}Sr in Ivankov region, 2014

Summary of the reduction factors of different countermeasures used after Chernobyl

Countermeasure	^{137}Cs	^{90}Sr
Selection of alternative land use		
Normal ploughing (first year)	2.5–4.0	
Skim and burial ploughing	8–16	
Liming	1.5–3.0	1.5–2.6
Application of mineral fertilisers	1.5–3.0	0.8–2.0
Application of organic fertilisers	1.5–2.0	1.2–1.5
Radical improvement:	1.5–9.0*	1.5–3.5
– First application	2.0–3.0	1.5–2.0
– Further applications		
Surface improvement:	2.0–3.0*	2.0–2.5
– First application	1.5–2.0	1.5–2.0
– Further applications		
Change in fodder crops	3–9	
Clean feeding	2–5 (time dependent)	2–5
Administration of Cs binders Prussian Blue	3-5	-
Clay mineral	2-3	-
Processing milk to butter	4–6	5–10
Processing rapeseed to oil	250	600

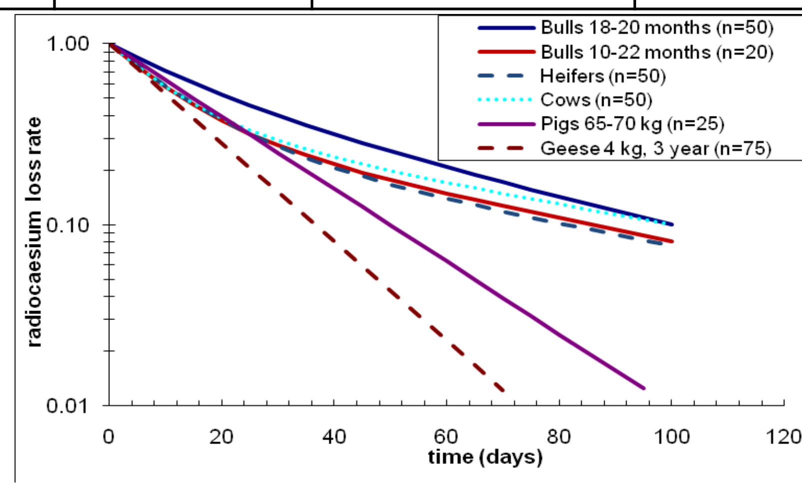
Animal-based countermeasures

Clean feeding (Astasheva et al., UIAR 1991)

The effective half-lives of ^{137}Cs in the muscle tissue A(t), Bq/kg of animals (UIAR data):

$$A(t)/A(0)=a1*\exp(-0.69*t/T1_{1/2})+a2*\exp(-0.69*t/T2_{1/2})$$

Animals	a1	$T1_{1/2}$, day	a2	$T2_{1/2}$, day
Bulls 18-20 months (n=50)	0.48±0.05	11±1	0.52±0.05	38±5
Bulls 10-12 months (n=20)	0.65	7.3	0.35	43
Heifers (n=50)	0.7±0.1	8.3±0.7	0.3±0.1	46±10
Cows (n=50)	0.63±0.05	7±2	0.37±0.05	48±5
Pigs 65-70 kg (n=25)			1	15±3
Geese 4 kg, 3 year (n=75)			1	11±2

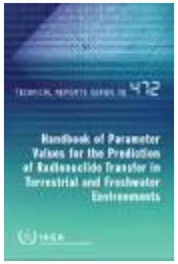


Addition of hexacyanoferrate (also known as Prussian blue or ferrocyn: $NH_4Fe[Fe(CN)_6]$, $KFe[Fe(CN)_6]$, $Fe_4[Fe(CN)_6]_3$) to feedstuffs for animals

The average radiological efficiency of ferrocyn application during several years (Ukraine)

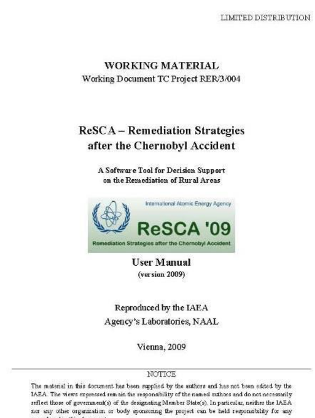
Year	Name of product	Efficiency (rate of milk contamination reduction))
1990-91	Prussian blue boli (Norway)	5-10
1992-94	Prussian blue boli (Ukraine)	2-4
1994	Prussian blue powder	2-5
1995-97	Prussian blue, salt briquettes	3-6
2004-2006	Prussian blue with mixed feed	3.4±2.0

Processing factors (ratio of activity concentrations in the product after and before processing) for various foodstuffs



Countermeasure	^{137}Cs	^{90}Sr
Processing grain to flour	0.3-0.9	0.2-0.4
Processing grain to bran	3	3
Processing vegetables, berry and fruits to juice	0.4-1	0.01-0.5
Processing of beet to sugar	0.01-0.08	-
Processing of a potatoes to of starch	0.12-0.17	-
Boiling, soaking and pickling of mushrooms	0.1-0.3	-
Processing milk to butter	0.2-0.3	0.1-0.5
Processing rapeseed to oil	0.004	0.002

ReSCA – Remediation Strategies after the Chernobyl Accident : decision support tool for remediation planning after the Chernobyl accident (*for private farms of populations*)



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Working Document TC Project RER/3/004

ReSCA – Remediation Strategies after the Chernobyl Accident

A Software Tool for Decision Support on the Remediation of Rural Areas

International Atomic Energy Agency
ReSCA '09
Remediation Strategies after the Chernobyl Accident

User Manual
(version 2009)

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The program ReSCA has been developed within framework of International Atomic Energy Agency Technical Co-operation Projects RER/9/074 "*Long-term countermeasure strategies and monitoring of human exposures in rural areas affected by the Chernobyl accident*" and RER/3/004 "*Radiological support for the rehabilitation of the areas affected by the Chernobyl nuclear power plant accident*" in 2003–2011.

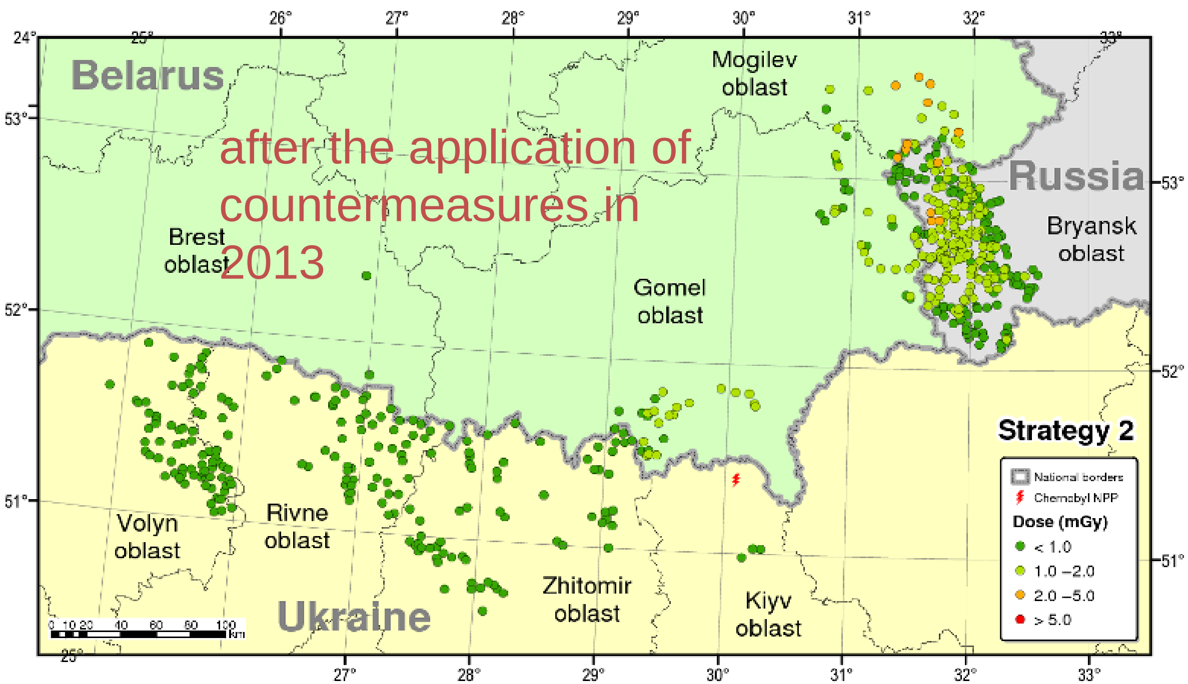
Optimizing a remediation strategy by RESCA

In ReSCA only seven different remedial actions are considered

- 1. Radical improvement of grassland (RI), which includes
- removing vegetation, ploughing, liming, fertilization,
- and reseeding. For areas with wet peat, this action
- includes also drainage (**RI, D**);
- 2. Surface improvement of grassland (**SI**);
- 3. Ferrocyn application to cows (**FA**);
- 4. Clean feed for pigs before slaughtering (**FP**);
- 5. Mineral fertilizers for potato fields (**MF**);
- 6. Information campaign on mushroom consumption
- (**IM**); and
- 7. Removal of contaminated soil in the settlement (**RS**).

Rural areas affected by the Chernobyl accident: Radiation exposure and remediation strategies

- ReSCA has been used for an estimation of strategy of rehabilitation of the contamenated territories at a level of countries



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Rural areas affected by the Chernobyl accident: Radiation exposure and remediation strategies

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ABSTRACT

Main objectives of the present work were to develop an internationally agreed methodology for deriving optimized remediation strategies in rural areas that are still affected by the Chernobyl accident, and to give an overview of the radiological situation in the three affected countries, Belarus, Russia and Ukraine. Study settlements were defined by having in 2004 less than 10,000 inhabitants and official dose estimates exceeding 1 mSv. Data on population, current farming practices, contamination of soils and foodstuffs, and remedial actions previously applied were collected for each of such 541 study settlements. Calculations of the annual effective dose from internal radiation were validated with extensive data sets on whole body counter measurements. According to our calculations for 2004, in 290 of the study settlements the effective dose exceeded 1 mSv, and the collective dose in these settlements amounted to about 66 person-Sv. Six remedial actions were considered: radical improvement of grassland, application of ferrocyn to cows, feeding pigs with uncontaminated fodder before slaughter, application of mineral fertilizers for potato fields, information campaign on contaminated forest produce, and replacement of contaminated soil in populated areas by uncontaminated soil. Side effects of the remedial actions were quantified by a 'degree of acceptability'. Results are presented for two remediation strategies, namely, Strategy 1, in which the degree of acceptability was given a priority, and Remediation Strategy 2, in which remedial actions were chosen according to lowest costs per averted dose only. Results are highly country-specific varying from preference for soil replacement in populated areas in Belarus to preference for application of ferrocyn to cows in Ukraine. Remedial actions in 2010 can avert a large collective dose of about 150 person-Sv (including averted doses, which would be received in the following years). Nevertheless, the number of inhabitants in Belarusian and Russian settlements with annual doses exceeding 1 mSv remains large. Compared to international values for the cost-effectiveness of actions to reduce occupational exposures, the recommended remediation strategies for rural areas affected by the Chernobyl accident are quite cost-effective (about 20 k€/person-Sv).

1. Introduction

Huge amounts of radioactive materials have been released during the reactor accident of Chernobyl in 1986. Large areas of agricultural land in Belarus, Russia and Ukraine were severely contaminated. Due to radioactive decay and remediation, the contamination levels in foodstuffs decreased significantly during the first two decades after the accident (Balonov, 2007). Nevertheless, there are still a few hundreds of settlements, in which annual effective doses of the population due to ionizing radiation caused by the accident exceed 1 mSv.

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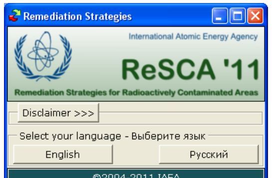
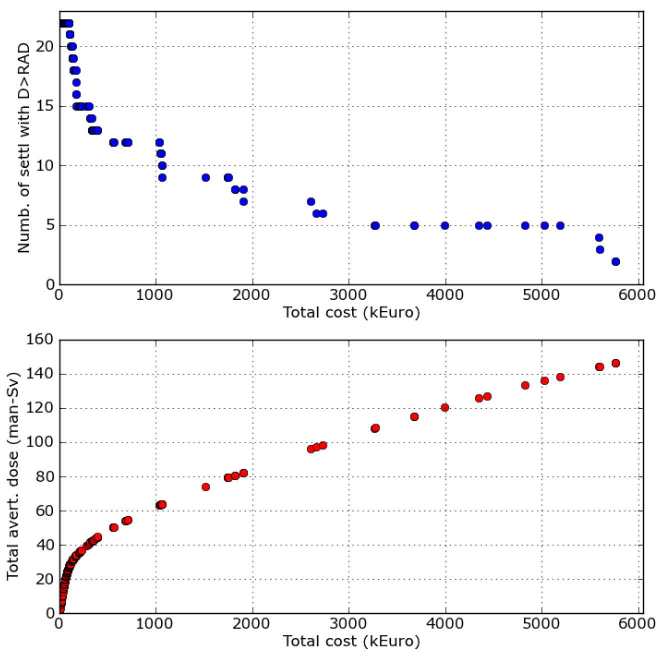
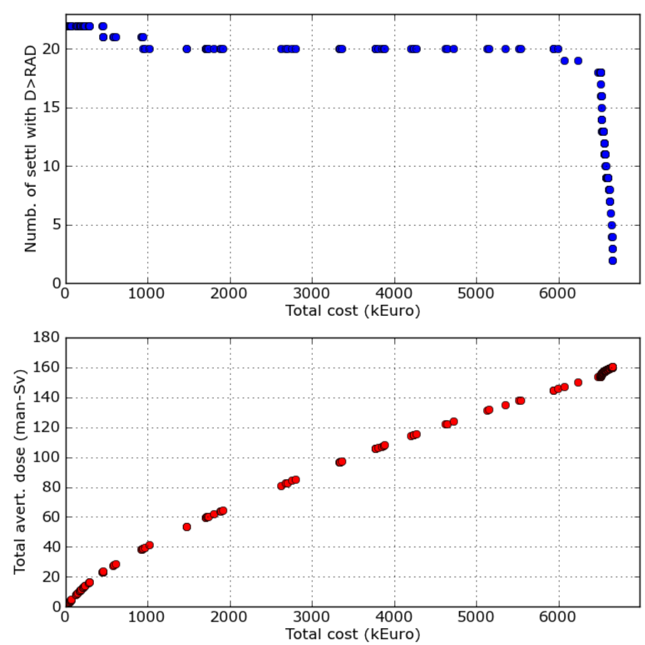
In the three countries, there are laws or acts of governmental authorities requesting or recommending relocation of the population from settlements with annual doses exceeding 5 mSv. In the dose range of 1 to 5 mSv, remedial actions should be optimized. However, an agreed strategy of optimization has been lacking for a long time. Therefore, the International Atomic Energy Agency initiated the project *Radiological support for the rehabilitation of the areas affected by the Chernobyl nuclear power plant accident*. In the frame of this project, a software tool called *ReSCA — Remediation Strategies after the Chernobyl Accident* has been developed (Ulanovsky et al., submitted for publication). The software is based on two decades of experiences with agricultural countermeasures against radioactive contaminations in the aftermath of the Chernobyl accident (Fesenko et al., 2007). A main feature of *ReSCA* is the use of settlement-specific levels of ground contaminations and activity



Remedial actions for 22 settlements where dose >1 mSv/year

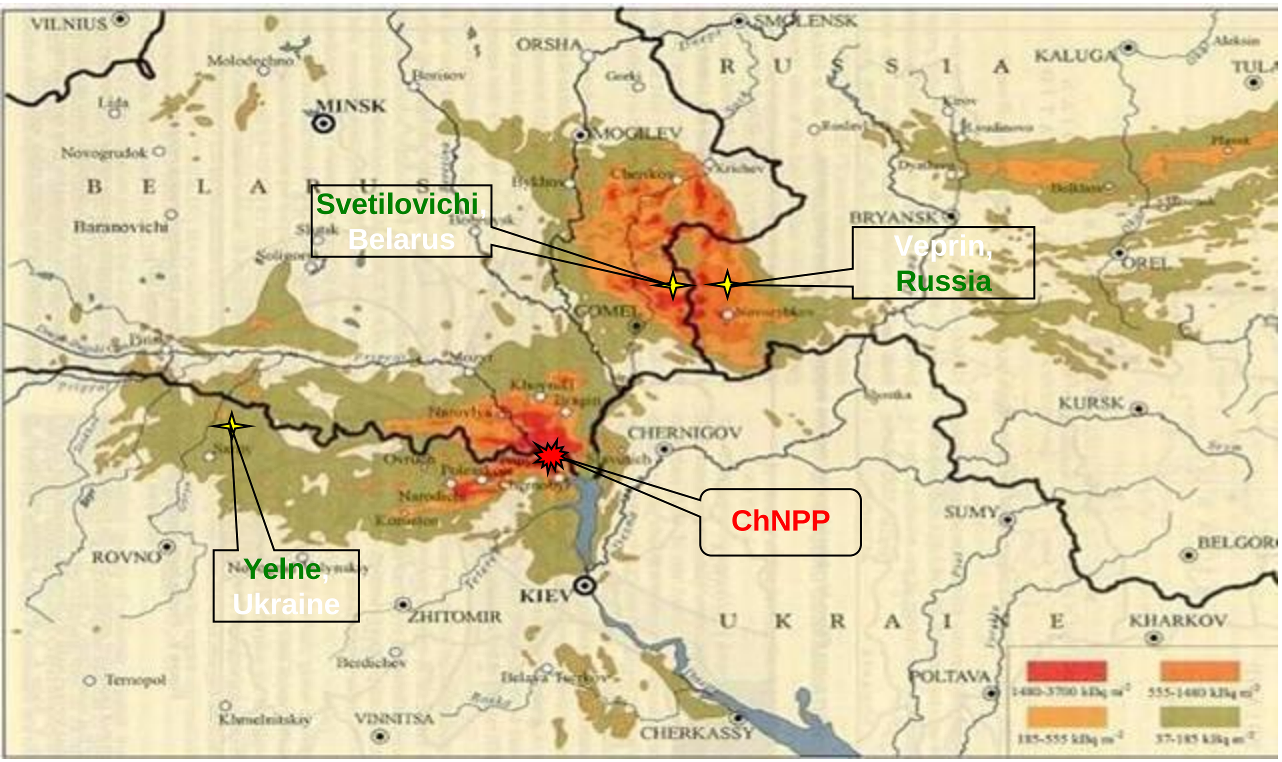
For Cost impact factor =	1.00	0.01
Total averted dose (man-Sv)	146.4	160.1
Total cost of the strategy (kEuro)	5767.8	6656.7
Cost per averted dose (kEuro/man-Sv)	39.4	41.6



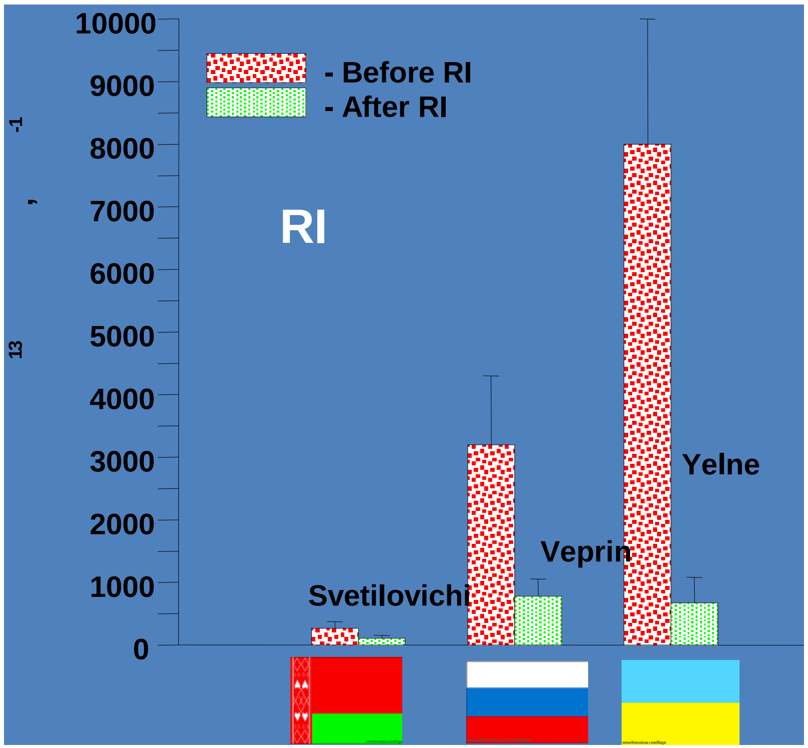


Distribution of settlements where dose > 1 mSv/year

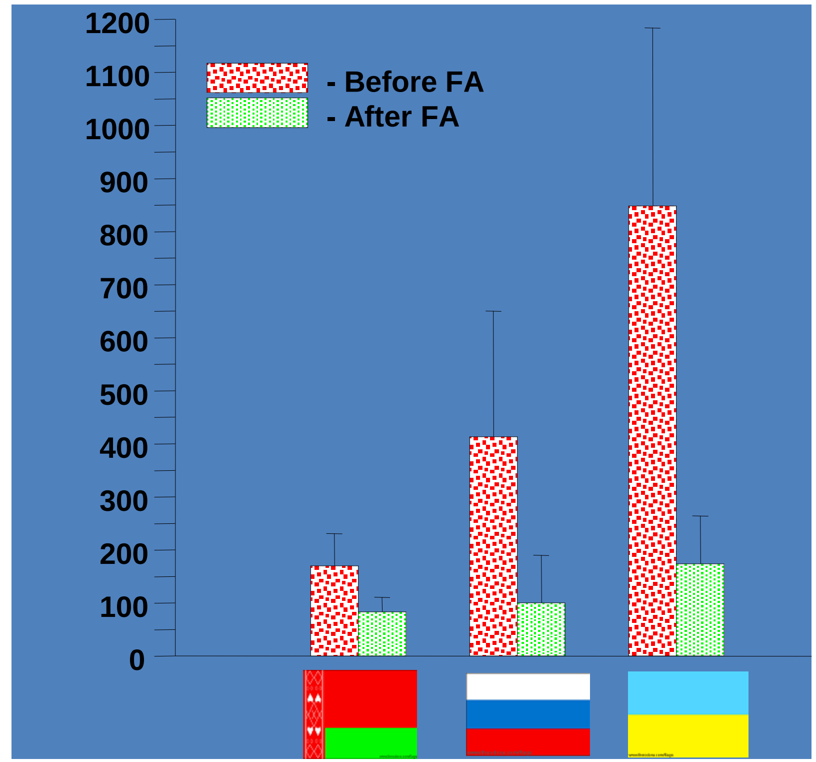
Location of the test settlements on the territory of Belarus, Russia and Ukraine affected after the Chernobyl accident



COMPARISON BETWEEN OBSERVED AND PREDICTED DATA FOR THE TEST SETTLEMENT



Hey



Milk

COMPARISON BETWEEN OBSERVED AND PREDICTED DATA FOR THE TEST SETTLEMENT

Dose, mSv/y

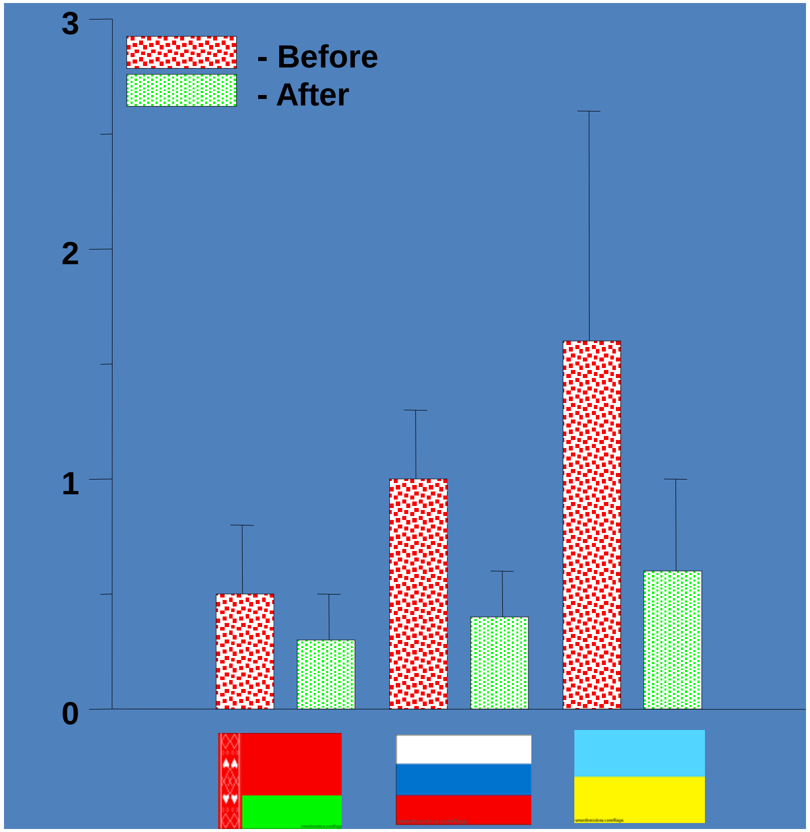
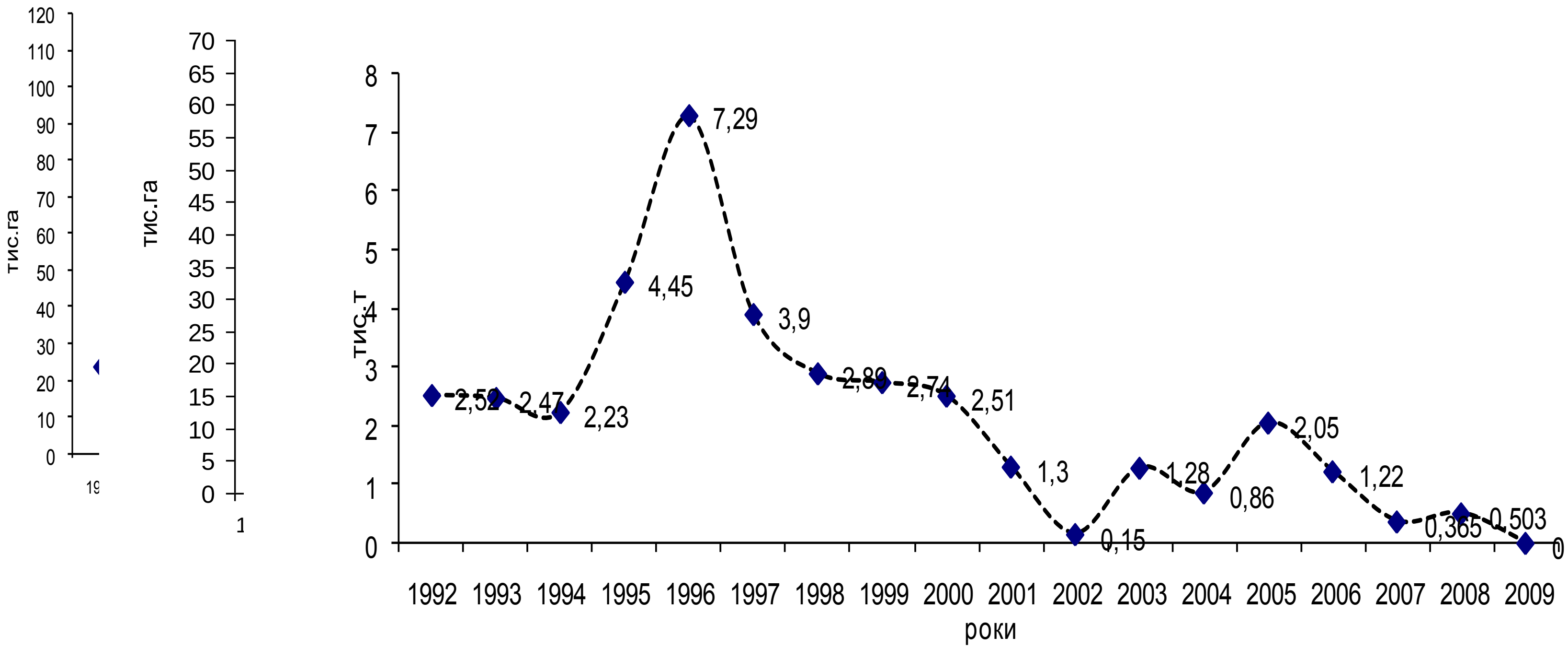


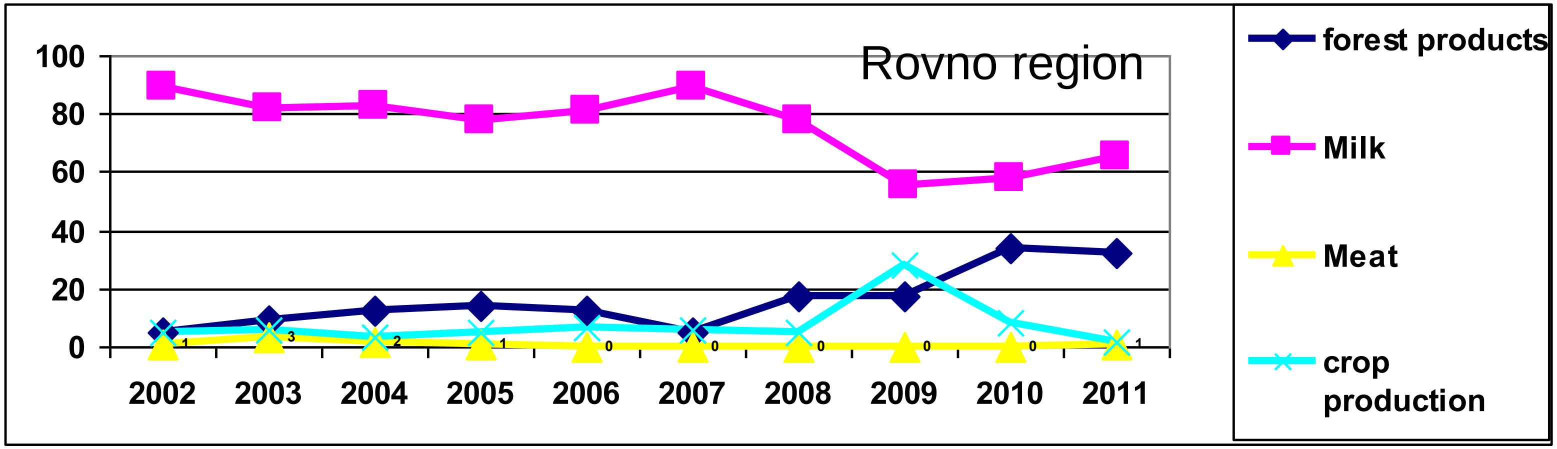
Фото УНЦРМ АМН

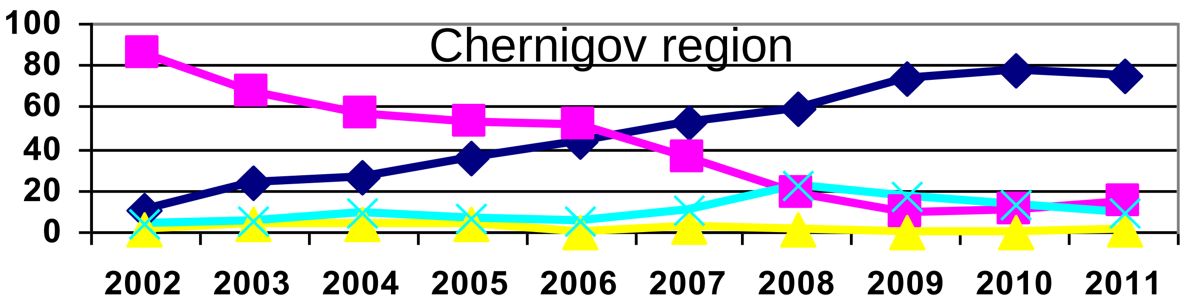
Dynamics of countermeasures application

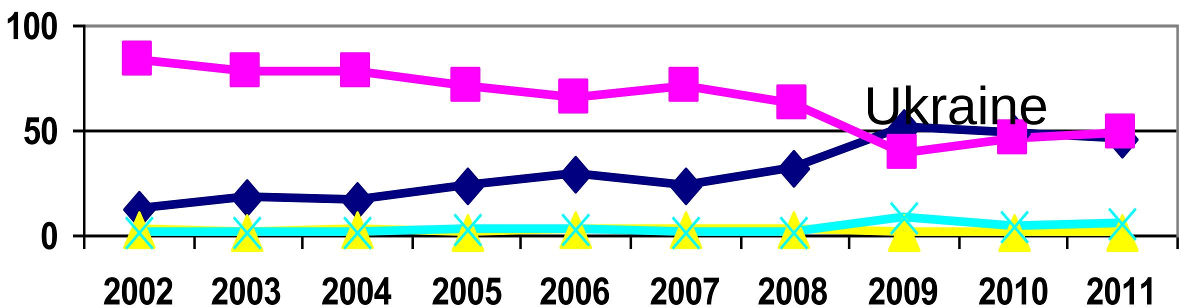


Changes with time in the use of Prussian blue with mixed fodder in Ukraine, thousand tone

Relative trend in the number of samples in Ukraine with excess of PL, %







The decrease of the ^{137}Cs specific activity of in the components of forest ecosystems is very slow ($T_{1/2}$=20-30 years),

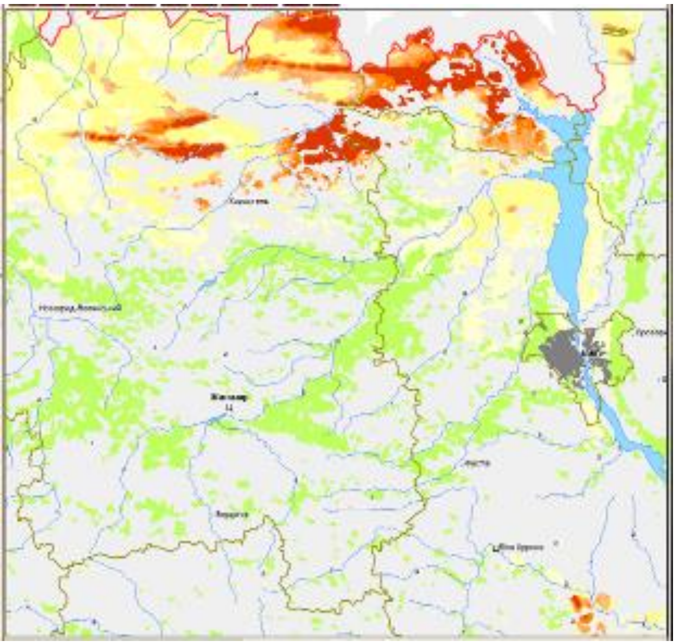
Permissible hygienic norms for the ^{137}Cs and ^{90}Sr specific activities in timber and timber production

Production	Permissible level, Bq/kg	
	^{137}Cs	^{90}Sr
Industrial application		
1. Rough wood		
1. Ricker		
- unbarked wood	1500	-
- barked wood	1000	-
- raw materials for veneer and plywood	1000	-
- construction timber for industrial building and temporary buildings	1500	-
- pulpwood	1500	-
- timber for props	3000	-
2. Firewood for technological needs	1500	-
2. Sawn timber		
- edge-unsurfaced lumber	1000	-
- edge-surfaced lumber	740	-
- squared beam, parquet (incl. for manufacturing the furniture)	740	-
- sawn material for Eurotrays	1500	-
- box board and beam	1000	-
3. Production for domestic and economical use		
- firewood	600	60
- fencing wood	1000	-
- souvenirs, domestic appliances (handles, kitchen boards)	740	-

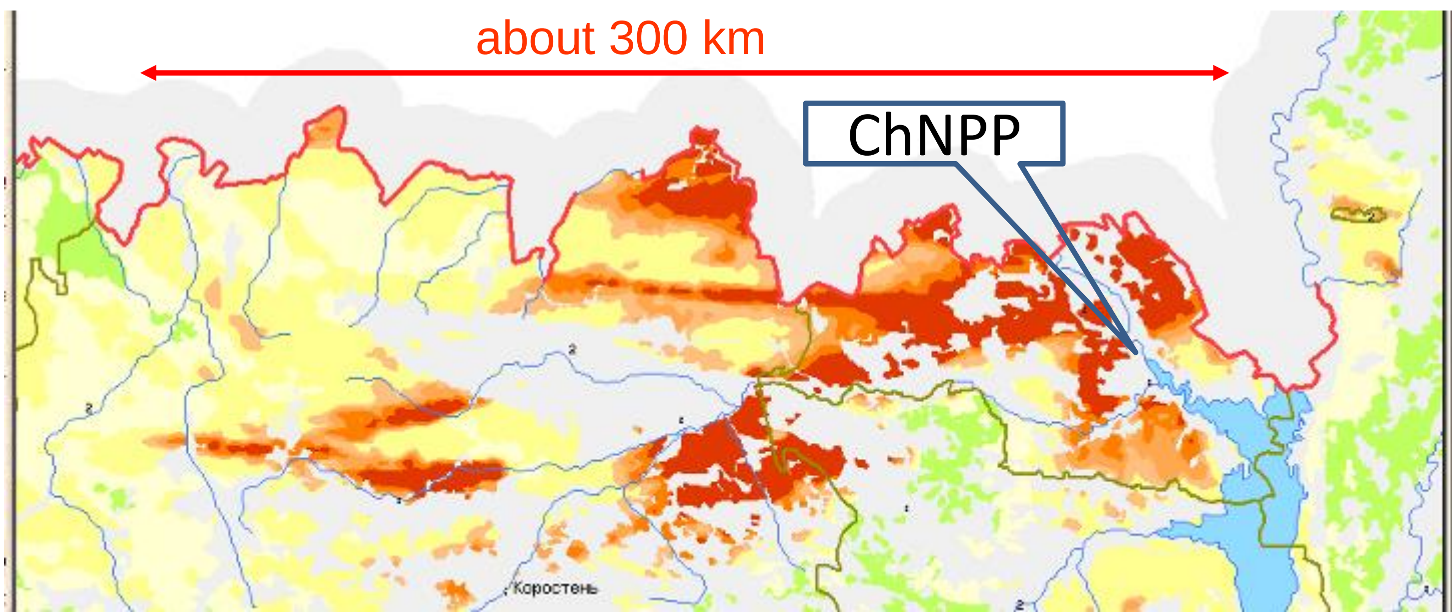
Wild mushrooms and berries

- Among all components of the forest ecosystems the largest accumulation of the radioactive cesium from the soil is inherent to mushrooms and berries (blueberries, cranberries, blackberries, etc.).
- About 50% of all samples of mushrooms (n = 77) that were collected in different regions of Ukraine during the monitoring in the UIAR in 2013-2014 did not comply with the requirements of the PL-2006.

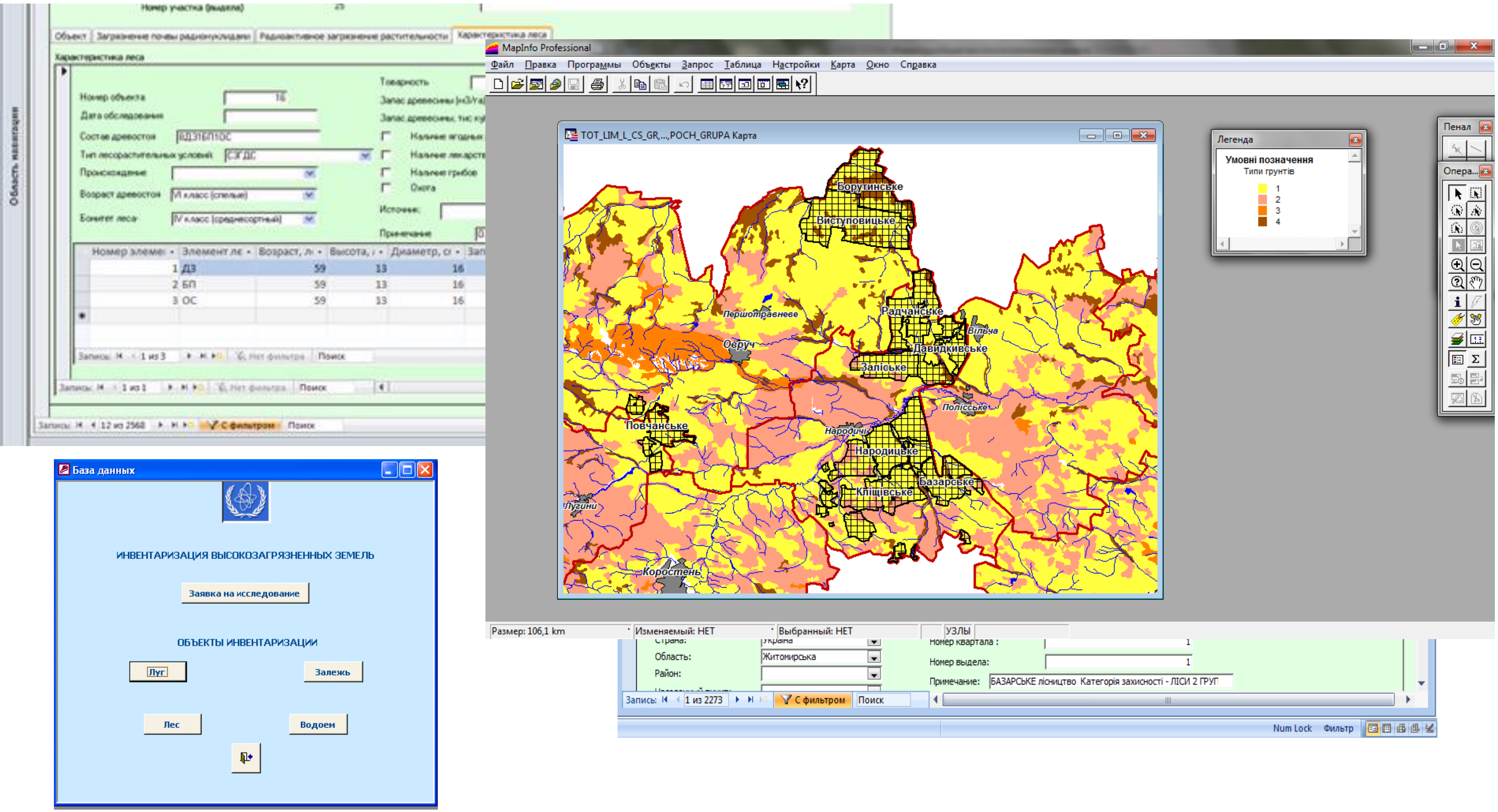
The zones of forest contamination with ^{137}Cs



Zone	Contamination	Measures
1st	> 555 kBq/m^2	Development of the special regime for forestry. Limitation of the working time
2nd-c	370- 555 kBq/m^2	Limitation of utilization of wood for the people's needs
2nd-b	370- 259 kBq/m^2	Not allowed to use wood as the fuel and to manufacture the domestic goods and facilities for the foodstuff storing
2nd-a	185- 259 kBq/m^2	Limitation of utilization of the fuel and hungry wood and meat of the wild animals. Prohibition to hunting roe
3th-b	74- 185 kBq/m^2	Prohibition of consumption of the wild berries and mushrooms. Limitation of utilization of the medical plants and wild animals
3th-a	37-74 kBq/m^2	Limitation of utilization of the mushrooms, wild berries and some medical plants
	<37 kBq/m^2	Utilization of the forest products without limitation

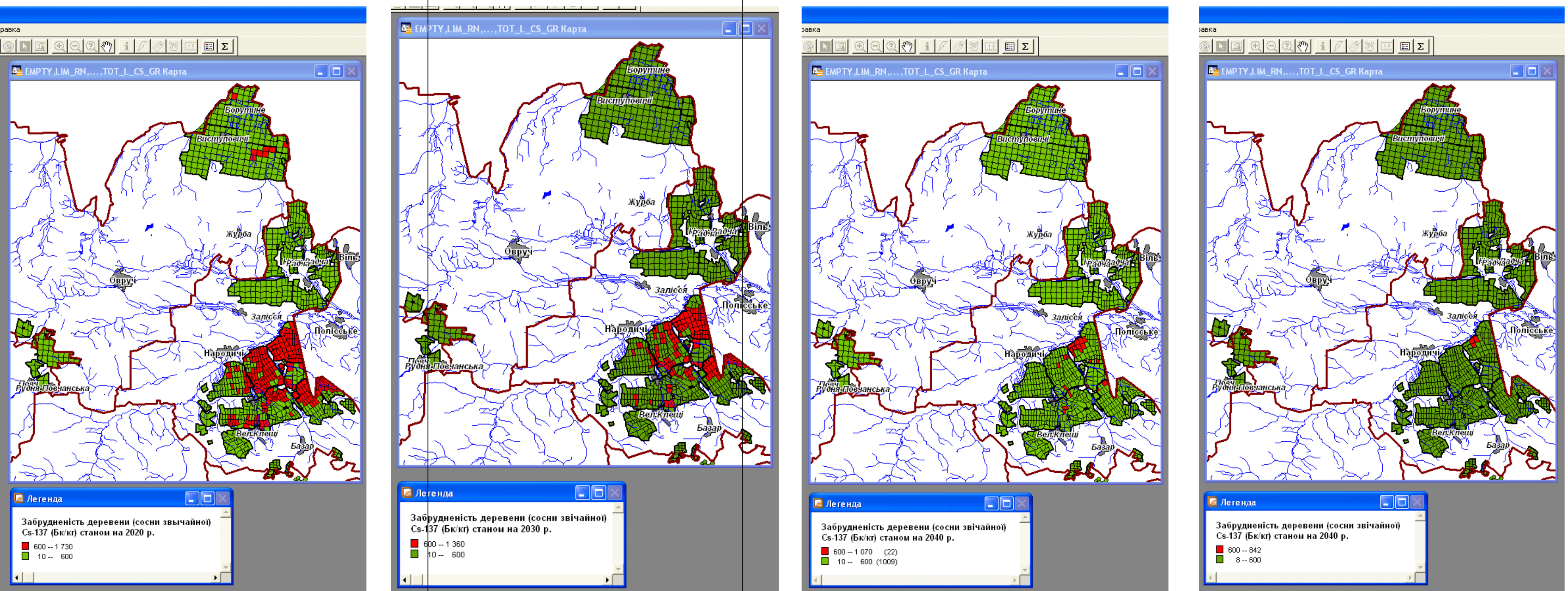


Decision-making support for forestry on the contaminated areas after nuclear and radiation accidents (*return to economic use of forests excluded*)



- The software ESTER (Expert Support of Technology for Remediation) has been developed within framework of IAEA Technical Co-operation Projects RER/3/004 “*Radiological support for the rehabilitation of the areas affected by the Chernobyl nuclear power plant accident*” in 2008–2011

The software ESTER - Decision-making support for forestry on the contaminated areas after nuclear and radiation accidents



- **Distribution quarters to forestry Zhytomyr Oblast at the 2020-2050 year where ^{137}Cs content in the wood would not exceed the hygienic standards– 600 Bq/kg**

What did we do right?

- **Quickly evacuation of 116 317 people from 187 settlements of exclusion zone (average cumulative effective dose was 33 mSv)**

- **After the Chernobyl accident application of agricultural countermeasures allowed more than in 2 times decrease effective internal dose of the population.**

(Practically all agricultural countermeasures implemented in the large scale on contaminated lands after Chernobyl accident can be recommended for use in case of future accidents. However, the effectiveness of most soil based countermeasures varies at each site. Therefore, analysis of soil properties and agricultural practice before their application is of great importance.)

IAEA and UNSCEAR (2005-2011)

EN: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1239_web.pdf
RU: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1239r_web.pdf
EN: http://www.iaea.org/Publications/Booklets/Chernobyl/chernobyl.pdf
RU: http://www.iaea.org/Publications/Booklets/Russian/chernobyl_rus.pdf
EN: http://www.unscear.org/unscear/en/chernobyl.html

What did we do wrong?

- Killed about 100 thousand agricultural animals from the exclusion zone.

- **Politics was an important radiological, economic and social factors:**

- compensation for unrealized potential risk (the greater the risk, the more compensation);

- resettlement after 5-8 years after the accident (town Poliske);

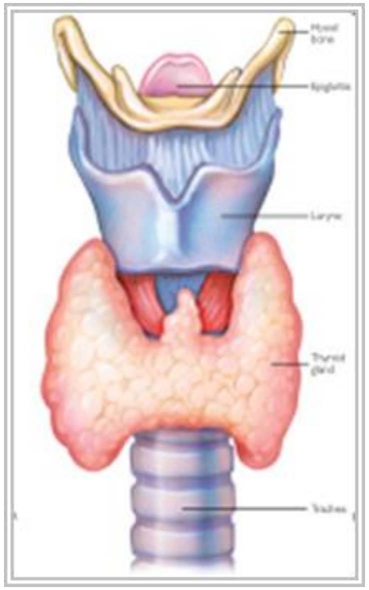
- too conservative criteria for zones from density of ridionuclides contamination and dose (0.5 mSv), as well as methods of assessment of effective doses to the population;

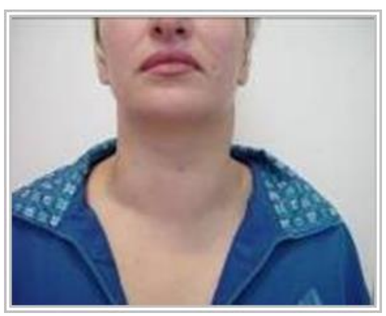
What did not?

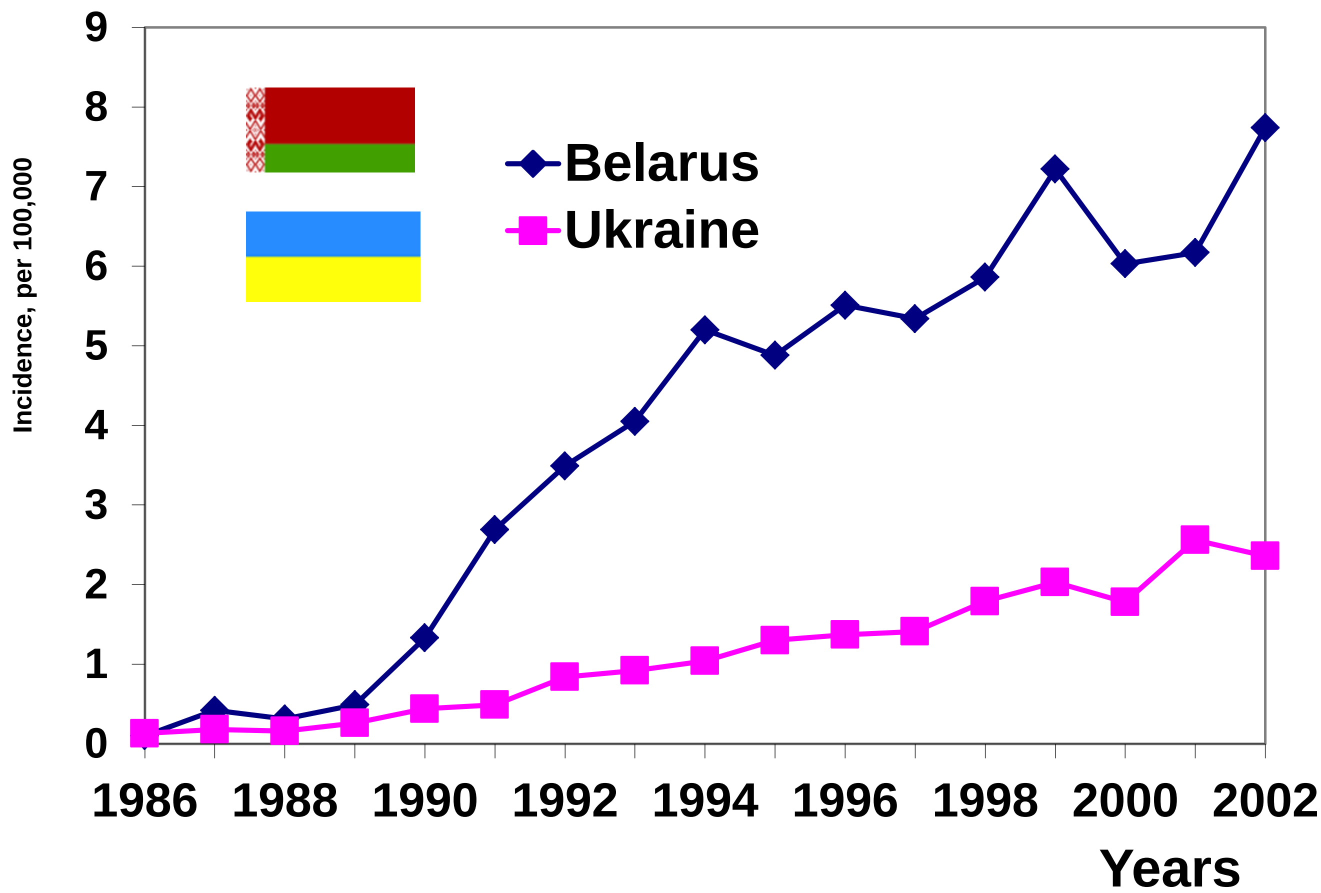
- Iodine prophylaxis was not done at the right time
- In the first days of restrictions on the consumption of milk and leafy vegetables in potentially contaminated areas by informing the public about the real situation was not done
- Did not informed and did not have a dialogue with the population in the first years after the accident
- We did not change the status of the territory as radiological situation changes after accident (28 year)
- The last 10 years we did not use remediation actions to reduce doses to the population, with a lot more money is spent on compensation

The first is short and false information about the accident was only after 5 days - April 30, 1986

Cancer of the thyroid gland (children, J. Konigsberg, 2009)







Dialogue with the public is the most difficult task. We started this dialogue very late

- (From **Chernobyl disaster** Wikipedia)

Дякую за увагу

Thank you very much for your attention!