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Spatial Development in the European Context

With 41 Figures and 28 Tables

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The Ecological Impact of the Chernobyl Catastrophe on Sustainable Development in Belarus

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Introduction

One of the principal causes hindering a sustainable, ecologically safe process of social and economic development in the Republic of Belarus relates to the negative consequences of the Chernobyl disaster. These consequences affect all the main spheres of social activity both in the contaminated regions and in the republic as a whole, and are a grave problem for Belarus. The nature and extent of the damage inflicted by the accident at the Chernobyl nuclear power station have become destabilising factors for the socio-economic advance of the republic, characterised as they are by a drastic deterioration of the ecological situation and a rise in morbidity levels. The problems brought about by the Chernobyl disaster involve changes in territorial structures relating to the use of natural resources, forced migration from contaminated regions, the depressed morale and psychological state of those affected, and the utter transformation of their whole way of life.

Extent and Ecological Consequences of Radioactive Contamination

The catastrophe at Chernobyl nuclear power station was, on account of its scale, complexity, and long-time consequences, one of the worst catastrophes ever in the history of atomic energy utilisation. According to estimates, about 50 million curies of 22 different radioactive isotopes was emitted into the environment. The substances released had their origins both in the immediate nuclear reactions (e.g. I, Cs, Cr, Ru) and in the reactor's fuel elements (U, Pu). For ten days after the disaster at Chernobyl, radioactive contamination was registered throughout Europe (Table 1).

The largest area of contamination was in Belarus. Fall-out from the accident affected roughly 25 % of the country, or some 4,000 communities and more than two million people. The territory of Belarus suffered not only the most extensive, but also the most intense contamination.

Approximately 20 % of the republic's agricultural land and about 25 % of its woodlands are located in the area affected. In the zone of radioactive contamination, radiologically unsafe lands deemed unsuitable for the production of food under both national regulations and international ecological agreements have been identified and withdrawn from economic use. To year end 1996, the total area of such lands amounted to 264,000 hectares. The Polesky radiation ecology reserve with a total surface area of about 220,000 hectares has been installed on territory with levels of contamination above 40 Ci/sq.km or above 1,480 kBq/sq.m.

Table 1. Caesium - 137 (total) contaminated areas in European countries in 000 sq. km
Source: Izrael (1996).

Countries	Area (in 000 sq.km) contaminated above specified levels (kBq/sq.m)						% of contamination deposited in Europe (%)
	10–20	20–37	37–185	185–555	555-1,480	>1,480	
Belarus	60	30	29.9	10.2	4.2	2.2	33.5
Russia	300	100	48.8	5.7	2.1	0.3	23.9
Ukraine	150	65	37.2	3.2	0.9	0.6	20
Sweden	37.4	42.6	12.0	–	–	–	4.4
Finland	48.8	37.4	11.5	–	–	–	4.3
Bulgaria	27.5	40.4	4.8	–	–	–	2.8
Austria	27.6	24.7	8.6	–	–	–	2.7
Norway	51.8	13.0	5.2	–	–	–	2.3
Romania	14.2	43.0	–	–	–	–	2.0
Germany	28.2	12.0	–	–	–	–	1.1
Greece	16.6	6.4	1.2	–	–	–	0.8
Slovenia	8.6	8.0	0.3	–	–	–	0.5
Italy	10.9	5.6	0.3	–	–	–	0.5
Moldova	20	0.1	0.06	–	–	–	0.45
Switzerland	5.9	1.9	1.3	–	–	–	0.35
Poland	8.6	1.0	–	–	–	–	0.23
Estonia	4.3	–	–	–	–	–	0.08
Czech. Rep.	3.4	0.36	–	–	–	–	0.09
Slovak Rep.	2.1	–	–	–	–	–	0.05
Lithuania	1.2	–	–	–	–	–	0.02

For decades to come, the main source of radioactive contamination will be Cs and Sr (with half-lives of 30 and 28 years respectively) and Pu (half-life of 86 years). It has been established that Cs accounts for about 90 % of the total radioactivity emitted. Radionuclides present in landscape systems contain two physical-chemical forms. The bulk of isotopes occurring in the southern region (over 80 %) are referred to as 'hot particles'. As a rule these isotopes have an average density of 10 particles/m³ and are concentrated in the immediate vicinity of the Chernobyl atomic power station up to a range of about 30 km. In other regions the level of contamination is lower, though the contaminated area is large due to radioactive fall-out through rainfall. These nuclides are present in molecular form.

Stationary observation of nuclide migration bears witness to the fact that as a whole the process has accelerated in the environment. This is a result of active assimilation of nuclides by plants, wind erosion, leakage of surface waters into deeper lying soil layers, isotopic redistribution through water currents and localisation in bottom sediments and coastal deposits. However, the greatest worry concerns the fact that practically all radioactive nuclides have been incorporated into the biological cycle, i.e. soil–water–plants–living organisms.

This in turn adds to the probability of radioactive penetration of human organisms and concomitant increases in the morbidity rates of those exposed to radiation.

For those living in the contaminated zones, a particular hazard is posed by what is known as "resuspended" material. Resuspension is a phenomenon linked to secondary transfer, as a rule horizontal transfer of radioactive nuclides, which we have dubbed "the ink spot effect". Resuspension is caused by natural phenomena like wind and water erosion. Human activity is also a major contributor to the resuspension of radioactive material, for example, through agricultural practices such as ploughing and harrowing, through various modes of conveyance, especially on unsurfaced roads, and through scrub burning in woodland areas. The main consequences of resuspension are twofold: radioactive material can be transferred to uncontaminated areas and it can be inhaled by humans, thus increasing their potential exposure to radiation.

What are the main factors conducive to radioactive nuclides entering the environment? Three principal aspects attract our attention. First, the retention of Cs^{137} for a long period of time in the upper 0–5 cm of soil of and of Sr^{90} in deeper layers. Second, the fact that, the vertical migration of practically all radionuclides increases as one moves further away from the station. Third, the migration capability of americium^{241}, a by-product of Pu^{241}, is higher than that of plutonium. The half-life in adjacent and remote zones for Cs^{137} is 24–27 years. In the case of Sr^{90}, the half-life in 0-5 cm of soil for adjacent and remote zones is lower, extending from 7–12 years. According to one forecast, up to the year 2006 the Sr^{90}, Cs^{137} and $Pu^{239,240}$ content in the 0–5 cm soil layer in the adjacent zone will make up 30–40 %, 60–70 % and 90–95 % of their respective potential. For the remote zone, the equivalent figures will be Sr^{90} 15–25 %, Cs^{137} 35–45 %, and $Pu^{239,240}$ 10–20 % (Konoplya and Rolevich 1996). In the aftermath of the Chernobyl power station accident, 1,73 million ha or 25 % of the republic's woodlands were within the radioactive contamination zone (Table 2). From the beginning of 1988, an increase of root inflow of Cs^{137} and Sr^{90} isotopes to the above-ground phytomass against the background of continuous self-purification of surfaces was registered. The forecast findings show that woodland contamination is set to increase and that the main channel for isotopic transfer to the wood layer will be root penetration. In the next 10–15 years the above-ground phytomass, 30-year-old pine plantations in particular, will accumulate up to 10–15 % of the total amount of Cs^{137} in large forests. The Cs^{137} content in woodland edibles such as mushrooms and berries (whortleberries, cranberries, wild strawberries) exceeds the permissible norms (dried mushrooms 3,700 Bq/kg, berries 185 Bq/kg) even in areas with levels of soil contamination as 'low' as 37–100 kBq/sq.m. Radioactive contamination of woodland foodstuffs that limits their usage can be expected for the next 30–40 years in areas with a contamination density of 150 kBq/sq.m or above (Parfenov and Yakushev 1995).

Radionuclidic accumulation in animals is equal to the radioactive contamination in a given area. The highest levels of radionuclide content in various types of fauna were observed during the first year after the accident. From 1988 the process of nuclidic concentration slowed down considerably, and in some groups of animals (fish, amphibians, small mammals) inhabiting the most contaminated territories the radioactive content has since fallen back to 1986 levels.

Table 2. Radioactive contamination of woodland and other plant communities
Source: Konoplya and Rolevich (1996).

Cs-137 contamination zones, kBq/sq.m	Coniferous species, 000 ha		Hard deciduous 000 ha		Soft deciduous 000 ha			
	Total	Pine	Total	Oak	Total	Birch	Aspen	Alder
37–185	762.8	691.8	73.2	67.0	280.7	170.1	18.4	91.5
185–555	188.8	170.2	19.1	17.6	71.7	43.7	5.4	22.3
555–1,480	90.1	80.6	9.0	8.3	34.0	20.8	2.8	10.2
> 1,480	24.5	21.1	2.1	2.1	9.2	5.7	0.8	2.5
Total	1,066.2	963.7	103.4	95.0	395.6	240.3	27.4	126.5

Termination of industrial activity in the contaminated areas had an impact on the structure of species and volumes of birds and game. Within the 30-km zone, considerable and steady growth in the number of populations of game species has taken place (Figure 1). Due to the abundance of food and the cessation of hunting, the wolf population has increased 4 to 5-fold. And in settled areas one can encounter species of woodland and open-area wildlife. As a whole, the number of rare animals in faunal complexes has increased.

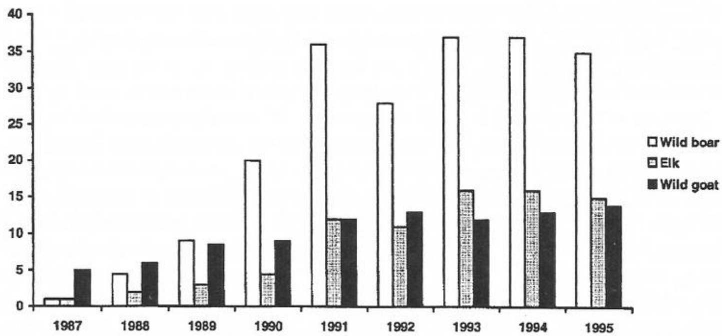


Figure 1. Population dynamics of selected animal species in the zone around Chernobyl (animals per 1,000 ha)
Souce: Pikulik and Nikiforov (1995).

The situation regarding parasites in the zone contaminated by radionuclides is worse than in control biocoenoses. Fauna and species of leeches and parasites living on wild birds and small mammals, or in their nests, in the radioactively contaminated areas are more abundant than in contiguous areas. It is to be expected that, in due course, the number of species of epidemic and epizootic significance in the contaminated areas will rise further (Pikulik and Nikiforov 1995).

The radiological situation in Belarus is characterised by complex, heterogeneous contamination by radioactive substances with varying half-lives, the presence of radioactive isotopes in practically all strata of ecosystems, and their intrusion into the geochemical and trophic cycles of migration.

Social and Medical Consequences

The after-effects of the Chernobyl accident on the sustainability of the process of social and economic development in Belarus are detrimental to both the present and future of the republic. This is due to the extraordinary extent of the damage inflicted.

Most severe are the social consequences, namely large-scale forced migration of the population (internal ecological migration) from the contaminated zone, the need to establish safe conditions for residents who remained in the contaminated areas, growing morbidity rates on account of radiation doses received, the social and psychological problems of adaptation to unaccustomed living conditions in the regions of radioactive contamination and new domiciles, growing rates of unemployment in the contaminated regions as a result of economic degradation of the latter and an aggravated crime situation.

The following data is designed to provide an insight into the extent of the social consequences of the Chernobyl accident in Belarus, their territorial structuring, and counter-measures undertaken.

The area of Belarus subjected to radioactive Cs^{137} contamination of at least 1 Ci/sq.km (37 kBq/sq.m) in 1986 comprised 3,600 communities with a population of 2.2 million. This represents over 20 % of the country's total population. According to data quoted as of 1 January 96 (i.e. 10 years after the disaster), 1.63 million people forming 15.8 % of the population are still living in zones of radioactive contamination (Konoplya and Rolevich 1996). More particularly, 1.3 million people are still living in areas with radioactive contamination levels of 1–5 Ci/sq.km (37–185 kBq/sq.m), 298,600 in areas with 5–15 Ci/sq.km (185–555 kBq/sq.m), and 24,400 in areas with 15–40 Ci/sq.km (555–1,480 kBq/sq.m). Given that safeguarding the population against radiation is the most pressing among measures aimed at overcoming the after-effects of the disaster, the Government of Belarus has been pursuing a programme of moving people from the most contaminated regions since 1986. Furthermore, special measures have been taken to provide safe living conditions for those who remained in the contaminated areas and social support for those who suffered from the accident (Table 3).

Table 3. Zoning of the territory of the Republic of Belarus by level of radioactive contamination and dose to which population was exposed

Name of the zone	Equivalent dose mSv per year	Contamination density, kBq/sq.m		
		Cs-137	Sr-90	Pu-238, -240
Residence zone with periodic radiation control	< 1	37–185 (1–5)*	5.55–18.5	0.37–0.74
Zone with evacuation rights	< 5 > 1	185–555 (5–15)*	18.5–74	0.74–1.85
Zone of later evacuation	> 5	555–1,480 (15-40)*	74–111	1.85–3.7
Zone of primary evacuation		(> 40)	> 111	> 3.7
Total exclusion zone	the territory around the Chernobyl NPP from which the population was evacuated in 1986			

By the end of 1986 more than 16,000 people from 108 communities had been evacuated from the 30-km zone around the Chernobyl nuclear power station, and by 1995, full evacuation of the population from areas with a contamination density above 40 Ci/sq.km and partial evacuation from areas with a contamination density between 15–40 Ci/sq.km had been practically completed. Relocation of a total of 131,000 people away from the contaminated regions had been organised by year end 1996. From 1989 to 1995, houses with a total floor space of 3,318 sq.m and more than 48 thousand flats were constructed for migrants by resorting to funds earmarked for dealing with the consequences of the accident. Expenditure on forced relocation during the period 1986–1995 is estimated to have totalled 4.36 billion USD.

Apart from organised relocation, population outflow from the contaminated regions was also to an extent initiated individually. It is possible to gain an idea of the magnitude of forced ecological migrations using data on population changes in different districts of Belarus over the past 10 years. Between 1985 and 1995, though the urban population in the republic as a whole increased by 14.3 %, in Gomel district it was only by 8.4 % and in Mogilev district by 6.8 %. During the same period the rural population of Belarus as a whole decreased by 13.6 %; the figure for Gomel district, however, was 23.1 % and for Mogilev district 14.7 %. In the 10 years referred to, total population increased by 3.7 %; in the same period, the population of Gomel district actually decreased by 4.2 % and that of Mogilev district by 1 %. Population decrease in the most contaminated areas of the Gomel and Mogilev districts averaged 46 % in the period from 1985–1995.

As has been demonstrated by sociological studies, the wish for a secure and ecologically sound life and for good health for one's children rates first among the reasons cited for induced migration. It can thus be inferred that the large-scale migratory processes of the post-Chernobyl period are forced in nature and have had negative material and psycho-social consequences for those moving.

Unfortunately, none of the measures undertaken (to wit urgent evacuation from contaminated regions and processes of compulsory and voluntary migration from radiologically hazardous zones that were dragged out for many years) were sufficient to ward off the appallingly deleterious impact of the Chernobyl disaster on the health of the Belorussian people. Morbidity and death rates have increased in Belarus due to the sizeable radiation dose received by practically everybody in the republic in the first days after the accident, the enormous dose suffered by 20 % of the population ("iodine shock"), and as a result of people being exposed to continued irradiation in contaminated areas (Figures 2, 3).

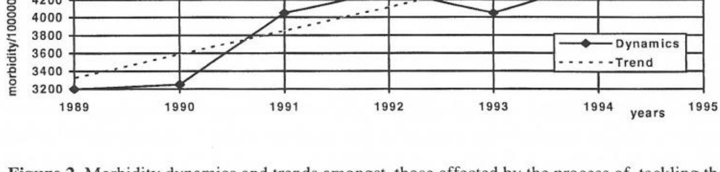


Figure 2. Morbidity dynamics and trends amongst those affected by the process of tackling the consequences of the Chernobyl NPP accident (per 100,000 people)
Source: Konoplya and Rolevich (1996).

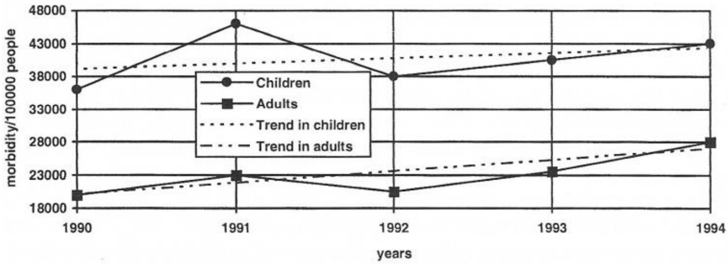


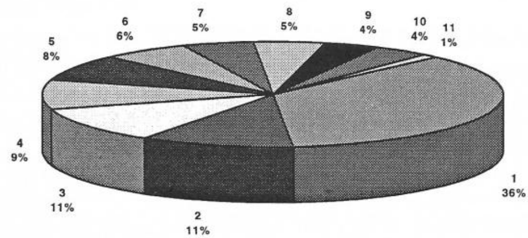
Figure 3. Morbidity dynamics amongst evacuees (per 100,000 people)
Source: Konoplya and Rolevich (1996).

Between 1985 and 1995 the birth rate in Belarus dropped from 16.5 % to 9.8 % (down by 40.6 %) whereas the death rate grew from 10.6 % to 13 % (up by 22.6 %). This tendency is particularly marked in Gomel and Mogilev districts. In the case of people moved from the area with a radioactive contamination level above 555 kBq/sq.m one observes a growth in the morbidity rate for all principal classes of diseases. Cases most often recorded relate to bronchopulmonary, circulatory, digestive, neural and endocrinal disturbances (Figure 4). Here, morbidity rates exceed the average for the republic by a factor of 2.1–9.8 (Konoplya and Rolevich 1996). At the same time, the number of cancer cases has also increased. Over the past 10 years the morbidity rate for malignant tumours in men has grown by 24.1 % and in women by 22.6 %. For those living in areas with a radioactive contamination level of above 555 kBq/sq.m, the rate has increased by 56.3 %, and at levels of between 185–555 kBq/sq.m the increase has been by 40.4 % (Table 4).

Table 4. Thyroid cancer incidence in Belarus
Source: Konoplya (1996).

Pre-accident period			Post accident period		
Years	Adults	Children	Years	Adults	Children
1977	121	2	1986	162	2
1978	97	2	1987	202	4
1979	101	0	1988	207	5
1980	127	0	1989	226	7
1981	132	1	1990	289	29
1982	131	1	1991	340	59
1983	136	0	1992	416	66
1984	139	0	1993	512	79
1985	148	1	1994	553	82
Total	1131	7	Total	2907	333

A link between an increase in malignant tumours of the thyroid gland and the after-effects of the Chernobyl accident has been established (Table 4).



1 respiratory organs
2 blood circulation system
3 nervous system and sense-organs
4 digestive organs
5 bone and muscle system
6 endocrine system
7 infectious and parasitic diseases
8 urogenital system
9 skin and subcutaneous cellular tissue
10 psychosomatic
11 malignant neoplasms

Figure 4. Breakdown of the morbidity of those inhabiting areas contaminated with over 555 kB/sq.m of Cs^{137}

Serious disturbances of a psycho-emotional nature are also common amongst those affected by the Chernobyl disaster (e.g. evacuees, migrants, those who remained in zones of radioactive contamination and those involved in the clear-up). All these people were traumatised and are in need not only of medical observation, treatment and sanitation but also require social and psychological rehabilitation.

Economic Losses

Assessment of the financial damage caused by increased morbidity in Belarus during the post-accident period presents a problem, since many phenomena associated with genetic or other medical and biological after-effects of continued exposure to low radiation doses are unexplained and call for extensive investigations. However, approximate calculations, performed by Belorussian statisticians with the use of special procedures, have demonstrated that the total financial loss resulting from the deterioration of health caused by radiation doses received or expected and from psychological trauma experienced in zones of radioactive contamination over the period 1986–2015 can be set at 821.3 million USD. Taking expenditure on required sanitation measures as well as national income shortfalls on account of a high sickness rate into consideration, the aggregate loss arising from health impairments in the thirty years after Chernobyl is estimated at 1.9 billion USD.

In addition, the government of Belarus also sees itself compelled to expend large amounts providing for ecologically viable living conditions in contaminated regions. Outlay includes compensation payments for the victims of the accident as foreseen by the 'On the Social Protection of Victims of the Chernobyl Accident' Act, improvement of the social service system, radiological decontamination in contaminated areas, utilisation and elimination of radioactive waste and organisation of monitoring services. The assessment of expenditure arrived at by Belorussian statisticians is contained in Table 5 and indicates that, between 1986 and 2015, actual financial losses combined with additional expenditure aimed at minimising the social consequences of the Chernobyl disaster will amount to as much as 146 billion USD. Clearly, such expenditure cannot be borne by the Belarus economy, which is in a critical enough state as it is.

Heavy financial losses were inflicted by the accident on the whole sphere of material production (industry, agribusiness, civil engineering, forestry, transport and communications, utilities) as well as on natural resources (Table 5). Worst hit were branches of the economy based on natural resources and landscape utilisation, viz. agriculture and forestry. In Belarus 1,8 million hectares of agricultural lands, or 20.8 % of the entire area given over to agriculture in the country, was subjected to radioactive contamination. 264,000 ha of agricultural lands were withdrawn from the agricultural cycle due to high levels of radioactive contamination. Moreover, expert assessments show that output of unpolluted agricultural products is impracticable over an area of 800,000 ha. The total loss sustained by Belorussian agriculture is assessed at about 70 billion USD and includes direct losses from withdrawal of land from the agricultural cycle, the value of products not obtained due to resultant under-production, losses in productive and intangible assets, additional expenditure relating to the specific conditions of agricultural production pertaining in the contaminated areas (respecialisation in plant growing and cattle breeding, adoption of specialised methods and procedures, etc.).

In zones of radioactive contamination great losses are recorded in industries that process agricultural products. Processing enterprises have been obliged to close and move to non-contaminated areas (direct losses) or else have been involved in additional outlay on decontamination of equipment, the search for new suppliers of raw materials, radiological control etc.

As a consequence of the Chernobyl disaster, about 2 million hectares of woodland, or 25.3 % of the republic's entire forestry resources, are now within the zone of radioactive contamination. This fact has given rise to direct losses of timber, wood pulp, mushrooms, berries and other important resources, loss of the protective and recreational functions of woodlands, and additional expenditure on the decontamination of forestry products. The total loss to forestry is estimated at 4.1 billion USD for the 30-year period after the accident (Table 5).

Table 5. Estimates of the economic damage from the Chernobyl catastrophe for the Republic of Belarus, billion USD

Type of damage	Total damage per period				
	1986–1990	1991–1995	1996–2000	2001–2015	1986–2015
Health impairments	0.69	0.29	0.24	0.65	1.87
Industry	0.06	0.13	0.11	0.33	0.63
Social sphere	2.77	5.00	2.04	4.43	14.23
Construction	0.15	1.25	0.32	0.96	2.68
Transport & communications	0.93	1.20	0.36	0.90	3.39
Housing & communal services	0.07	0.45	0.92	2.02	3.46
Agribusiness	18.31	20.00	15.60	18.10	72.00
Timber industry undertakings	0.58	0.68	0.70	2.15	4.11
Resettlement	2.80	1.56	.39	0.33	5.08
Implementation of the Social Compensation Act for Victims of the Chernobyl Catastrophe	0.56	14.92	17.50	53.34	86.32
Pollution of mineral & water resources	2.00	0.12	0.15	0.10	2.67
Decontamination of polluted areas	0.04	4.19	22.48	10.12	36.83
Setting up of monitoring service	0.05	0.21	0.19	1.27	1.72
Total	29.00	50.00	61.00	95.00	235.00

340 industrial enterprises, which together generated 17 % of overall output in 1990, are located in zones of radioactive contamination. Analysis shows that the crisis phenomena that dogged of Belarus economic policy between 1990–1995 are most profound in the industries within the Chernobyl zone. There the setback in production is greatest on account of the closure of industrial facilities and the phasing-out of products.

Losses incurred by Belarus industry as a result of the accident at the Chernobyl nuclear power station are assessed at 630 million USD. The greater part of this (94 % of total value) is made up of losses caused by production cut-backs or curtailment.

The loss incurred by the building and construction, communications, and housing and communal sectors, relates to direct losses taking the form of equity capital relinquished in the exclusion and relocation zones, lost income potential due to the curtailment and cessation of production as well as additional expenditure on decontamination procedures and relocation and the setting-up of new economic units.

The aggregate loss incurred by the Belorussian economy in the wake of the accident and assessed at 235 billion USD for the period from 1986–2015 (or 32 annual budgets of the republic from 1985) is a prime cause of the fragile, unsustainable social and economic evolution as a sovereign state. Unfortunately, this tendency is likely to persist for quite some time to come. Expenditure allocated by the Government to tackling the consequences of the accident at the Chernobyl nuclear power station is placing a heavy burden on the national budget despite the fact that such expenditure is currently in a state of enforced curtailment due to the crisis phenomena associated with transition.

By way of example, budgetary funds earmarked for the Chernobyl programme in 1991 represented 16.8 % of the overall budget, whereas by 1995 these funds had been reduced to 7.3 % and by 1997 to just 6.3 %.

Considering the global ramifications of the Chernobyl disaster and the fact that it occurred beyond the borders, and through no fault of, Belarus and that Belarus nevertheless took the brunt of the impact of the accident and is, moreover, a small state with a stagnant economy, it can be stated that the government and the people of Belarus have a right to expect active support from the world community in overcoming the negative after-effects of what was, after all, the greatest nuclear disaster of the century.

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