10. Radiation situation

Radioactive contamination of the environment is the most serious environmental and socio-economic problem.

The monitoring of the environment organized in Belarus after the Chernobyl disaster allows to assess regularly the radiation situation in areas affected by radioactive contamination and to predict the change of radioactive-ecological condition of environment in the future for the purpose of working out the recommendations for administrative decisions.

As on January 1, 2009 the area of pollution in Belarus with cesium-137 with level above 37 kBq/m^2 (1 Ci/km^2) is 41,11 ths km^2, or 19,75 % of the territory *(Table 10.1)*.

Pollution of atmospheric air

Key indicators to assess the contamination of atmospheric air are **the dose of gamma radiation (MD)** and **total beta activity** of natural atmospheric precipitation.

Nowadays 55 dosimetry positions operate in the country with daily MD level measures, at 27 positions the precipitations from the atmospheric boundary layer are controlled. At 21 dosimetry positions the total beta activity tests are taken daily, 6 stations operate in standby mode (tests are taken once in 10 days).

In seven cities – Braslav, Gomel, Minsk, Mogilev, Mozyr, Pinsk and Mstislavl – the tests of radioactive aerosols in the atmospheric surface layer using filter-plants are taken. In Mogilev and Minsk the tests are taken in a standby mode (once in 10 days), at other locations in the zones of influence of nuclear power plants of neighboring states the tests are taken daily.

In samples of radioactive aerosols total beta activity and content of short-lived radionuclides are measured daily, particularly iodine-131. The isotopic composition of gamma-emitting radionuclides is analyzed monthly in the monthly samples of radioactive aerosols, as well as in monthly samples of atmospheric precipitation, which are grouped by territories.

Table 10.1

The areas polluted with cesium-137 after the Chernobyl disaster as on January 1, 2009

Region	Polluted areas, total		Including the level of pollution on the territory, ths km^2			
	ths km^2	% from total area	1–5 Ci/km^2	5–15 Ci/km^2	15–40 Ci/km^2	40 end more Ci/km^2
Brest	3.55	10.82	3.38	0.17	–	–
Vitebsk	0.02	0.04	0.02	–	–	–
Gomel	25.91	64.13	17.13	5.61	1.69	1.48
Grodno	1.35	5.40	1.35	<0.01	–	–
Minsk	1.44	3.53	1.44	<0.01	–	–
Mogilev	8.84	30.48	5.86	1.80	0.81	0.37
Republic of Belarus	41.11	19.75	29.18	7.58	2.50	1.85

All information about the levels of MD, the value of total beta-activity and content of gamma-emitting radionuclides in the atmospheric air tests is recorded into the automated data bank.

Analysis of the data for the period 2005-2009 showed that the levels of MD, the radioactivity of natural precipitation and aerosols in the air on the territory of Belarus corresponded to the established long-term values. The radiation situation in the country remains stable.

The levels of MD which exceed the pre-accident values are recorded in the cities located in the zones of radioactive contamination – Bragin, Narovlia, Slavgorod, Khoiniki, Chechersk *(Table 10.2)*. During 2005-2009 in regional cities the average level of MD ranged from 0.10 to 0.13 μSv/h.

In other controlled cities MD did not exceed the level of natural gamma-ray background (up to 0.20 μSv/h).

Table 10.3 shows the annual average total beta activity tests of radioactive precipitation from the atmosphere for some of the cities of Mogilev and Gomel regions.

The largest monthly levels of total beta activity are recorded in the cities of Mogilev and Gomel regions (Mogilev, Narovlia, Slavgorod and Kostiukovichi).

Table 10.4 shows the average values of total beta activity and the content of cesium-137 in the radioactive aerosols of the atmospheric boundary layer tests in 2006-2009.

The results of the gamma-spectrometric analysis in 2005-2009 in the aerosol tests

Table 10.2

Maximum values of MD in some cities in Belarus over the period 2005 – 2009, μSv/h

City	2005	2006	2007	2008	2009*
Bragin	0.82	0.64	0.67	0.70	0.60
Narovlia	0.70	0.64	0.59	0.58	0.52
Slavgorod	0.26	0.24	0.25	0.24	0.22
Hoiniki	0.29	0.27	0.24	0.26	0.24
Chechersk	0.30	0.26	0.25	0.25	0.26

* Presents the average values.

Table 10.3

The average value of total beta activity of samples of radioactive precipitation from the atmosphere in some cities in Belarus over the period 2005 – 2009, Bq/m² day

City	2005	2006	2007	2008	2009
Mogilev	1.30	1.20	1.10	1.30	1.49
Narovlia	0.60	0.70	0.60	0.70	0.69
Hoiniki	0.50	0.60	0.60	0.70	0.72
Bragin	0.40	0.60	0.60	0.60	0.65
Chechersk	0.60	0.50	0.50	0.60	0.59
Vasilevichy	0.50	0.50	0.50	0.60	0.57
Mozyr	0.40	0.40	0.60	0.50	0.48

Table 10.4

The average values of total beta activity (Σ β) and cesium-137 (^{137}Cs) in radioactive aerosols of the atmospheric boundary layer tests in 2006-2009

Year	Mozyr		Braslau		Gomel		Minsk		Mogilev		Mstislavl		Pinsk	
	$1\cdot10^{-5}$ Bq/m^3													
	Σ β	^{137}Cs	Σ β	^{137}Cs	Σ β	^{137}Cs	Σ β	^{137}Cs	Σ β	^{137}Cs	Σ β	^{137}Cs	Σ β	^{137}Cs
2006	–	–	12.40	0.23	14.80	1.28	15.50	0.74	26.80	1.14	17.50	0.65	14.00	0.66
2007	17.80	2.40	9.30	0.24	11.60	1.19	13.80	1.18	21.90	1.19	14.60	1.01	29.10	1.45
2008	16.80	1.46	9.00	0.20	12.40	0.90	11.70	1.22	24.70	0.98	15.40	0.74	12.50	1.11
2009	15.40	1.46	11.40	0.20	14.30	0.90	17.00	1.22	24.80	0.98	18.20	0.74	13.70	1.11

the following radionuclides were identified: cesium-137, potassium-40, beryllium-7 and lead-210.

Over the period 2005-2009 in radioactive aerosols and atmospheric precipitations tests there were not detected any changes in the behavior of cesium-137 in the air compared to previous years. The activity of natural radionuclides in the atmospheric surface layer corresponds to historical averages.

If control index of total beta activity exceeds protective measures are carried out:

– For radioactive precipitation from the atmosphere – 110 Bq/m^2 day;

– For radioactive aerosols – 3700·10^{-5} Bq/m^3.

Pollution of surface waters

Key indicators to assess the contamination of surface waters are **the concentration of cesium-137** and **strontium-90**.

Monitoring of radioactive contamination of surface water is held in Belarus since 1987, that allows us to estimate the transfer of radioactive substances through trans-border cross-sections of rivers flowing through Belarus, Russia and the Ukraine.

In 2005-2009 monitoring was held on 6 Belarusian rivers flowing through the territories contaminated as the result of the Chernobyl disaster: the Dnieper (Rechitsa), the Pripyat (Mozyr), the Sozh (Gomel), the Iputs (Dobrush), the Besyad (Svetilovichi), the Lower Braginka (Gden) and lake Drisvyaty (Drisvyaty).

Every month on the main rivers the tests of controlled water were taken with simultaneous measurement of costs. On the river Nizhney Braginka the test was taken 4 times a year. The water samples were analyzed for cesium-137 and strontium-90. The relative error in measuring low activity levels of cesium-137 in surface waters was 25-30%.

The analysis of radioactive contamination of the rivers in 2005-2009 showed that the radiation situation in the controlled water bodies remained stable *(Figure 10.1-10.2)*. Through processes of water transport, sedimentation of suspensions at the bottom of ponds and natural decay of the concentration of cesium-137 and strontium-90 in medium and large rivers dropped considerably. However, for most controlled rivers their activity is higher than the pre-accident levels.

During last 5 years annual average concentrations of cesium-137 and strontium-90 in the water of the rivers within Gomel region were significantly lower sanitary standards stipulated by Republican permissible levels for drinking water (RDU-99 for Cesium-137 – 10 Bq/L and strontium-90 – 0.37 Bq/L).

A higher concentration of radionuclides

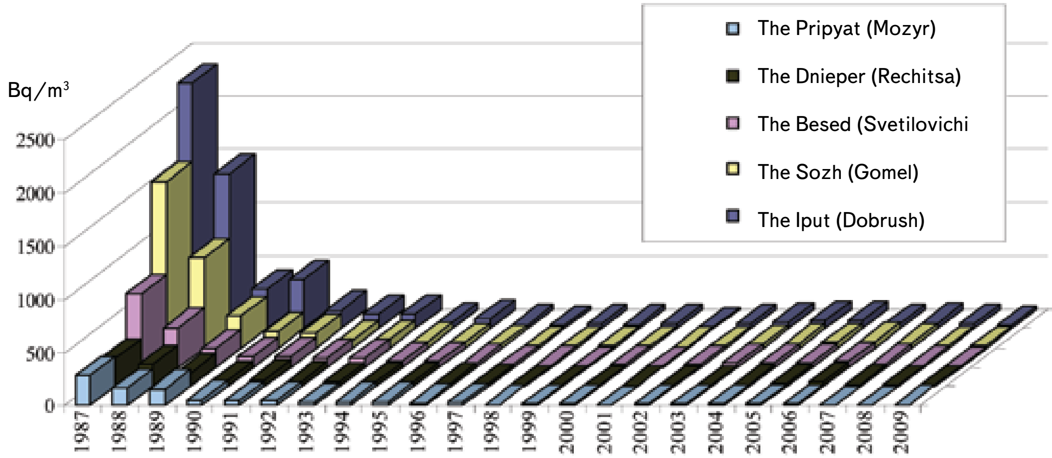

Figure 10.1 – Change in annual average concentrations of cesium-137 in the waters of rivers of Belarus during 1987-2009

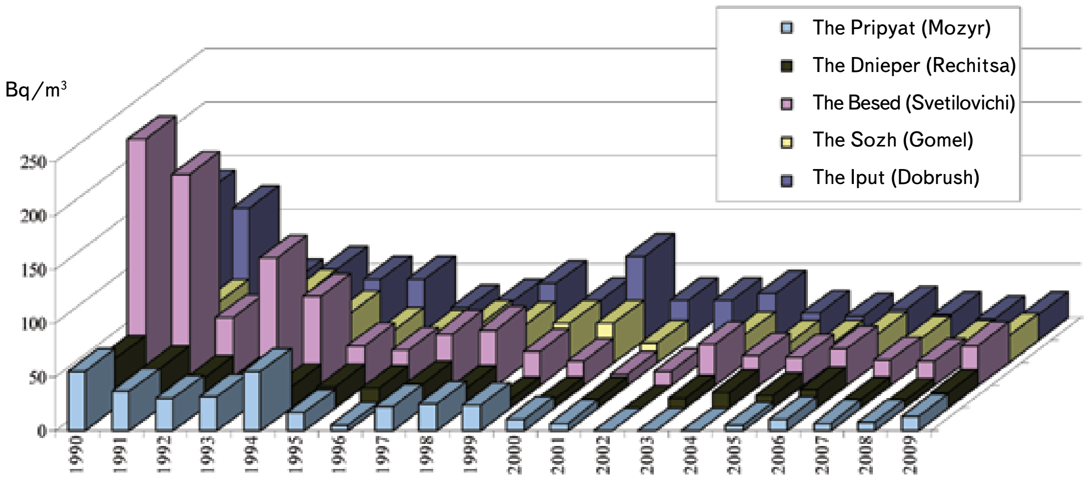

Figure 10.2 – Change in annual average concentrations of strontium-90 in the waters of rivers of Belarus during 1987-2009

is observed during the flood waters of rivers, watersheds of which are wholly or partially located in the 30-km Chernobyl zone. Thus, the increase in the activity of strontium-90 in the water of the Lower Braginka (Gden) is noted during spring and autumn floods, as the result of flooding there is a flush of this radionuclide. During period 2005-2009 exceeded hygienic standards of the RDU-99 for strontium-90 are recorded for 2-15 times. Despite the fact that cesium-137 in approximately 7-10 times higher compared with its content in water and other controlled rivers the exceedance of RDU is not observed.

Outside the zone of the Chernobyl nuclear power plant the radiation situation remains stable. However, water bodies, which watersheds are wholly or partially located in the zone of the Chernobyl nuclear power plant, require constant supervision.

The assessment of the transfer of contamination through trans-border cross-sections is carried out on the rivers the Pripyat, the Iputs and the Besyad. Beginning in 1991 there is a tendency of decreasing in removal of cesium-137 through the cross-sections of the Belarusian rivers flowing on the territories of Russia and Belarus. The main factor reducing the amount of cesium-137 in rivers is to reduce its metabolic forms in the soils of watersheds, as well as natural decay. If during first few years after the disaster significant cross-border transfer was marked by rivers the Iputs and the Besyad, nowadays it is insignificant.

As shown in *Figure 10.3* the trans-border transfer of cesium-137 by the Pripyat river through the cross-section «the border Belarus-Ukraine» significantly decreased. Total removal of radionuclide by the river for the period 1987-2008 was 36.49 TBq.

In general, the total removal of cesium-137 by the Pripyat river through the cross-section «the border Belarus-Ukraine» for the period 1987-2008 was about 0.75% from its storages in the Chernobyl exclusion zone within Belarus.

In contrast to the removal of cesium-137, strontium-90 removal by the rivers is largely dependent on the dryness of the year, as its flush with the catchment area is in soluble form. Despite the fact that the average content of strontium-90 has a tendency to decrease, from time to time the rise of its concentrations in river waters is observed, as the result of flushing by melt and rain waters from the catchment area. Thus, the total removal of strontium-90 by a river for the period 1987-2008 was 67.63 TBq (the calculation of the removal for 1986-1999 was carried out according to UkrNIGMI, for 2000-2008 – according to RCRCM). The dynamics of average annual removal of

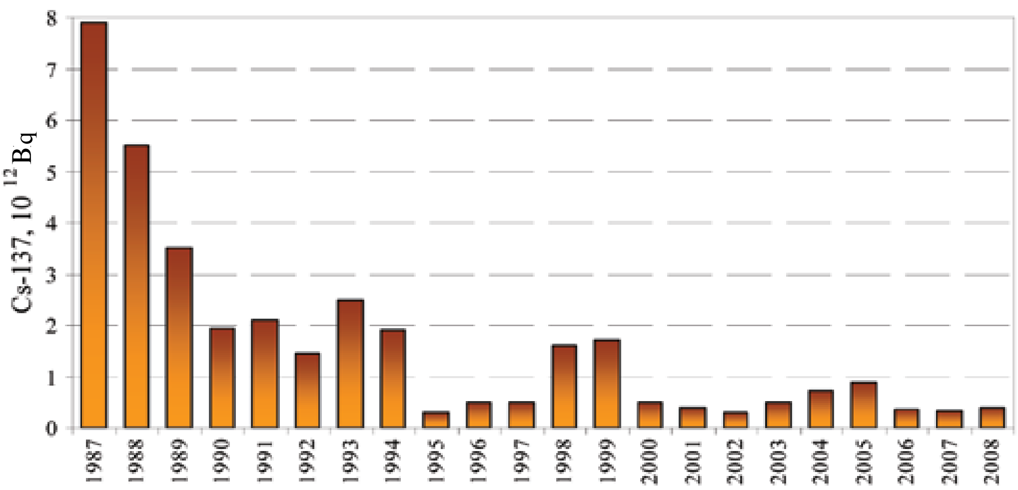

Figure 10.3 – **The dynamics of the average annual removal of cesium-137 by the Pripyat river through the cross-section «the border Belarus-Ukraine» in the period 1987-2008**

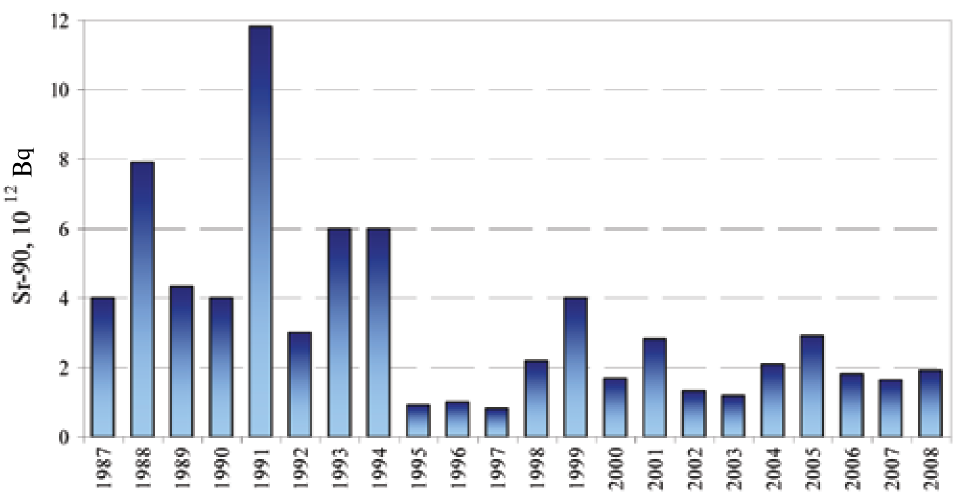

Figure 10.4 – **The dynamics of the average annual removal of strontium-90 by the Pripyat river through the cross-section «the border Belarus-Ukraine» in the period 1987-2008**

strontium-90 by a river during this period is shown in *Figure 10.4.*

The rivers the Iputs and the Besyad are the most important tributaries of the Sozh which flow on the Belarus-Bryansk «cesium spot» with the levels of contamination with cesium-137 from 37.0 to 2220.0 kBq/m^2. Constant monitoring of the radionuclide content in water and sediments of these rivers is carried out on cross-sections in Dobrush (the Iput river) and Svetilovichi village (the Besyad river).

During the first years after the disaster there was a significant trans-border transfer of cesium-137 with the waters of the river Iput (Dobrush) and the river the Besyad (Svetilovichi village), nowadays it is insignificant. The main factor reducing the concentration of cesium-137 in water is a significant decrease in washout of the radionuclide from the surface catchment area associated with a decrease in the number of its metabolic forms in soils, as well as its natural decay.

As shown in *Figure 10.5* during the first two years after the Chernobyl disaster there was a significant removal of cesium-137 through the wing of Dobrush town. In the following years it gradually declined and now its value depends on the hydrological regime of the river.

Total removal of cesium-137 by trans-boundary rivers (Russia-Belarus) in all cases is about 1% of its common stock in the affected watersheds.

Contamination of agricultural land

The main indicator for assessing radioactive contamination of agricultural soils is the density of land contamination with cesium-137 and strontium-90. The importance of these indicators is due to the fact that in the case of Belarus, about 70% of the collective dose is formed due to radionuclide intake with food. The problem of reducing radiation dose to the population was most acute during the first ten years after the disaster, but it remains relevant in the present. The main criterion of the effectiveness of protective measures is the reduction of the intake of radionuclides from the soil into the food chain and getting products containing radionuclides within acceptable levels which are periodically reconsidered. During the post-accident period in Belarus the transition of cesium-137 from soil to agricultural products declined more than an order of magnitude. According to expert assessments about half of this decline is due to the countermeasures, the other half is due to the natural factors of decay and fixation by soil cesium radionuclides.

Nowadays the radiation situation on the agricultural lands of Belarus has improved considerably. There was a disintegration of

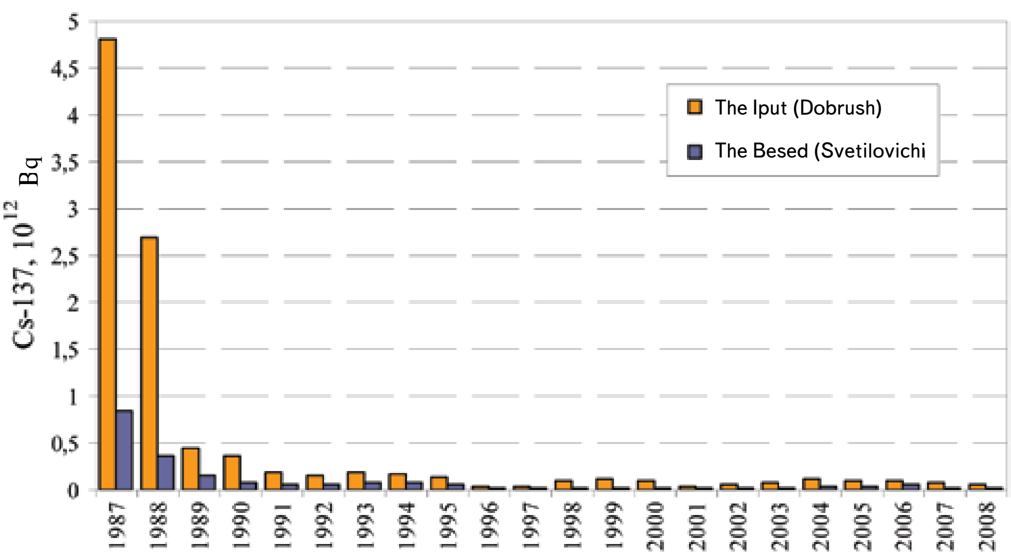

Figure10.5 – The dinamics of removal of cesium-137 by the waters the Iput river (Dobrush) and the river Besyad (Svetilovichi) during 1987–2008

short-lived radionuclides. The concentration of long-lived radionuclides cesium-137 and strontium-90 in the soil decreased by about 40% only because of natural decay. A gradual decrease in the area of contaminated land is observed with controlled minimum density of cesium-137 with more than 37 kBq/m^2 and strontium-90 with more than 5.5 kBq/m^2 due to the natural decay of radionuclides and the transfer of some land in the category of non-contaminated *(Figure 10.6).*

Over the past 18 years into the category of non-contaminated 424 hectares of land were transferred previously contaminated by cesium-137, and the area contaminated with strontium-90 decreased by 295 ha. Agricultural production as on 01.01.2010 is on 1014.2 thousand hectares of land contaminated by ^{137}Cs with a density of 37-1480 kBq/m^2 *(Table 10.5).*

In cultivated sod-podzol sandy loam soil about 90% of the gross margin of cesium-137 and 75% of strontium-90 is in the plow layer 0-25 cm. The biggest transition of radionuclides from soil to vegetation is noted on sandy and peat soils in natural conditions, the lowest – on the cultivated lands. In general after 24 years after the disaster the principal amount of radionuclides cesium-137 and strontium-90 is in the root zone and is included in the biological cycle.

On uncultivated lands the principal amount of cesium-137 (70-85% of its gross content) and strontium-90 (58-61%) is concentrated in the upper 0-5 cm root zone.

The main arrays of agricultural land contaminated with cesium-137 are concentrated in Gomel (47,3% of total area) and Mogilev (23.6%) regions. In Brest, Grodno and Minsk regions the proportion of contaminated land is small and is respectively 6,1%, 2,6 and 3,6%.

Contamination of strontium-90 has a local character. Radionuclide contamination of soil data with a density of more than 6 kBq/m^2 is detected on 10% of the total land area. Maximum levels of strontium-90 in the soil are typical for a 30-km zone around Chernobyl and reach 1798 kBq/m^2 in Khoiniki district of Gomel region.

Lands contaminated with strontium-90 are located within the areas contaminated by cesium-137 that makes agricultural production very difficult. *Table 10.6* shows the distribution of agricultural land contaminated with strontium-90 with a density of more than 5.6 kBq/m^2 (0,15 Ci/km^2).

From the total area of land contaminated with strontium-90, 331.0 hectares of agricultural land including 190.8 thousand hectares of arable land and perennial plantations are concentrated in Gomel region. Here, the

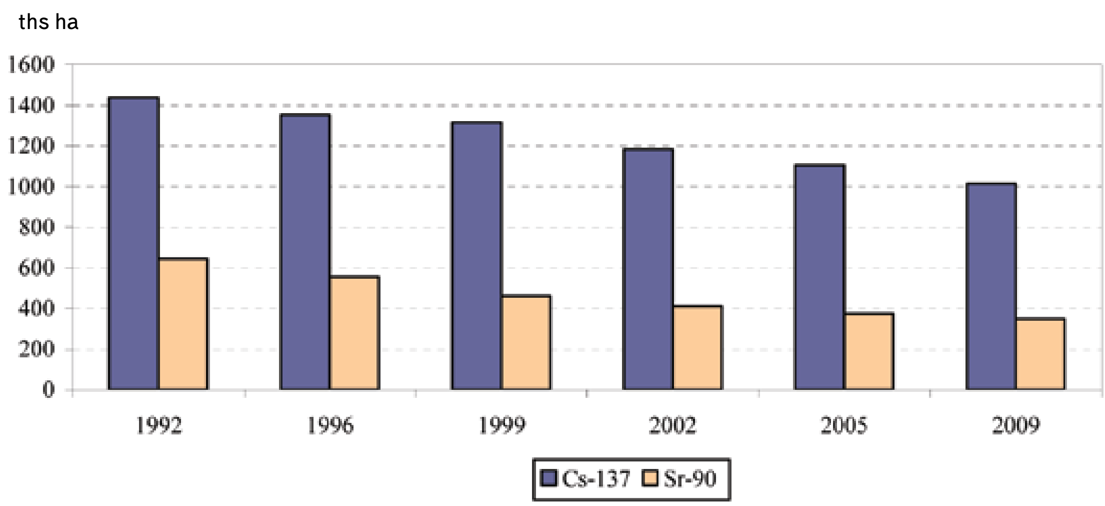

Figure 10.6 – The dynamics of the area used by the contaminated land in Belarus for the period 1992-2009 (Cesium-137 with a density> 37 kBq/m^2, strontium-90> 5.5 kBq/m^2)

Table 10.5

The density of contamination of agricultural land in Belarus by Cesium-137 in 2007-2009*

Year	Area, ths ha	Total contaminated >37 kBq/m² (>1,0 Ci/km²)		In % of contaminated zones, kBq/m² (Ci/km²)		
		ths ha	%	37–184 (1.0–4.9)	185–554 (5.0–14.9)	555–1476 (15.0–39.9)
Agricultural land						
2007	7584.0	1026.6	13.5	77.0	20.0	3.0
2008	7634.8	1018.8	13.3	77.3	20.1	2.6
2009	7634.8	1014.2	13.3	77.8	19.5	2.7
Arable						
2007	4657.1	596.6	13.0	76.5	21.0	2.5
2008	4696.1	596.6	12.6	77.0	21.0	2.0
2009	4696.1	595.6	12.6	77.3	20.2	2.5
Hayfield and pasture						
2007	2926.70	429.95	14.70	77.50	19.50	3.00
2008	2938.7	425.0	14.5	78.0	19.0	3.0
2009	2938.7	418.6	14.2	78.5	18.6	2.9

* According to the Ministry of Agriculture of the Republic of Belarus.

share of polluted arable and grassland soils is 27,2% of the total area used by agricultural land. In Mogilev region the share of arable and grassland soils contaminated with strontium-90 is much lower – respectively 1,2 and 1,7%.

Particularly problematic are 347.9 thousand ha of agricultural land with a density of strontium-90 0,15-3,0 Ci/km² simultaneously contaminated with cesium-137 with a density of 5-40 Ci/km².

Soil pollution with plutonium isotopes with a level of more than 0.37 kBq/m² was found in 2% of Belarus. These areas are mainly in Gomel region and Cherikov district of Mogilev region. The content of plutonium in the soil more than 3,7 kBq/m² is characteristic only for the 30-km zone. Polesye State Radiation Ecological Reserve (PSRER) was created on the territory of 2.162 thousand km² of Belarusian sector 30-km zone around Chernobyl and its adjacent lands where the population was resettled.

In 2007-2008 a detailed re-examination of radiological lands of PSRER was carried out in step of 1 km and the maps of pollution on a scale of 1:200 000 were created.

The main part of agricultural lands taken out of use was included in the exclusion zone and is now the part of PSRER. Main exclusion zone cannot be returned to agricultural use even in the distant future, due to the high density of contamination of many long-lived radionuclides – cesium-137, strontium-90 and plutonium-238, 239, 240, 241, americium-241. The part of lands adjacent to evict settlements with a lower density of contamination, was included in the evacuation zone.

Measures for the rehabilitation of contaminated areas

Measures to ensure the country's ecological security in connection with the radioactive contamination of the territory are provided by

Table 10.6

The density of contamination of agricultural lands in Belarus by Strontium-90 in 2007-2009*

Year	Area, ths ha	Total contaminated >5,6 kBq/m² (>0,15 Ci/km²)		In % of contaminated zones, kBq/m² (Ci/km²)		
		ths ha	%	5.6–11.0 (0.15–0.30)	11.1–37.0 (0.31–1.00)	37.1–107.0 (1.01–2.99)
Agricultural land						
2007	7584.0	343.7	4.5	58.0	35.0	7.0
2008	7634.8	347.1	4.6	57.0	36.0	7.0
2009	7634.8	347.9	4.6	56.8	36.4	6.8
Arable						
2007	4601.5	194.6	4.2	58.0	34.0	8.0
2008	4696.1	198.5	4.2	58.0	34.0	8.0
2009	4696.1	199.6	4.2	58.9	34.1	7.0
Hayfield and pasture						
2007	2926.7	149.1	5.1	57.0	37.0	6.0
2008	2938.7	148.6	5.1	55.0	38.5	6.5
2009	2938.7	148.3	5.0	54.1	39.4	6.4

* According to the Ministry of Agriculture of the Republic of Belarus.

the State program of overcoming the effects of the Chernobyl disaster during 2001-2005 and for the period up to 2010. It includes the following main activities.

The first direction refers to decontamination area, recycling and disposal of radioactive waste. Decontamination of social objects – kindergartens, schools, health institutions was scheduled to finish in 2005. By 2010 it was expected to complete dumping yards and industrial buildings.

The second direction is related to farming in contaminated areas. Protective measures in agriculture are the set of institutional, agricultural, agro-chemical and veterinary measures aimed at obtaining food and raw materials that meet sanitary and hygienic standards for the content of radionuclides, radiation safety of agricultural work.

The third direction is associated with protective measures in forestry, contributes to the ecological role of forests as a biogeochemical barrier for the removal of radionuclides beyond the contaminated area, prevents the loss of forests from fires, pests and diseases, radiation safety of workers in the forest, local population and products consumers.

The fourth direction includes the measures for the rehabilitation of contaminated territories and the contents of exclusion, includes control over the use of evacuated areas, compliance with fire safety, protection of property, historical monuments, culture and architecture, places of military graves and cemeteries, works to transfer radioactive land in agricultural use.