OJSC "Kiev Scientific and Research
Design-and-Engineering Institute "ENERGOPROEKT"

Khmelnytska NPP

FEASIBILITY STUDY OF THE POWER UNITS 3,4 CONSTRUCTION

VOLUME 13

Environmental Impact Assessment Report (OVOS)

PART 14

Assessment of the transboundary transfer consequences under normal and emergency conditions

43-814.203.004.ОЭ.13.14.

Chief Engineer	Chernavskiy V.N.
Deputy Chief Engineer	Shenderovich V.Ya.
Chief Project Engineer	Bakhanovich A.L.

2011

	National University of Bioresources and Nature Management of Ukraine

Khmelnytska NPP

FEASIBILITY STUDY OF THE POWER UNITS 3,4 CONSTRUCTION

VOLUME 13

Environmental Impact Assessment Report (OVOS)

PART 14

Assessment of the transboundary transfer consequences under normal and emergency conditions

43-814.203.004.ОЭ.13.14.

Director of UkrNDISGR, Doctor of Biological Sciences	Kashparov V.A.
Research Supervisor, Candidate of Biological Sciences	Levchuk S.E.

2011

Khmelnytska NPP

FEASIBILITY STUDY OF THE POWER UNITS 3,4 CONSTRUCTION

VOLUME 13

Environmental Impact Assessment Report (OVOS)

PART 14

Assessment of the transboundary transfer consequences under normal and emergency conditions

43-814.203.004.ОЭ.13.14.

Approval Sheet

Technical Leader of the FS project	Vetchinkin S.O.
Chief Environmental Specialist	Paseschenko V.I.

Khmelnytska NPP

FEASIBILITY STUDY OF THE POWER UNITS 3,4 CONSTRUCTION

VOLUME 13

Environmental Impact Assessment Report (OVOS)

PART 14

Assessment of the transboundary transfer consequences under normal and emergency conditions

43-814.203.004.ОЭ.13.14.

Work Executors

Director of UkrNDISGR, Doctor of Biological Sciences	Kashparov V.A.
Head of the Laboratory of UkrNDISGR, Candidate of Biological Sciences	Yoschenko V.I.
Head of the Laboratory of UkrNDISGR, Candidate of Biological Sciences	Levchuk S.Ye.
Director of the Private Enterprise "Institute of Radioecology", Doctor of Physical and Mathematical Sciences	Garger Ye.K.
Leading Researcher of the Private Enterprise "Institute of Radioecology", Candidate of Physical and Mathematical Sciences	Talerko N.N.

Volume No.	Indication	Title	Remarks
1	43-814.203.004.ОЭ.01	Basic reference provisions	
2	43-814.203.004.ОЭ.02	Necessity and expediency of the power units 3,4construction. NPP capacity, unit capacity of power unit	
3	43-814.203.004.ОЭ.03	Provision of NPP with fuel, goods, water and other resources	
4	43-814.203.004.ОЭ.04	Confirmation on the applicability of the KNPP site for construction of power units 3,4 in line with the requirements of the effective normative documentation	
5	43-814.203.004.ОЭ.05	Configuration of power units 3,4 and NPP on the whole taking into account extension of power units 3,4	
6	43-814.203.004.ОЭ.06	General plan and transportation	
7	43-814.203.004.ОЭ.07	Principle technological decisions	
8	43-814.203.004.ОЭ.08	Assurance of nuclear and radiation safety	
9	43-814.203.004.ОЭ.09	Principle design and construction decisions	
10	43-814.203.004.ОЭ.10	Operation	
11	43-814.203.004.ОЭ.11	Decommissioning	
12	43-814.203.004.ОЭ.12	Quality assurance at all stages of the NPP service life	
13	43-814.203.004.ОЭ.13	Environmental Impact Assessment Report (OVOS)	
14	43-814.203.004.ОЭ.14	Organization of project management	
15	43-814.203.004.ОЭ.15	Basic provisions in organization of construction, construction period	
16	43-814.203.004.ОЭ.16	Basic decisions in preparation of the territory and protection of facilities from hazardous natural and/or anthropogenic factors	
17	43-814.203.004.ОЭ.17	Basic decisions in sanitary and consumer services	
18	43-814.203.004.ОЭ.18	Basic decisions in fire safety and labor safety	
19	43-814.203.004.ОЭ.19	Social aspects of the project implementation	
20	43-814.203.004.ОЭ.20	Estimates	
21	43-814.203.004.ОЭ.21	Substantiation of the economic efficiency of the NPP extension	
22	43-814.203.004.ОЭ.22	Engineering-and-economical performance	
23	43-814.203.004.ОЭ.23	Conclusions and suggestions	

Volume No.	Indication	Title	Remarks
1	43-814.203.004.ОЭ.13.01	Grounds for Environmental Impact Assessment Report (OVOS)	
2	43-814.203.004.ОЭ.13.02	Physical and geographical peculiarities of the area and of the power unit site location	
3	43-814.203.004.ОЭ.13.03	Power units general characteristics	
4	43-814.203.004.ОЭ.13.04	Climate and microclimate	
5	43-814.203.004.ОЭ.13.05	Air quality	
6	43-814.203.004.ОЭ.13.06	Geological environment of the radiation-control area, point, site and the NPP residential neighborhood	
7	43-814.203.004.ОЭ.13.07	Surface waters	
8	43-814.203.004.ОЭ.13.08	Underground waters	
9	43-814.203.004.ОЭ.13.09	Soils	
10	43-814.203.004.ОЭ.13.10	Flora and fauna, protected objects of the radiation-control area	
11	43-814.203.004.ОЭ.13.11	Forecast estimates of the radiation exposure on the agro-ecosystems and the population during normal operation and accidents	
12	43-814.203.004.ОЭ.13.12	Power unit social environmental impact assessment	
13	43-814.203.004.ОЭ.13.13	Power unit anthropogenic environmental impact assessment	
14	43-814.203.004.ОЭ.13.14	Assessment of the transboundary transition consequences under normal and emergency conditions	
15	43-814.203.004.ОЭ.13.15	Environmental impact assessment during power unit construction	
16	43-814.203.004.ОЭ.13.16	Comprehensive measures to ensure a normative condition of the environment and its safety	
17	43-814.203.004.ОЭ.13.17	Statement on the ecological consequences of power units operation	
18	43-814.203.004.ОЭ.13.18	Materials for public hearings and consultative referendum (OVOS summary)	

Table of content

Introduction

Part 14 of the volume 13 "Environmental Impact Assessment Report" (OVOS) is prepared in line with the requirements of the section 2.8, 2.26, 2.34 "Assessment of impacts of the planned activity on the anthropogenic environment" DBN (State Construction Norms) A.2.2-1-2003 [1] and in line with the international convention [2].

Part 14 contains:

- assessment of the transboundary transition of radioactive gas and aerosol releases of the plant during normal operation;
- assessment of the transboundary transition of radioactive releases during accidents at the plant.

Documents of this part are prepared according to the results of the modeling of the contaminant transfer in the air and calculation of individual radiation dose for the reference group of population.

Experience of the accident at Chernobyl NPP in 1986 showed that in the conditions of the communal radiation accident the radioactive materials in the air can spread hundreds and thousands kilometers away, resulting in the radioactive contamination of the air and the surface at a large distance away from the source of the emission.

In line with the Radiation Safety Norms of Ukraine - 97 (NRBU-97) [3], communal radiation accidents are divided into local, regional and global. To the special type of global radiation accidents belong transboundary accidents, when the accident zone spreads outside the state borders. Khmelnytska NPP (along with Rivne NPP) is located the closest to the state borders of Ukraine, and, consequently, is the biggest potential threat from the point of view of the radioactive contamination of the neighboring countries – above all Belorussia and Poland.

The objective of this Part is to assess the transboundary transfer of the radioactive release in case of radiation accident at KNPP. As a method to perform such assessments the mathematical modeling of the dispersion of gas and aerosol emissions during normal operation of the power plant and during accidents, assessment of the radiation doze on population with the use of the dimensional field of contamination was chosen.

1. TRANSBOUNDARY TRANSITION DURING NORMAL OPERATION OF KNPP

For the assessment of the radiological significance of the transboundary transfer during normal operation of the power plant it is suggested to use the results of the calculation of the dispersion of the gas and aerosol emissions for beyond-design basis norms of KNPP (see part 11), received within the frames of the Gaussian dispersion model [11]. These calculations are made taking into account the actual meteorological data in the area of the power unit location (frequency of the stability categories, average speeds of wind for these categories and the wind rose extent) with the actual reserve of persistence. As far as the distance from the source of releases, the contamination of the territory with radionuclide decreases rapidly, which leads to the reduction of the radiation doze for population (figure 1.1). Besides, even in the sanitary-protection zone the radiation dose does not exceed the limits of the radiation doze for population. It means that even if the plant is located directly on the border, in this case the limit quota of the radiation doze for population of the neighboring countries will not be exceeded (for most European countries it is higher, than for Ukraine and makes 200 microsievert per hour $^{-1}$)

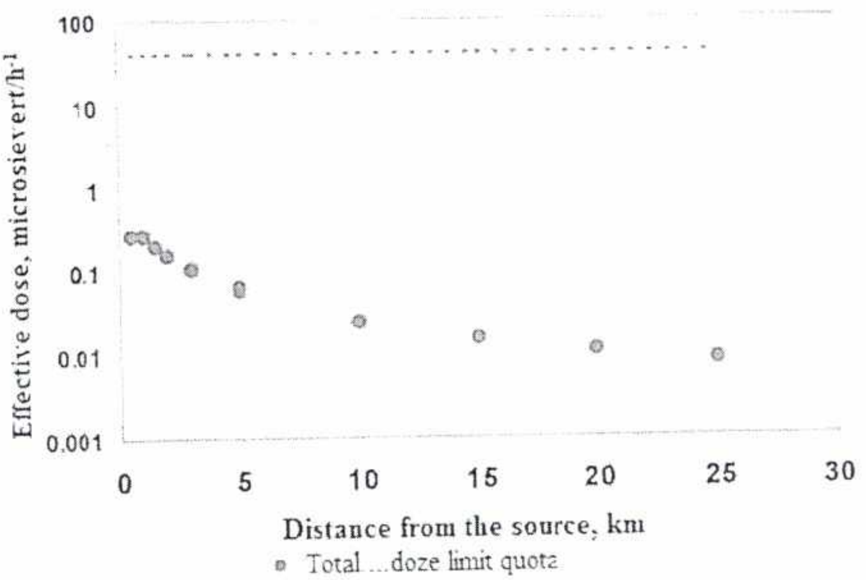


Figure 1.1– **Dependence of the radiation doze for the reference group of population on gas and aerosol releases from the source (normal operation)**

Radioactive contamination due to gas and aerosol releases at long distances outside the radiation-control area of KNPP cannot exceed such at the border of the radiation-control area according to the following physical reasons:

- Gas and aerosol release occurs regularly and the impact of the short-term weather conditions, which are favorable for the transfer to long distances, is not significant in terms of average annual transfer;

- There is no reverse diffusion in nature (the process of the impurity dilution is irreversible as long as there is a concentration gradient);
- Activity of radionuclide decreases in course of time as the result of the radioactive decay. The closest borders of the neighboring countries are at about 150 km distance from KNPP and by the wind speed of 3 m/sec^{-1} and its linear trajectory (which is never the case in the nature), the time for the cloud to approach the border makes around 14 hours. During this time the activity of the radionuclide with the period of the half-decay of 1,4 hour will reduce in 1000 times;
- During the movement of the radioactive cloud its depletion due to gravitational settling of radionuclide and wash-out whereof through precipitation.

Taking into account the above stated one can assert that the radiation impact during normal operation of KNPP on the neighboring countries will be significantly less than the established doze quotas, and consequently less than the limit of the individual effective annual doze of 1 microsievert.

2. TRANSBOUDARY TRANSITION DURING ACCIDENTS

2.1 Substantiation of the choice of the mathematical model of the radionuclide spread in the air

Mathematical models of the spread of accidental radionuclide release in the air can be classified according to two principle criteria [4]:

a) Spatial scale of the problem, which is defined by an accident class;

b) Detail of the description of physical processes of the nuclide transfer and the related level of complexity of the applied mathematical algorithms.

A wide range of approaches is used for the calculation of the spread of radioactive release in the air: from the simplest methods to calculate the trajectories of the radioactive cloud transfer, which enable evaluating the direction of the release spread and making a semi quantitative assessment of the impact [5], up to the calculations of numerical three-dimensional models of the turbulent diffusion [6].

In the nearest zone of the emission source (local scale), the assessments of the surface air and underlying surface contamination are carried out mainly with the help of the method of IAEA Gaussian jet [7]. Herewith it should be noted, that in the IAEA recommendations it is stated, that the model can be used at the distance up to 10 km from the source (depending on the relief complexity). The margins of its applicability are limited in distance, because the model assumes stationarity and horizontal homogeneity of meteorological conditions, stationarity of the emission source (continuous or finite duration), horizontal homogeneity of the underlying surface. The extension of the margins of the model applicability in this region (of the distances from 20 to 30 km) requires special additional researches, which would confirm such possibility, and validation with regulatory authorities. Thus, in case of big radiation accidents, potentially capable to lead to radioactive contamination of the territory beyond the NPP radiation-control area, the use of the IAEA model is not proper.

For the description of the distant transfer of the contamination (for distances of about thousand and more kilometers) mainly the simplified methods are use, with the use whereof one can get the averaged characteristics of the air contamination in the area.

In the area under study, the interim and the most complicated for the modeling are the processes of the contaminant diffusion at the distance of about hundreds and thousands kilometers, i.e. the space scales, where air-synoptic measurements are not carried out, but at the same time all special meteorological phenomena can be observed.

This is related to the fact that the mesogrid model shall take into account the diurnal variation of turbulence in the boundary layer, orographic and thermal heterogeneity of the underlying surface etc. Its peculiarity is, on one hand, the necessity to have a detailed and proper description of the main physical processes, which define the spread and deposition of the contaminant in such areas; and on the other hand the necessity to achieve a reasonable compromise with computational capabilities.

Taking into account, that KNPP is located at the distance of 160 km from the border with Belorussia and of about 190 km from the border with Poland, for the solution of the transboundary transfer of the radioactive release from KNPP the most optimal is the choice of the mesogrid model of the atmospheric transfer. Thus, the relative assessments were carried out, using the mesogrid model of the Lagrangian-Eulerian diffusion model (LEDI) of the contaminant transfer in the atmosphere [8]. The model was developed for calculations of the contaminant transfer to the distances up to 1000 km from the gas and aerosol "point" source with the effective altitude of the emission from 0 to 1500 m. The model was used for the reconstruction of the dynamics of the radioactive contamination with radionuclide ^{137}Cs [9] and ^{131}I [10] of the territory of Ukraine in the initial period after the Chernobyl accident.

The model takes into account the following information:

- Nonstationarity (as the result of the diurnal way of characteristics of the boundary layer and weather changes);
- Spatial inhomogeneity of the meteorological characteristics of the atmosphere;
- Different types of the source according to the duration of emission (volley, of the limited period, continuous), according to the phase composition (gas, aerosol), according to the isotopic composition;
- Horizontal inhomogeneity of the underlying surface.

The source of emission into the air is modeled in the form of the sequence of emissions ("puffs"), taking into account the variability of the substance quantity or activity in them. The combination of the Lagrangian and Eulerian methods is used for the description of the contaminant transfer in the boundary layer. Such approach allows with relatively small investment of time for computer calculations to physically correctly take into account main factors, which define the contaminant transfer. The three-dimensional task of calculation of the contaminant transfer in the atmosphere boundary layer is divided into three stages:

- Calculations of the horizontal trajectory of the contaminant spread based on the Lagrangian method of the particle;
- Calculations of the vertical profile of the contaminant concentration in the nodes of the horizontal trajectory, carried out with the help of the one-dimensional semi empirical equation of the turbulent diffusion;
- Distribution of the contaminant in the cross direction is considered normal with the dispersion, parameterized as a function, which appears as a sum of contributions of the horizontal turbulent diffusion and the expansion of the contaminant jet taking into account the interaction of the wind turn with the turbulence in the boundary layer.

The model enables calculating the transfer and the deposition of the radioactive contaminant for the horizontal underlying surface as well as in the conditions of heterogeneity of the underlying surface, in particular taking into account the moderately broken ground relief and heterogeneous plant cover on it.

The model calculates the dependence of the immediate concentration of the contaminant in the air on the time, time-integrated concentration in the air and the density of the contaminant deposition on the underlying surface during the radioactive cloud or trail passing above the given point.

2.2 Choice of typical meteorological scenarios of radioactive emission transfer in the air

Meteorological conditions of the emission transfer in the air play a decisive role in the formation of the fields of radioactive contamination of the air and of the underlying surface. Since for this task the period for the emission from KNPP to reach the borders with Poland and Belorussia is about half a day, then for such periods of time the temporal dynamics of the meteorological parameters play an important role, conditioned by the diurnal characteristics of the atmosphere boundary layer as well as by the change of the weather of the synoptic scale. Thus, the most reasonable approach to the choice of the meteorological scenarios of the radioactive emission transfer in the air is not the design of the artificial "extremely conservative" scenarios (for example, a fortiori unrealistic assumption about the wind permanency during the whole period of the transfer), but the use of the realistic data of the atmosphere characteristics measurement. Taking into account that for the modeling of the transfer to mesoscale distances the information on the atmosphere characteristics in the layer to the altitude of 2 to 3 km is required, the data of the radio sounding of the atmosphere was used, carried out by the Hydro-Meteorological Service of Ukraine. Three typical meteorological situations were chosen, where there may be an intensive transboundary activity carry-over in the direction of Poland and Belorussia.

Meteorological scenario 1. The data of the atmosphere radio sounding was used (vertical profiles of the wind speed and direction, as well as the temperature of the air in the layer up to 3 km), which were carried out on 10-12 of February 1984 by the nearest upper-air station in the town Shepetovka (located at the distance of 35 km, south-east from KNPP). At that time the east wind was observed with the speed from 5 to 6 m/sec^{-1} at the altitude of 1km, conditioned by the periphery of the southern cyclone. In this scenario there are no atmospheric precipitations on the whole territory of the emission spread.

Meteorological scenario 1A. The same actual data of the atmosphere radio sounding was used like in the scenario 1. However in this scenario the availability of precipitations (snow) with the intensity 0.5 mm/h is assumed. The precipitations of such intensity were in fact observed in the specified period at several meteorological stations of the area under review. For this meteorological scenario the assumption was made, that the area of the atmospheric precipitations of such intensity exists on the territory of Belorussia directly behind the border with Ukraine in the period of passing of the radioactive release from KNPP there, i.e. in the period, when the activity reach the territory of Belorussia. Such meteorological scenario was chosen, taking into account significant contribution of the radioactivity washout from the atmosphere by atmospheric precipitations and, respectively, their role in the formation of the density field of the radioactive fallouts. In this scenario the atmospheric precipitations are absent on the whole territory of Ukraine, which ensures the highest density value of precipitations on the territory of Belorussia under the given scenario of the emission.

Meteorological scenario 2. The data of the atmosphere radio sounding of 26-27th of November 1982 was used. The weather conditions were formed, influenced by the anticyclone with the center in the east, which conditioned the southern wind with the speed 3-5 m/sec^{-1} close to the ground surface and 7-9 m/sec^{-1} at the altitude 1 km. Atmospheric precipitations are absent on the whole territory of the emission spread.

Meteorological scenario 2a. The same data of the atmosphere radio sounding was used like in the scenario 2. Herewith it was assumed that in that period when the radioactive emission reached the territory of Poland, it would start snowing with the intensity of 0,5 mm/h.

Meteorological scenario 3. As opposed to the previous scenarios, typical for a cold season, meteorological scenario 3 characterizes weather conditions with the high turbulence in the daytime atmosphere boundary layer (data of the radio sounding of the atmosphere during May 6-9, 1986). East light wind (from 2 to 5 m/sec^{-1} in the layer up to 1 km) during the spread of the hypothetical release changes to south-eastern and then to north-eastern. Atmospheric precipitations are absent on the whole territory of the release spread.

Meteorological scenario 3A. The same data of the atmosphere radio sounding was used like in the scenario 3. Herewith it was assumed that in that period when the radioactive release reached the territory of Poland, it would start raining with the intensity of 0,5 mm/h. The duration of rainfall was assumed to be equal to 4 hours.

2.3 Methodology of assessment of radiation doze for population

The assessment of individual radiation dozes for population is an important part of the radiation protection system. Information on the dozes is the criteria for decisions making on performing certain protective measures. In the report the annual individual effective dozes are evaluated, received in different ways: inhalation, radiation from a radioactive cloud, radiation from radionuclides, deposited on the ground and radiation from radionuclides, coming with food. As a reference group of population, rural residents were chosen which consume mainly food of their own production (farmers). The assessment of the doze was made for two age groups – adults and 1-2 year old children. Calculations were made using the set of application programs RadEnvir3.1, which was developed jointly by IAEA and Scientific and Research Institute of the radiation protection of the Academy of Technical Science of Ukraine. During calculations the approaches were used, contained in the works [11, 12]. The radionuclide entry into the human body was estimated using the average daily ration of inhabitants of Poland [16] and Belorussia [17]. The children's ration was received using recommendations, contained in the direction [12]. Only the food was used, which give the maximum contribution to the dose. The ration is given below in the table 2.1

Food	Poland (2007)		Belorussia (2005)	
	Adults, kg/year^{-1}	Children (1-2 y.o.) kg/year^{-1}	Adults, kg/year^{-1}	Children (1-2 y.o.) kg/year^{-1}
Milk	73[1]	95	192[2]	250
Potato	121	36	182	55
Veal	4	0,8	21	4,2
Pork	43,6	4,4	26	2,6
Poltry	24	2,4	13	1,3

In the report the assessments of the radioactivity transfer were made for the actual meteorological conditions. Meteorological conditions according to the scenarios 1 and 2 happened in winter time. Since in this time agricultural products are not produced on lands, radionuclide may enter into the population ration only in the next vegetation period, at that radionuclide will enter the plants through roots. Radionuclide entry through roots is in itself a kind of additional barrier for the radionuclide to get into the ration of the population. So, from the point of view of the radiological safety, these scenarios are favorable. The third scenario is implemented in the spring time, and the radionuclide will penetrate the agricultural products mostly through external aerial contamination of plants during fallouts. These peculiarities were taken into account during calculation of the radiation dose for the selected reference group of population.

During calculation of the radiation dose due to radionuclides, which penetrated the body with the food, it was conservatively assumed that the contamination occurs at the beginning of the harvest and the food is consumed immediately. During calculation of the radiation dose due to inhalation, radiation from the radioactive cloud and the ground surface, the period of stay of the reference group members in a premise was conservatively not assumed, but instead it was considered, that they had been staying for 24 hours in the open air.

2.4 Radiation Contamination Assessment Criteria

The basic criteria of the radiation limitation of the population in Europe through anthropogenic sources is the limit of the individual effective dose (all ways of radiation), established [14] at the level of 1 microsievert per hour $^{-1}$. It coincides with the dose limit for population in Ukraine. There are also acceptable annual levels of radionuclide penetration into the human body in different ways (air, water, food). They are derivatives from the dose limit.

In this report the annual individual effective doses are assessed and they will be the main safety criteria of the population during accidents.

2.5 Results of modeling of the transfer of the emergency emissions at KNPP

With the use of the LEDI model calculations were made of the atmosphere transfer of the possible transboundary emergency radioactive emission in case of hypothetical accident at KNPP for typical meteorological conditions. The period of the emission was conservatively accepted equal to 1 hour for all accidents. By the longer duration of the emission the dispersion of the contaminant and the time to achieve the detection point will be bigger, and respectively the radioactive contamination of the territory and radiation doses will be smaller.

For further calculations the following scenarios of the typical accidents at one of the KNPP power units were selected:

- Maximum Design-Basis Accident (MDBA) with the double-sided rupture of the Main Circulation Pipe (MCP);
- Beyond Design-Basis Accident (BDBA), caused by the guillotine rupture of the Main Circulation Circuit (MCC) with the failure of the active Emergency Core Cooling Systems (ECCS) and of the operable sprinkler system.

The reference data on radionuclide activity in the emission were chosen in accordance with the document [13].

2.5.1 Maximum Design-Basis Accident

By the Maximum Design-Basis Accident (MDBA) the source of the radioactive release is the leak through the containment. The effective height of the release was taken as 0 m.

The duration of the emission was conservatively assumed equal to 1 hour.

The values of the activity of the released radionuclides, which were used in the calculations, are given in the table 2.2. Radionuclides with short periods of half-decay were not taken into account in the calculations. Their contribution into the total dose is negligible, because the transfer to larger distances is long enough for their decay.

Table 2.2. **Full release of radionuclides during the accident with the double-sided rupture of MCP**

Nuclide	Release, Bq	Release for different iodine compounds, Bq	
		I^2	methyl iodide
^{131}I	-	$1,89 \cdot 10^{11}$	$8,68 \cdot 10^{11}$
^{132}I	-	$1,55 \cdot 10^{11}$	$5,09 \cdot 10^{11}$
^{133}I	-	$1,53 \cdot 10^{11}$	$6,78 \cdot 10^{11}$
^{135}I	-	$6,1 \cdot 10^{10}$	$2,49 \cdot 10^{11}$
^{85m}Kr	$3,11 \cdot 10^{11}$		
^{85}Kr	$2,77 \cdot 10^{11}$		
^{88}Kr	$7,80 \cdot 10^{11}$		
^{133}Xe	$2,22 \cdot 10^{13}$		
^{135}Xe	$8,46 \cdot 10^{11}$		
^{90}Sr	$1,85 \cdot 10^{10}$		
^{95}Zr	$4,26 \cdot 10^{11}$		
^{95}Nb	$7,39 \cdot 10^{11}$		
^{103}Ru	$1,52 \cdot 10^{11}$		
^{106}Ru	$1,63 \cdot 10^{10}$		
^{134}Cs	$3,69 \cdot 10^{10}$		
^{137}Cs	$2,29 \cdot 10^{10}$		
^{140}Ba	$1,86 \cdot 10^{11}$		
^{140}La	$2,53 \cdot 10^{11}$		
^{144}Ce	$2,44 \cdot 10^{11}$		

Figure 2.1 depicts the isolines of the density field of the release ^{131}I during the maximum design-basis accident at KNPP for the meteorological scenario 1. Maximum levels of density of the fallouts for this radionuclide on the territory of Belorussia will make about 13 $Bq \cdot m^{-2}$ The asterisk in the figure marks the point, for which the values of the time integral of the radionuclides volume activity, radioactive fallouts density were given in the report and individual effective doses were evaluated. The total individual radiation doses for the reference groups of population in this point (table A.1) by the conservative approach makes for adults 0,13 microsievert per hour $^{-1}$ and for children – 0,12 microsievert per hour $^{-1}$.

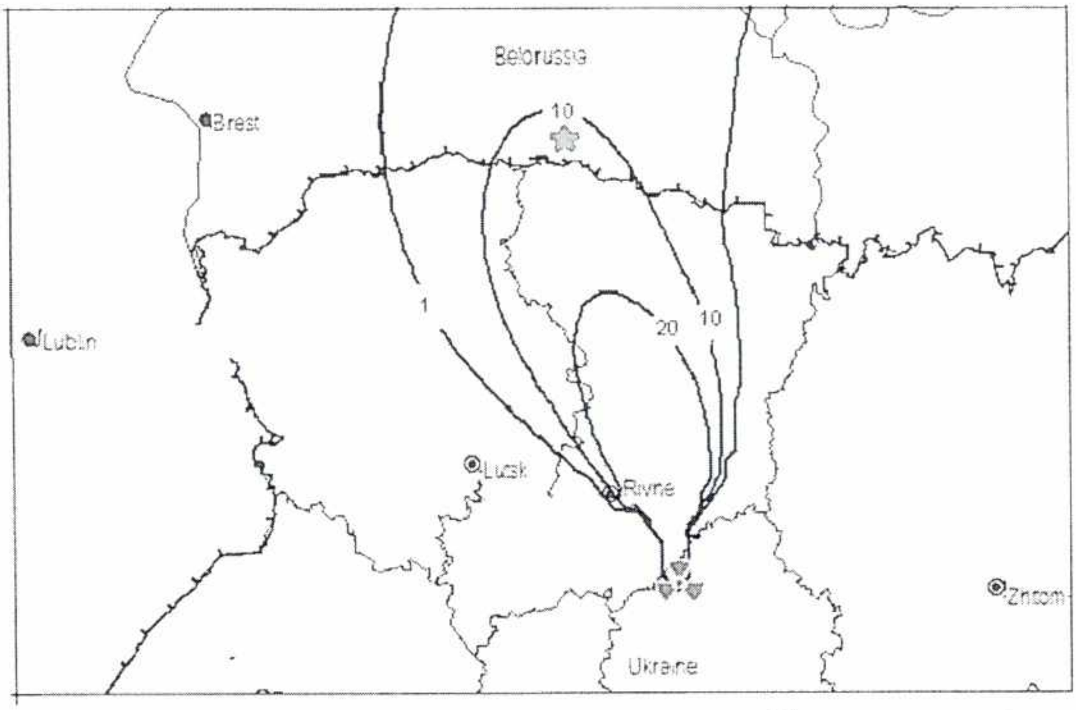


Figure 2.1 – **Isolines of the density field of the fallouts ^{131}I (Bq·m-2) under maximum design-basis accident at KNPP (meteorological scenario 1)**

For the chosen meteorological scenario 1 the period of time when the emission from KNPP will reach the border between Ukraine and Belorussia equals approximately 9.5 hours. According to the calculations, about 45% of the initial release is carried out to Belorussia (taking into account its precipitation on the territory of Ukraine and the radioactive decay). For long-living nuclides in the aerosol form (here and hereafter: all radionuclides under review, except for isotopes of iodine and inert gases), the relative transboundary carryover makes more than 80%.

During precipitations on the territory of Belorussia (figure 2.2) the density of the radionuclide fallouts will significantly increase and it will lead to the increase of the radiation doses for population. The calculated values of the density of the radioactive fallouts increase for isotopes of iodine more than in 4 times and significantly for radionuclides in the aerosol form. The assessed effective doses (figure A.2) will make for adults and children 0,65 microsivert per hour $^{-1}$.

The figure 2.3 shows the isolines of the density field of the fallouts 131I under MDBA at KNPP for the meteorological scenario 2. Maximum levels of density of the fallouts for this radionuclide on the territory of Poland will make about 3 Bq· m^{-2} In the point of the detection the calculated values of the individual effective doses (table A.3) will make about 0,04 microsivert per hour $^{-1}$ for both age groups.

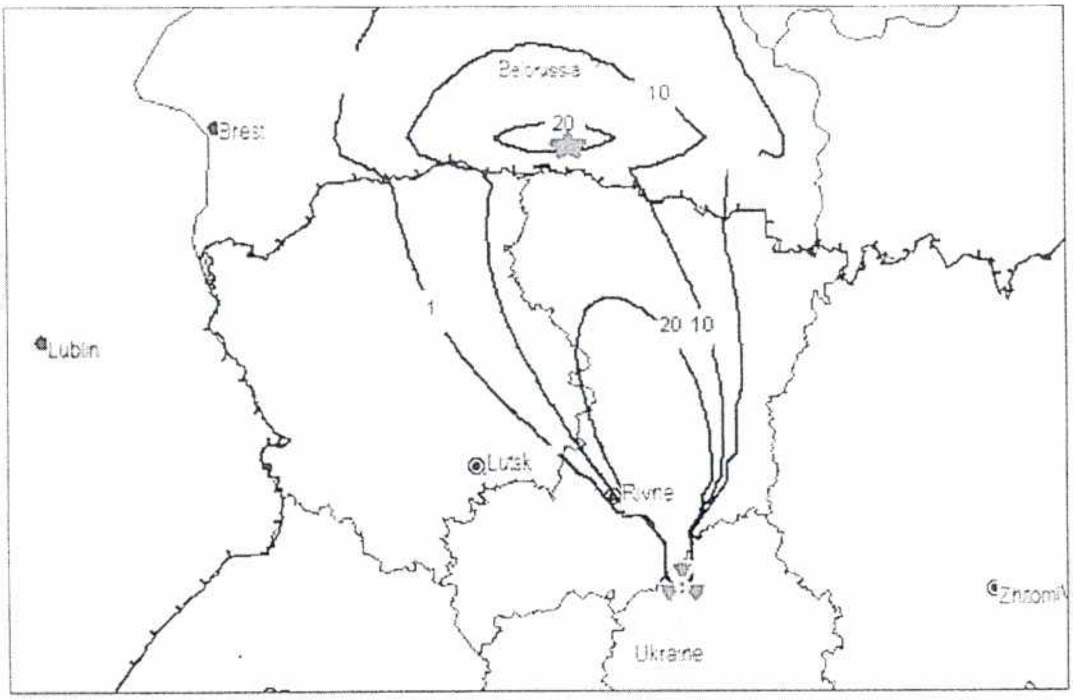


Figure 2.2 – **Isolines of the density field of the fallouts ^{131}I (Bq·m-2) under MDBA at KNPP (meteorological scenario 1A)**

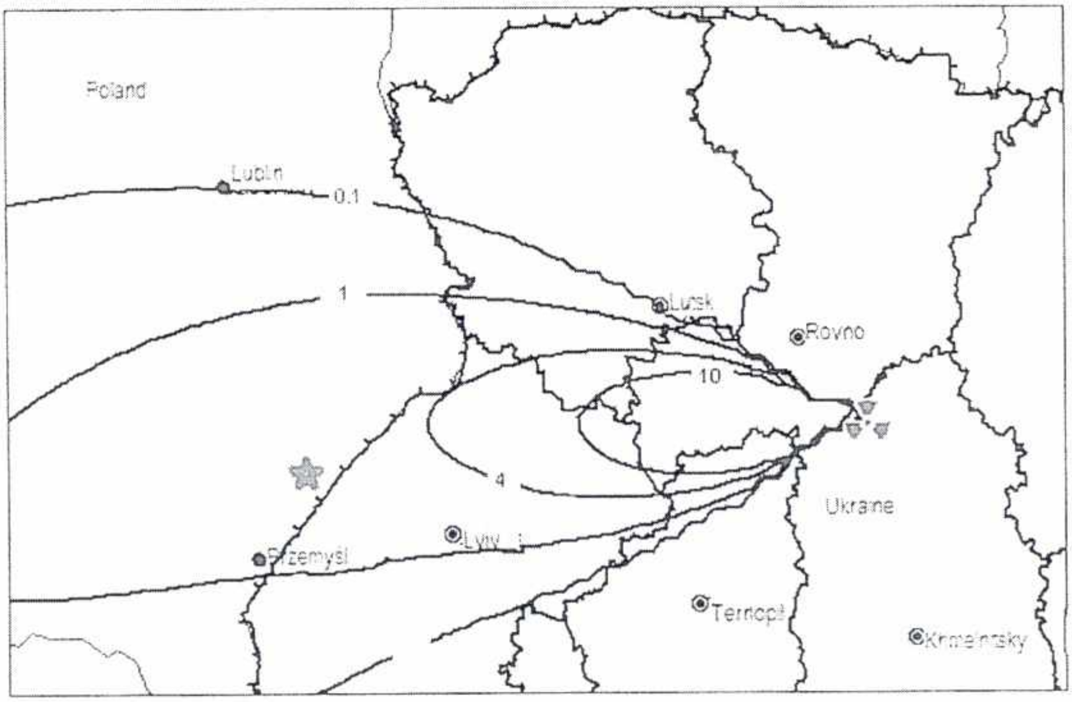


Figure 2.3 – **Isolines of the density field of the fallouts ^{131}I (Bq·m-2) under MDBA at KNPP (meteorological scenario 2)**

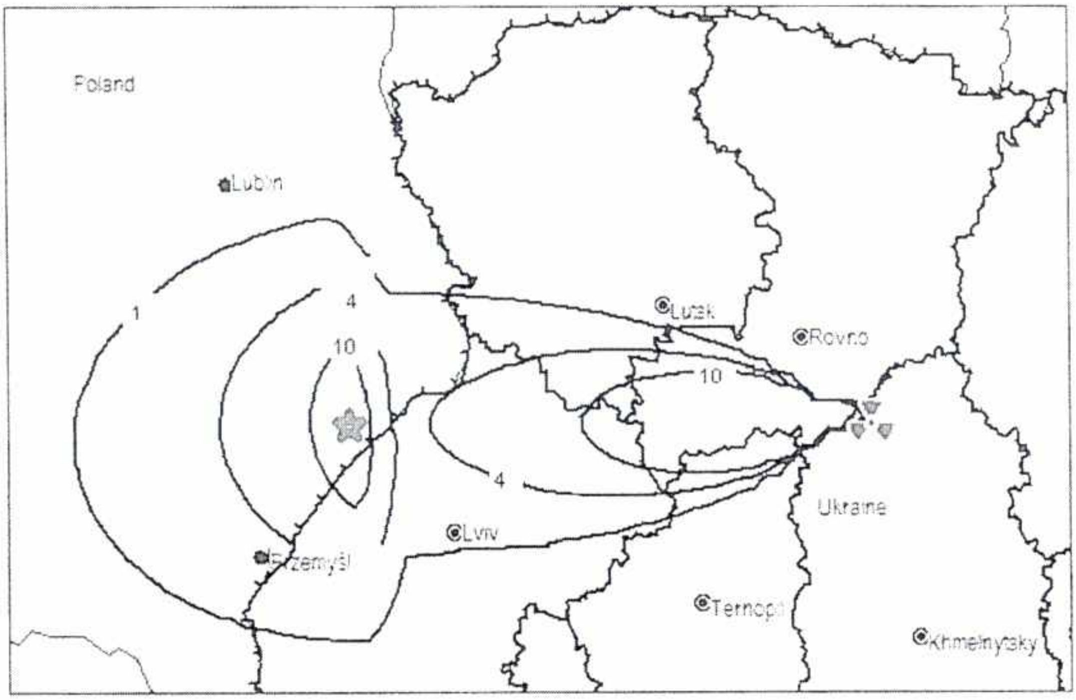


Figure 2.4 – **Isolines of the density field of the fallouts ^{131}I (Bq·m-2) under MDBA at KNPP (meteorological scenario 2A)**

For the meteorological scenario 2 the period of time for the emission from KNPP to reach the borders between Ukraine and Poland equals approximately 7,5 hours. According to the calculations, about 50 % of the initial release of ^{131}I, nearly 5% of ^{132}I and more than 80% of the long-living nuclides in the aerosol form are carried out to Poland.

In case of snowfall on the territory of Poland during radioactivity passing (figure 2.4) the density of the radionuclide fallout will increase, and respectively the radiation doses for the population will increase too (table A.4). The individual doses for adults and children will make 0,3 microsivert per hour $^{-1}$. Calculated values of the fallouts density increase for iodine in more than 5 times and in almost 15 times for radionuclides in the aerosol form.

Figure 2.5 shows the isolines of the density field of the fallouts ^{131}I under the maximum design-basis accident at KNPP for the meteorological scenario 3. The maximum levels of the fallout density for this radionuclide on the territory of Poland will make about 2 Bq·m^{-2}. In the point of the detection the calculated values of the individual effective doses will make about 0,18 microsivert per hour $^{-1}$ for adults and 0,43 microsivert per hour $^{-1}$ for children (table A.5). The difference of the radiation doses from the previous scenarios lies in the time of the fallouts and respectively in the different approach to the calculation of doses through dietary pathways of the radionuclides penetration (see Section 2.3).

For the meteorological scenario 3 the period of time for the emission from KNPP to reach the borders between Ukraine and Poland equals approximately 17,5 hours. According to the calculations, about 30 % of the initial release of ^{131}I (is mostly defined by a high speed of the dry deposition of iodine in the elementary form), less than 2% of ^{132}I and more than 90% of the long-living nuclides in the aerosol form are carried out to Poland.

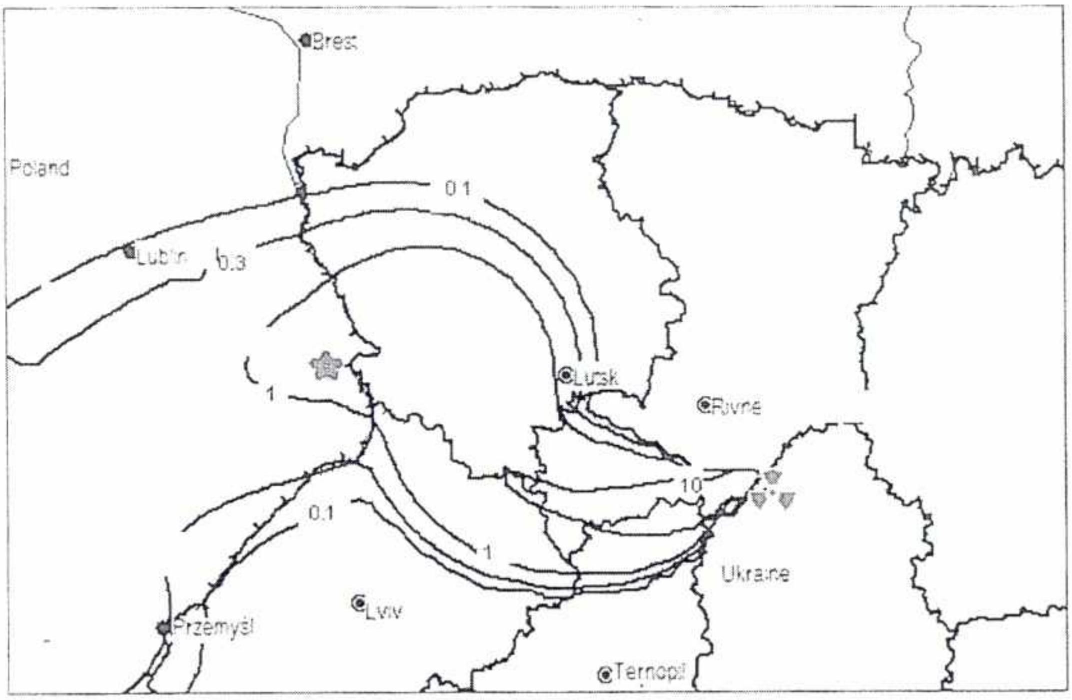


Figure 2.5 – **Isolines of the density field of the fallouts ^{131}I (Bq·m-2) under MDBA at KNPP (meteorological scenario 3)**

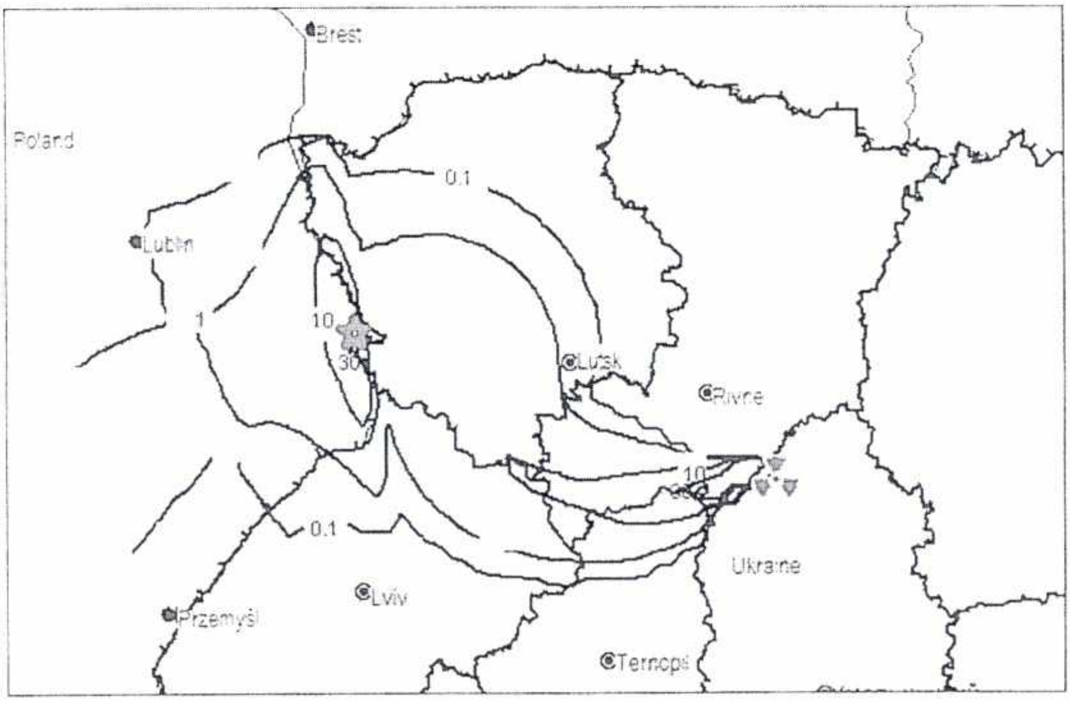


Figure 2.6 – **Isolines of the density field of the fallouts ^{131}I (Bq·m-2) under MDBA at KNPP (meteorological scenario 3A)**

Table A 6 shows the calculated values of the density of radioactive emissions, time integral of the volumetric activity in the surface air and radiation doses for the reference group of population at the border of Ukraine and Poland (in the center of the trail) for the meteorological scenario 3A. In case of rainfall on the territory of Poland during radioactivity passing (figure 2.4) the calculated values of fallouts increase in almost 30 times for isotopes of iodine and in almost 140 times for radionuclides in the aerosol form (figure 2.6). In the point of the detection the calculated values of the individual effective doses will make 16,9 microsivert per hour $^{-1}$ for adults and 29,1 microsivert per hour $^{-1}$ for children (table A.6).

2.5.2 Beyond Design-Basis Accident (BDBA)

The beyond design-basis accident is studied, caused by the guillotine-type rupture of the MCC Du 2x850 mm with the failure of the active ECCS and of the operable sprinkler system.

Considering that the period of the transfer to the border with the neighboring countries makes (under the chosen meteorological scenarios) from 7,5 up to 17,5 hours, the radionuclides with a small period of half-decay, presented in the table 2.3, were not taken into account. For this accident, the radionuclide release power is different from the above ones. The calculation of the dispersion was made under the same conditions and the assessments were carried out from the same point, as for the MDBA. The results of the calculations are presented in the annex A (tables A7-12).

By the BDBA for the meteorological scenario 1 the maximum density levels of the fallouts of ^{131}I on the territory of Belorussia will make about 120 Bq·m^2. The total individual radiation doses of the reference groups of population in this point (table A.7) will make 2,6 microsivert per hour $^{-1}$ for adults and 3,9 microsivert per hour $^{-1}$ for children.

By precipitations on the territory of Belorussia the density of the radionuclide fallouts will increase significantly and it will result in the increase of the radiation doses for the population. The calculated values of the density of the radioactive fallouts increase in more than 30 times for isotopes of iodine and significantly for radionuclides in the aerosol form. The evaluated effective doses (table A.8) will make 7,5 microsivert per hour $^{-1}$ for adults and 8,7 microsivert per hour $^{-1}$ for children.

For the meteorological scenario 2 the maximum density levels of fallouts of iodine-131 on the territory of Poland will make around 300 Bq·m^2. In the detection point the calculated values of the individual effective doses will make 0,8 microsivert per hour $^{-1}$ for adults and 1,2 microsivert per hour $^{-1}$ for children (table A.9).

In case of snowfall on the territory of Poland during radioactivity passing the density of the radionuclide fallout will increase, and respectively the radiation doses for the population will increase too (table A.10). The individual doses for both groups will make around 3 microsivert per hour $^{-1}$. Calculated values of the fallout density increase for iodine in more than 5 times and in almost 15 times for radionuclides in the aerosol form.

The maximum density levels of fallouts of ^{131}I for the meteorological scenario 3 on the territory of Poland will make around 160 $Bq{\cdot}m^2$. In the detection point the calculated values of the individual effective doses will make 5,8 microsivert per hour $^{-1}$ for adults and 25.6 microsivert per hour $^{-1}$ for children (table A.11).

Table A 12 shows the calculated values of the density of radioactive releasde, time integral of the volumetric activity in the surface air and radiation doses for the reference group of population at the border of Ukraine and Poland (in the center of the trail) for the meteorological scenario 3A. In case of rainfall on the territory of Poland during radioactivity passing the calculated values of fallouts increase in almost 30 times for isotopes of iodine and in almost 130 times for radionuclides in the aerosol form (figure 2.6). In the point of the detection the calculated values of the individual effective doses will make 177 microsivert per hour $^{-1}$ for adults and 683 microsivert per hour $^{-1}$ for children (table A.12).

Table 2.3 **Full emission of radionuclides under BDBA, which were taken into account when studying the transboundary transfer**

Nuclide	Emission, Bq	Emission for different iodine compounds, Bq	
		I^2	methyl iodide
^{131}I	-	$1,805\cdot10^{13}$	$6,987\cdot10^{13}$
^{132}I	-	$2,219\cdot10^{13}$	$5,391\cdot10^{13}$
^{133}I	-	$4,393\cdot10^{13}$	$1,613\cdot10^{14}$
^{135}I	-	$1,027\cdot10^{13}$	$3,66\cdot10^{13}$
^{85m}Kr	$1,92\cdot10^{14}$		
^{85}Kr	$1,17\cdot10^{13}$		
^{133}Xe	$2,18\cdot10^{15}$		
^{135}Xe	$4,67\cdot10^{14}$		
^{90}Sr	$4,09\cdot10^{10}$		
^{95}Zr	$2,60\cdot10^{10}$		
^{95}Nb	$8,88\cdot10^{10}$		
^{103}Ru	$8,13\cdot10^{11}$		
^{106}Ru	$8,04\cdot10^{10}$		
^{134}Cs	$7,21\cdot10^{11}$		
^{137}Cs	$4,48\cdot10^{11}$		
^{140}Ba	$8,74\cdot10^{11}$		
^{144}Ce	$6,12\cdot10^{11}$		

2.6 Assessment of accidents consequences on the territory of the neighboring countries

Made calculations showed that under no studied accident the level of the individual annual effective dose for the members of the reference group in the neighboring countries will be exceeded. (figure 2.8). The children's age group (1-2 years) remains critical. The critical scenario is the scenario 3A, according to which the fallouts happen during vegetation of plants. For this meteorological scenario the main way of the dose formation (for all studied accidents) is the food chain (figure 2.7). About 99% of the dose is formed according to it. The main dose-forming radionuclide for all scenarios is ^{131}I.

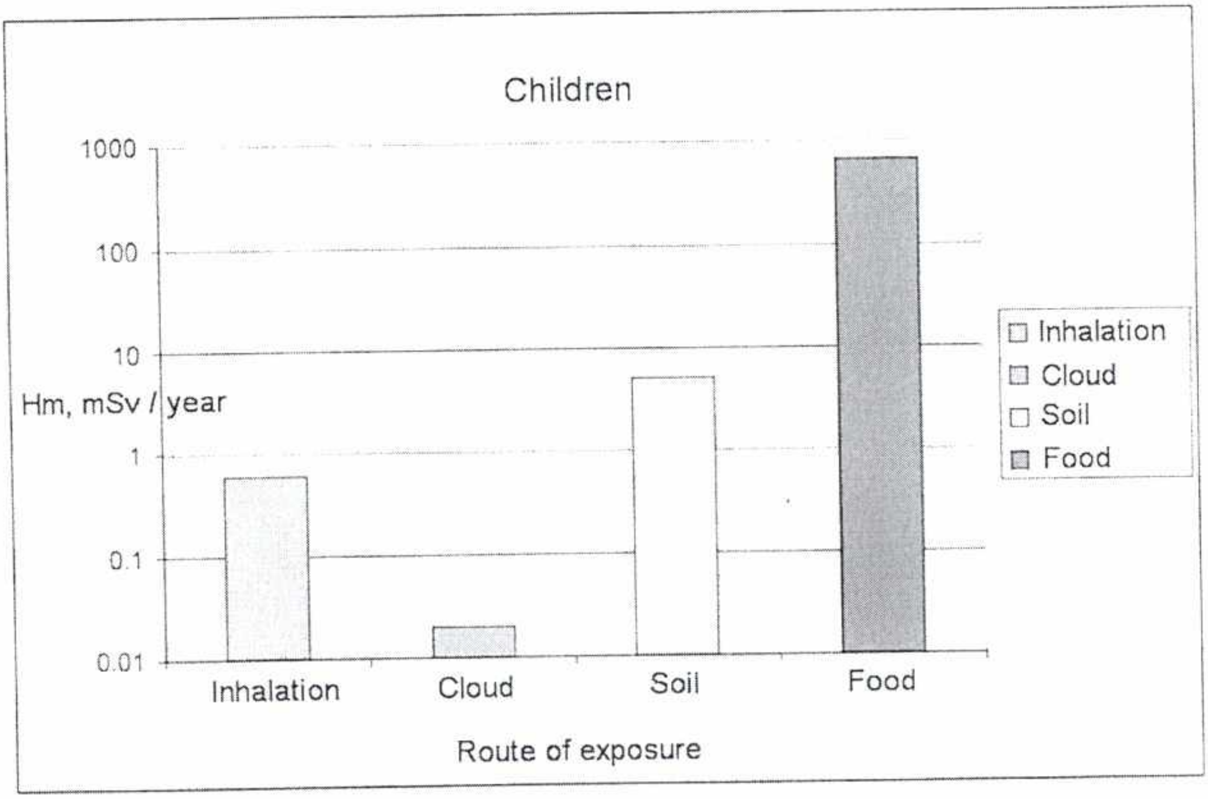
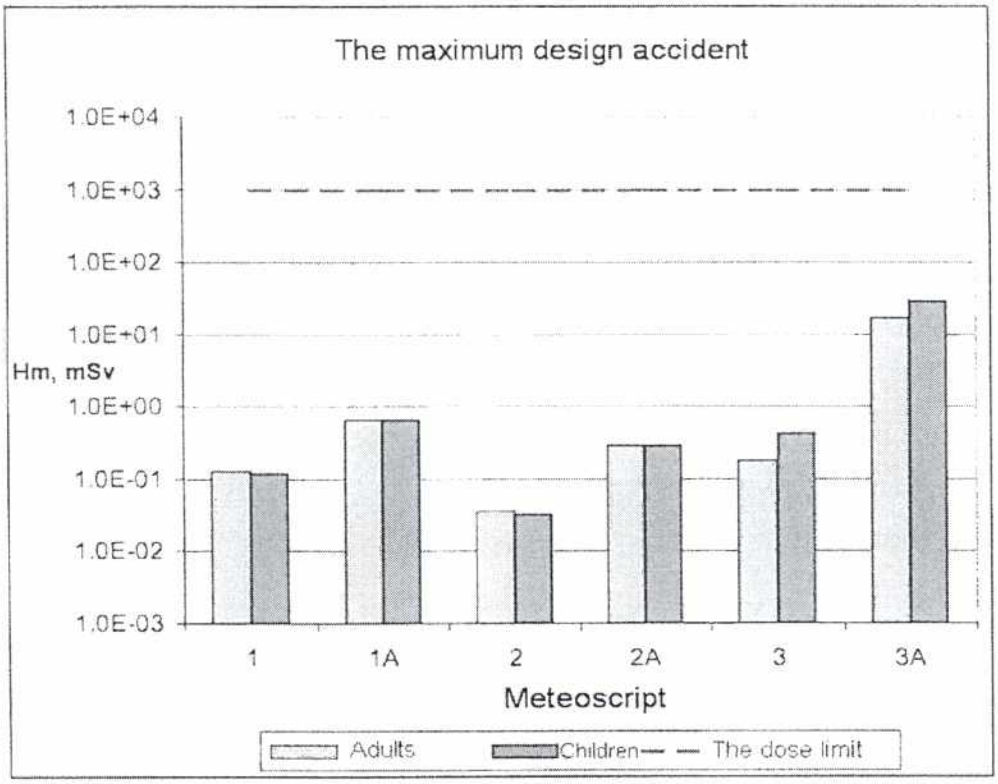


Figure 2.7– **Structure of the annual effective dose formation for the children's age group for the meteorological scenario 3A (BDBA)**



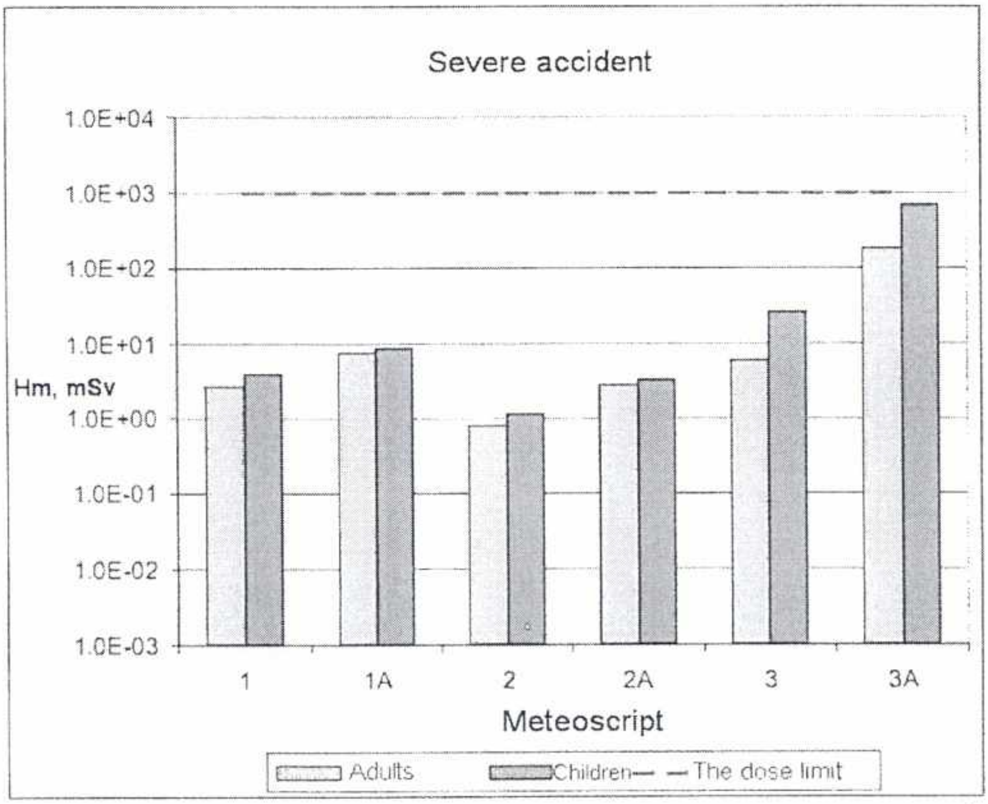


Figure 2.8– **Effective annual individual doses of Nt (microsivert per hour $^{-1}$) for the reference groups of population under different accidents and meteorological scenarios. The doses are received for points on the trail axis next to the borders of the neighboring countries.**

Conclusions

1. The performed analysis showed that the radiation impact of the gas and aerosol emissions of KNPP under its normal operation on the neighboring countries will be significantly lower than the established dose limits for the population due to the operation of nuclear facilities in the neighboring countries [15] (this limitation varies for different countries mainly in the range of 02,-0,3 microsivert per hour $^{-1}$). At the distance of 25 km away from the plant the annual effective dose according to all ways of formation for the reference group of population (rural population) makes $4{,}4 \cdot 10^{-2}$ microsivert per hour ˉ1.
2. The basic criteria of the radiation limitation of the population in Europe through anthropogenic sources is the limit of an individual effective dose (all ways of radiation), which is established [14] at the level of 1 microsivert per hour $^{-1}$. Calculations, made with the help of the mesogrid model of the atmospheric transfer LEDI, showed that under no studied accident the level of the individual annual effective dose [14] for the members of the reference group in the neighboring countries will be exceeded.
3. The children's age group (1-2 years) remains critical. The critical meteorological scenario is scenario 3A, according to which the fallouts happen during vegetation of plants. For this meteorological scenario the main way of the dose formation (for all studied accidents) is the food chain. About 99% of the dose is formed according to it.
4. The main dose-forming radionuclide under hypothetical accidents for all studied meteorological scenarios is ^{131}I.

Acronyms

IAEA - International Atomic Energy Agency
BDBA - Beyond Design-Basis Accident
DBN - State Construction Norms
ECCS - Emergency Core Cooling Systems
KNPP - Khmelnytska Nuclear Power Plant
MCC - Main Circulation Circuit
MCP - Main Circulation Pipe
MDBA - Maximum Design-Basis Accident
NPP - Nuclear Power Plant
OVOS - Environmental Impact Assessment Report

Reference Standard Documents and Literature

1. DBN A.2.2-1-2003 Composition and content of the materials of the Environmental Impact Assessment Report (OVOS) during design and construction of enterprises, buildings and facilities. State Committee for Construction and Architecture. Kyiv, 2004.
2. Convention on the environmental impact assessment in the transboundary context № 534-14 of 19.03.1999.
3. Radiation Safety Norms of Ukraine (NRBU-97). State Sanitary Norms (DGN). DGN 6.6.1. – 6.5.001-98. – K.: UTsGSEN, 1998. – 135 pages.
4. The utilization of real time models as a decision aid following large release of redionuclides into the atmosphere. IAEA-TECDOC-733. - Vienna: IAEA, 1994.
5. Orlov M.Yu., Snykov V.P., Khvalenskiy Yu.A., Volokitin A.A. Soil contamination of the European part of the USSR territory by ^{131}I after the Chornobyl NPP accident. – 1996. - T. 80, Rev.6. – P. 466 - 471.
6. Haas H., Memmesheimer M., Geiss H. et al. Simulation of the Chernobyl radioactive cloud over Europe using the EURAD model // Atmospheric Environment. – 1990. – Vol. 24A. – P. 673 – 692.
7. Atmospheric dispersion in nuclear power plant siting: A safety guide, Safety series No. 7. 50 - SG-S3. -, Vienna: IAEA, 1980.
8. Talerko N.N., Garger Ye.K. Experience in testing of the atmospheric transport modeling LEDI based on the natural experiments and Chernobyl data. Institute for safety problems of the NPP National Academy of Sciences of Ukraine, Preprint 05-1 (2005).
9. Talerko N. Mesoscale modelling of radioactive contamination formation in Ukraine 9 caused by the Chernobyl accident // J. Environ. Radioactivity. – 2005. – Vol. 78, No. 3. – P. 311 - 329.
10. Talerko N. Reconstruction of ^{131}I radioactive contamination in Ukraine caused by the Chernobyl accident using atmospheric transport modeling // Journal of Environmental Radioactivity. – 2005 - Vol. 84. - P. 343 - 362.
11. Generic models for use in assessing the impact of discharges of radioactive substances to the environment Safety report series No. 19. International atomic energy agency, Vienna, 2001.
12. K.A.Jones, C. Walsh, A. Bexton, J. R. Simose, A.L. Jones, M. Harvey, A. Artmann, R. Martens, 2006. Gidance on the Assessment of Radiation Doses to Member of the Public due to the Operation of Nuclear Installations under Normal conditions HPA-RPD-019.
13. Knmelnytska NPP. Power units 3,4. Environmental Impact Assessment Report. Reference Data for the assessment of the radiological impact. 43-14.203.001.ИД.00.
14. Council Directive 96/29 EUROATOM of 13 May 1996.
15. REGULATORY CONTROL OF RADIOACTIVE DISCHARGES TO THE ENVIRONMENT. SAFETY STANDARDS SERIES No. WS-G-2.3 INTERNATIONAL ATOMIC ENERGY AGENCY VIENNA, 2000.
16. Statistical yearbook of agriculture and rural areas. 2008. Warsaw. ISSN 1895-121X. www.stat.gov.pl.
17. FAOSTAT 2010, 2005 Food Balance Sheets http://faostat.fao.org.

Annex A
(mandatory)

Results of calculations of the transboudary transfer of the radionuclides under accidents

Table A.1 – **Calculated values of the fallout density and of the time integral of the volumetric activity in the surface air and effective annual doses for the critical groups of population on the territory of Ukraine and Belorussia (in the center of trail) for the meteorological scenario 1. Maximum Design-Basis Accident**

Radionuclide	**A_s, Бк·м$^{-2}$**	**A_v, Бк·с·м$^{-3}$**	**H_a, microsivert per hour $^{-1}$**	**H_i, microsivert per hour $^{-1}$**
^{131}I	1,30E+01	8,03E+03	2,08E-02	3,07E-02
^{132}I	1,12E+00	5,18E+02	1,01E-04	1,10E-04
^{133}I	8,38E+00	5,00E+03	2,69E-03	4,69E-03
^{135}I	1,95E+00	1,08E+03	2,74E-04	3,62E-04
^{85m}Kr	0,00E+00	9,44E+02	7,06E-06	7,06E-06
^{85}Kr	0,00E+00	2,03E+01	8,38E-07	8,38E-07
^{88}Kr	0,00E+00	1,01E+03	1,03E-04	1,03E-04
^{133}Xe	0,00E+00	2,76E+05	4,31E-04	4,31E-04
^{135}Xe	0,00E+00	5.42E+03	6,45E-05	6,45E-05
^{103}Ru	1,32E+00	1,32E+03	3,88E-03	3,62E-03
^{106}Ru	1,43E-01	1,43E+02	1,60E-03	2,02E-03
^{134}Cs	3,24E-01	3.24E+02	1,43E-02	1,36E-02
^{137}Cs	2,01E-01	2,01E+02	4,15E-03	3,88E-03
^{144}Ce	2,14E+00	2,14E+03	2,14E-02	2,65E-03
^{90}Sr	1,62E-01	1,62E+02	3,15E-03	5,32E-03
^{95}Zr	3,72E+00	3,72E+03	2,70E-02	2,43E-02
^{95}Nb	6,43E+00	6,43E+03	2,43E-02	2,29E-02
^{140}Ba	1,60E+00	1,60E+03	3,27E-03	2,38E-03
^{140}La	1,88E+00	1,88E+03	1,62E-03	1,60E-03
Total			**1,29E-01**	**1,19E-01**

Table A.2 – **Calculated values of the fallout density and of the time integral of the volumetric activity in the surface air and effective annual doses for the critical groups of population on the territory of Ukraine and Belorussia (in the center of trail) for the meteorological scenario 1A. Maximum Design-Basis Accident**

Radionuclide	A_s, Бк·м$^{-2}$	A_v, Бк·с·м$^{-3}$	H_a, microsivert per hour $^{-1}$	H_i, microsivert per hour $^{-1}$
^{131}I	1,30E+01	8,03E+03	2,08E-02	3,07E-02
^{132}I	1,12E+00	5,18E+02	1,01E-04	1,10E-04
^{133}I	8,38E+00	5,00E+03	2,69E-03	4,69E-03
^{135}I	1,95E+00	1,08E+03	2,74E-04	3,62E-04
^{85m}Kr	0,00E+00	9,44E+02	7,06E-06	7,06E-06
^{85}Kr	0,00E+00	2,03E+01	8,38E-07	8,38E-07
^{88}Kr	0,00E+00	1,01E+03	1,03E-04	1,03E-04
^{133}Xe	0,00E+00	2,76E+05	4,31E-04	4,31E-04
^{135}Xe	0,00E+00	5,42E+03	6,45E-05	6,45E-05
^{103}Ru	1,32E+00	1,32E+03	3,88E-03	3,62E-03
^{106}Ru	1,43E-01	1,43E+02	1,60E-03	2,02E-03
^{134}Cs	3,24E-01	3,24E+02	1,43E-02	1,36E-02
^{137}Cs	2,01E-01	2,01E+02	4,15E-03	3,88E-03
^{144}Ce	2,14E+00	2,14E+03	2,14E-02	2,65E-03
^{90}Sr	1,62E-01	1,62E+02	3,15E-03	5,32E-03
^{95}Zr	3,72E+00	3,72E+03	2,70E-02	2,43E-02
^{95}Nb	6,43E+00	6,43E+03	2,43E-02	2,29E-02
^{140}Ba	1,60E+00	1,60E+03	3,27E-03	2,38E-03
^{140}La	1,88E+00	1,88E+03	1,62E-03	1,60E-03
Total			**1,29E-01**	**1,19E-01**

Table A.3 – **Calculated values of the fallout density and of the time integral of the volumetric activity in the surface air and effective annual doses for the critical groups of population on the territory of Ukraine and Poland (in the center of trail) for the meteorological scenario 2. Maximum Design-Basis Accident.**

Radionuclide	**A_s, Бк·м$^{-2}$**	**A_v, Бк·с·м$^{-3}$**	**H_a, microsivert per hour $^{-1}$**	**H_i, microsivert per hour $^{-1}$**
^{131}I	2,98E+00	2,22E+03	5.54E-03	8,27E-03
^{132}I	2,57E-01	1,43E+02	2,64E-05	2,89E-05
^{133}I	1,93E+00	1.39E+03	7,21E-04	1,28E-03
^{135}I	4,46E-01	3,00E+02	7,11E-05	9,56E-05
^{85m}Kr	0,00E+00	3,28E+02	2,45E-06	2,45E-06
^{85}Kr	0,00E+00	1.56E+01	6.44E-07	6,44E-07
^{88}Kr	0,00E+00	4.28E+02	4.37E-05	4,37E-05
^{133}Xe	0,00E+00	7,18E+04	1,12E-04	1,12E-04
^{135}Xe	0,00E+00	1,61E+03	1,91E-05	1,91E-05
^{103}Ru	3,73E-01	3.73E+02	1,09E-03	1,02E-03
^{106}Ru	4,03E-02	4,03E+01	4,50E-04	5,67E-04
^{134}Cs	9,09E-02	9,09E+01	3,96E-03	3,79E-03
^{137}Cs	5,64E-02	5,64E+01	1,14E-03	1,07E-03
^{144}Ce	6,03E-01	6,03E+02	6.04E-03	7,46E-04
^{90}Sr	4,58E-02	4,58E+01	7,55E-04	1,24E-03
^{95}Zr	1,05E+00	1,05E+03	7,63E-03	6,87E-03
^{95}Nb	1,82E+00	1,82E+03	6,87E-03	6,47E-03
^{140}Ba	4,52E-01	4,52E+02	9,28E-04	6,75E-04
^{140}La	5,50E-01	5,50E+02	4,74E-04	4,66E-04
Total			**3,59E-02**	**3,28E-02**

Table A.4 – **Calculated values of the fallout density and of the time integral of the volumetric activity in the surface air and effective annual doses for the critical groups of population on the territory of Ukraine and Poland (in the center of trail) for the meteorological scenario 2A. Maximum Design-Basis Accident.**

Radionuclide	**A_s, Бк·м$^{-2}$**	**A_v, Бк·с·м$^{-3}$**	**H_a, microsivert per hour $^{-1}$**	**H_i, microsivert per hour $^{-1}$**
^{131}I	1,68E+01	2.22E+03	1,07E-02	1,35E-02
^{132}I	1,43E+00	1.43E+02	5,74E-05	5,99E-05
^{133}I	1,08E+01	1.39E+03	1.30E-03	1,85E-03
^{135}I	2,50E+00	3.00E+02	1,75E-04	1,99E-04
^{85m}Kr	0,00E+00	3,28E+02	2,45E-06	2,45E-06
^{85}Kr	0,00E+00	1.56E+01	6,44E-07	6,44E-07
^{88}Kr	0,00E+00	4.28E+02	4.37E-05	4,37E-05
^{133}Xe	0,00E+00	7,18E+04	1.12E-04	1,12E-04
^{135}Xe	0,00E+00	1,61E+03	1,91E-05	1,91E-05
^{103}Ru	5,24E+00	3.73E+02	1,21E-02	1,21E-02
^{106}Ru	5,65E-01	4,03E+01	2,39E-03	2,59E-03
^{134}Cs	1,28E+00	9.09E+01	5.34E-02	5,27E-02
^{137}Cs	7,92E-01	5,64E+01	1,51E-02	1,48E-02
^{144}Ce	8,46E+00	6,03E+02	9,41E-03	4,18E-03
^{90}Sr	6,42E-01	4,58E+01	4,87E-03	6,79E-03
^{95}Zr	1,47E+01	1,05E+03	8.51E-02	8,43E-02
^{95}Nb	2,55E+01	1,82E+03	8,41E-02	8,37E-02
^{140}Ba	6,35E+00	4,52E+02	2,60E-03	2,35E-03
^{140}La	7,72E+00	5.50E+02	3.71E-03	3,70E-03
Total			**2,85E-01**	**2,83E-01**

Table A.5 – **Calculated values of the fallout density and of the time integral of the volumetric activity in the surface air and effective annual doses for the critical groups of population on the territory of Ukraine and Poland (in the center of trail) for the meteorological scenario 3. Maximum Design-Basis Accident.**

Radionuclide	A_s, $Бк \cdot м^{-2}$	A_v, $Бк \cdot с \cdot м^{-3}$	H_a, microsivert per hour $^{-1}$	H_i, microsivert per hour $^{-1}$
^{131}I	1,74E+00	1,74E+03	4,47E-02	2,50E-01
^{132}I	7,57E-03	5,65E+00	1,00E-06	1,25E-06
^{133}I	8,34E-01	8,06E+02	8,09E-04	3,89E-03
^{135}I	9,44E-02	8,50E+01	1,86E-05	2,55E-05
^{85m}Kr	0,00E+00	4,74E+01	3,55E-07	3,55E-07
^{85}Kr	0,00E+00	4,55E-02	1,88E-09	1,88E-09
^{88}Kr	0,00E+00	2,59E+01	2,64E-06	2,64E-06
^{133}Xe	0,00E+00	4,61E+04	7,19E-05	7,19E-05
^{135}Xe	0,00E+00	5,07E+02	6,03E-06	6,03E-06
^{103}Ru	3,04E-01	3,04E+02	1,26E-03	1,96E-03
^{106}Ru	3,33E-02	3,33E+01	2,13E-03	6,45E-03
^{134}Cs	7,51E-02	7,51E+01	4,60E-02	2,86E-02
^{137}Cs	4,65E-02	4,65E+01	2,23E-02	1,48E-02
^{144}Ce	4,96E-01	4,96E+02	2,23E-02	6,51E-02
^{90}Sr	3,78E-02	3,78E+01	1,77E-02	3,20E-02
^{95}Zr	8,63E-01	8,63E+02	8,94E-03	1,33E-02
^{95}Nb	1,49E+00	1,49E+03	6,82E-03	8,57E-03
^{140}Ba	3,65E-01	3,65E+02	1,55E-03	3,57E-03
^{140}La	3,82E-01	3,82E+02	3,83E-04	4,96E-04
Total			**1,75E-01**	**4,29E-01**

Table A.6 – **Calculated values of the fallout density and of the time integral of the volumetric activity in the surface air and effective annual doses for the critical groups of population on the territory of Ukraine and Poland (in the center of trail) for the meteorological scenario 3A. Maximum Design-Basis Accident.**

Radionuclide	**A_s, Бк·м$^{-2}$**	**A_v, Бк·с·м$^{-3}$**	**H_a, microsivert per hour $^{-1}$**	**H_i, microsivert per hour $^{-1}$**
^{131}I	4,76E+01	1,74E+03	1,13E+00	6,69E+00
^{132}I	1,96E-01	5,65E+00	6,67E-06	1,06E-05
^{133}I	2,26E+01	8,06E+02	1,29E-02	8,80E-02
^{135}I	2,53E+00	8,50E+01	1,41E-04	1,48E-04
^{85m}Kr	0,00E+00	4,74E+01	3,55E-07	3,55E-07
^{85}Kr	0,00E+00	4,55E-02	1,88E-09	1,88E-09
^{88}Kr	0,00E+00	2,59E+01	2,64E-06	2,64E-06
^{133}Xe	0,00E+00	4,61E+04	7,19E-05	7,19E-05
^{135}Xe	0,00E+00	5,07E+02	6,03E-06	6,03E-06
^{103}Ru	3,96E+01	3,04E+02	1,38E-01	2,37E-01
^{106}Ru	4,33E+00	3,33E+01	2,45E-01	7,96E-01
^{134}Cs	9,78E+00	7,51E+01	5,97E+00	3.73E+00
^{137}Cs	6,06E+00	4,65E+01	2,90E+00	1.93E+00
^{144}Ce	6,46E+01	4,96E+02	2,29E+00	8.42E+00
^{90}Sr	4,92E+00	3,78E+01	2,26E+00	4.08E+00
^{95}Zr	1,12E+02	8,63E+02	9,85E-01	1.64E+00
^{95}Nb	1,94E+02	1,49E+03	7,89E-01	1.06E+00
^{140}Ba	4,75E+01	3,65E+02	1,19E-01	4,08E-01
^{140}La	4,97E+01	3,82E+02	2,96E-02	4,50E-02
Total			**1,69E+01**	**2,91E+01**

Table A.7 – **Calculated values of the fallout density and of the time integral of the volumetric activity in the surface air and effective annual doses for the critical groups of population on the territory of Ukraine and Belorussia (in the center of trail) for the meteorological scenario 1. Beyond Design-Basis Accident.**

Radionuclide	**A_s, Бк·м$^{-2}$**	**A_v, Бк·с·м$^{-3}$**	**H_a, microsivert per hour $^{-1}$**	**H_i, microsivert per hour $^{-1}$**
^{131}I	1,23E+02	6,55E+05	1,35E+00	2,15E+00
^{132}I	1,59E+02	5,69E+04	1,20E-02	1,30E-02
^{133}I	2,38E+03	1,21E+06	6,75E-01	1,16E+00
^{135}I	3,27E+02	1,62E+05	4,27E-02	5,59E-02
^{85m}Kr	0,00E+00	5,81E+05	4,34E-03	4,34E-03
^{85}Kr	0,00E+00	1,54E+05	2,94E-05	2,94E-05
^{88}Kr	0,00E+00	2,15E+04	2,19E-03	2,19E-03
^{133}Xe	0,00E+00	2,71E+07	4,23E-02	4,23E-02
^{135}Xe	0,00E+00	2,98E+06	3,55E-02	3,55E-02
^{103}Ru	7,09E+00	7,09E+03	2,08E-02	1,94E-02
^{106}Ru	7,04E-01	7,04E+02	7,89E-03	9,96E-03
^{134}Cs	6,32E+00	6,32E+03	2,79E-01	2,66E-01
^{137}Cs	3,92E+00	3,92E+03	8,10E-02	7,58E-02
^{144}Ce	5,36E+00	5,36E+03	5,37E-02	6,65E-03
^{90}Sr	3,59E-01	3,59E+02	7,02E-03	1,18E-02
^{95}Zr	2,27E-01	2,27E+02	1,65E-03	1,48E-03
^{95}Nb	7,72E-01	7,72E+02	2,92E-03	2,75E-03
^{140}Ba	7,49E+00	7,49E+03	1,54E-02	1,12E-02
Total			**2,63E+00**	**3,87E+00**

Table A.8 – **Calculated values of the fallout density and of the time integral of the volumetric activity in the surface air and effective annual doses for the critical groups of population on the territory of Ukraine and Belorussia (in the center of trail) for the meteorological scenario 1A. Beyond Design-Basis Accident.**

Radionuclide	**A_s, Бк·м$^{-2}$**	**A_v, Бк·с·м$^{-3}$**	**H_a, microsivert per hour $^{-1}$**	**H_i, microsivert per hour $^{-1}$**
^{131}I	4,20E+03	6,55E+05	2,88E+00	3,68E+00
^{132}I	5,37E+02	5,69E+04	2,20E-02	2,30E-02
^{133}I	8,13E+03	1,21E+06	1,05E+00	1,53E+00
^{135}I	1,11E+03	1,62E+05	8,22E-02	9,54E-02
^{85m}Kr	0,00E+00	5,81E+05	4,34E-03	4,34E-03
^{85}Kr	0,00E+00	1,54E+05	2,94E-05	2,94E-05
^{88}Kr	0,00E+00	2,15E+04	2,19E-03	2,19E-03
^{133}Xe	0,00E+00	2,71E+07	4.23E-02	4,23E-02
^{135}Xe	0,00E+00	2,98E+06	3,55E-02	3,55E-02
^{103}Ru	6,23E+01	7,09E+03	1,46E-01	1,45E-01
^{106}Ru	6,19E+00	7,04E+02	2,83E-02	3,15E-02
^{134}Cs	5,56E+01	6,32E+03	2,36E+00	2.32E+00
^{137}Cs	3,45E+01	3,92E+03	6,74E-01	6,58E-01
^{144}Ce	4,71E+01	5,36E+03	7,17E-02	2,50E-02
^{90}Sr	3,16E+00	3,59E+02	3,49E-02	5,42E-02
^{95}Zr	1,99E+00	2,27E+02	1.16E-02	1,15E-02
^{95}Nb	6,79E+00	7,72E+02	2,25E-02	2,24E-02
^{140}Ba	6,59E+01	7,49E+03	3.20E-02	2,78E-02
Total			**7,50E+00**	**8,71E+00**

Table A.9 – **Calculated values of the fallout density and of the time integral of the volumetric activity in the surface air and effective annual doses for the critical groups of population on the territory of Ukraine and Poland (in the center of trail) for the meteorological scenario 2. Beyond Design-Basis Accident.**

Radionuclide	**A_s, Бк·м$^{-2}$**	**A_v, Бк·с·м$^{-3}$**	**H_a, microsivert per hour $^{-1}$**	**H_i, microsivert per hour $^{-1}$**
^{131}I	2,82E+02	1.81E+05	4,66E-01	6,88E-01
^{132}I	3,63E+01	1,56E+04	3,10E-03	3,37E-03
^{133}I	5,46E+02	3.35E+05	1,79E-01	3,13E-01
^{135}I	7,48E+01	4.46E+04	1,10E-02	1,47E-02
^{85m}Kr	0,00E+00	2.03E+05	1,52E-03	1.52E-03
^{85}Kr	0,00E+00	3,95E+04	7,55E-06	7,55E-06
^{88}Kr	0,00E+00	1,66E+04	1,69E-03	1,69E-03
^{133}Xe	0,00E+00	7.06E+06	1,10E-02	1,10E-02
^{135}Xe	0,00E+00	8.86E+05	1,05E-02	1,05E-02
^{103}Ru	2,00E+00	2.00E+03	5,86E-03	5.47E-03
^{106}Ru	1,98E-01	1,98E+02	2,21E-03	2,79E-03
^{134}Cs	1,78E+00	1,78E+03	7,75E-02	7,42E-02
^{137}Cs	1,11E+00	1.11E+03	2,24E-02	2,10E-02
^{144}Ce	1,51E+00	1.51E+03	1,51E-02	1,87E-03
^{90}Sr	1.01E-01	1.01E+02	1,68E-03	2,75E-03
^{95}Zr	6,39E-02	6.39E+01	4,64E-04	4,17E-04
^{95}Nb	2,17E-01	2,17E+02	8,22E-04	7,74E-04
^{140}Ba	2,12E+00	2,12E+03	4.34E-03	3,16E-03
Total			**8,14E-01**	**1,16E+00**

Table A.10 – **Calculated values of the fallout density and of the time integral of the volumetric activity in the surface air and effective annual doses for the critical groups of population on the territory of Ukraine and Poland (in the center of trail) for the meteorological scenario 2A. Beyond Design-Basis Accident.**

Radionuclide	**A_s, Бк·м$^{-2}$**	**A_v, Бк·с·м$^{-3}$**	**H_a, microsivert per hour $^{-1}$**	**H_i, microsivert per hour $^{-1}$**
^{131}I	1,58E+03	1,81E+05	9,53E-01	1,17E+00
^{132}I	2,01E+02	1,56E+04	7,45E-03	7,72E-03
^{133}I	3,05E+03	3,35E+05	3,41E-01	4,75E-01
^{135}I	4,17E+02	4,46E+04	2,83E-02	3,19E-02
^{85m}Kr	0,00E+00	2,03E+05	1,52E-03	1,52E-03
^{85}Kr	0,00E+00	3,95E+04	7,55E-06	7,55E-06
^{88}Kr	0,00E+00	1,66E+04	1,69E-03	1,69E-03
^{133}Xe	0,00E+00	7,06E+06	1,10E-02	1,10E-02
^{135}Xe	0,00E+00	8,86E+05	1,05E-02	1,05E-02
^{103}Ru	2,79E+01	2,00E+03	6,46E-02	6,43E-02
^{106}Ru	2,76E+00	1,98E+02	1,17E-02	1,27E-02
^{134}Cs	2,49E+01	1,78E+03	1,04E+00	1,03E+00
^{137}Cs	1,55E+01	1,11E+03	2,95E-01	2,89E-01
^{144}Ce	2,11E+01	1,51E+03	2,35E-02	1,04E-02
^{90}Sr	1,41E+00	1,01E+02	1,09E-02	1,51E-02
^{95}Zr	8,92E-01	6,39E+01	5,15E-03	5,10E-03
^{95}Nb	3,04E+00	2,17E+02	1,00E-02	9,97E-03
^{140}Ba	2,96E+01	2,12E+03	1,21E-02	1,10E-02
Total			**2,83E+00**	**3,16E+00**

Table A.11 – **Calculated values of the fallout density and of the time integral of the volumetric activity in the surface air and effective annual doses for the critical groups of population on the territory of Ukraine and Poland (in the center of trail) for the meteorological scenario 3. Beyond Design-Basis Accident.**

Radionuclide	**A_s, Бк·м$^{-2}$**	**A_v, Бк·с·м$^{-3}$**	**H_a, microsivert per hour $^{-1}$**	**H_i, microsivert per hour $^{-1}$**
^{131}I	1,64E+02	1,41E+05	4,16E+00	2,35E+01
^{132}I	1,07E+00	6,12E+02	1,16E-04	1,47E-04
^{133}I	2,36E+02	1,94E+05	2,14E-01	1,07E+00
^{135}I	1,58E+01	1,26E+04	2,84E-03	3,87E-03
^{85m}Kr	0,00E+00	2,92E+04	2,19E-04	2,19E-04
^{85}Kr	0,00E+00	2,69E+04	5,14E-06	5,14E-06
^{88}Kr	0,00E+00	4,82E+01	4,92E-06	4,92E-06
^{133}Xe	0,00E+00	4,54E+06	7,08E-03	7,08E-03
^{135}Xe	0,00E+00	2,81E+05	3,34E-03	3,34E-03
^{103}Ru	1,63E+00	1,63E+03	6,73E-03	1,05E-02
^{106}Ru	1,63E-01	1,63E+02	1,04E-02	3,16E-02
^{134}Cs	1,47E+00	1,47E+03	9,01E-01	5,60E-01
^{137}Cs	9,11E-01	9,11E+02	4,37E-01	2,90E-01
^{144}Ce	1,24E-01	1,24E+02	5,58E-03	1,63E-02
^{90}Sr	8,32E-02	8,32E+01	3,91E-02	7,05E-02
^{95}Zr	5,27E-02	5,27E+01	5,46E-04	8,14E-04
^{95}Nb	1,80E-01	1,80E+02	8,24E-04	1,03E-03
^{140}Ba	1,75E+00	1,75E+03	7,43E-03	1,71E-02
Total			**5,80E+00**	**2,56E+01**

Table A.12 – **Calculated values of the fallout density and of the time integral of the volumetric activity in the surface air and effective annual doses for the critical groups of population on the territory of Ukraine and Poland (in the center of trail) for the meteorological scenario 3A. Beyond Design-Basis Accident.**

Radionuclide	A_s, Бк·м$^{-2}$	A_v, Бк·с·м$^{-3}$	H_a, microsivert per hour $^{-1}$	H_i, microsivert per hour $^{-1}$
^{131}I	4,35E+03	1,41E+05	1,03E+02	6,11E+02
^{132}I	2,64E+01	6,12E+02	8,78E-04	1,40E-03
^{133}I	6,19E+03	1.94E+05	3,52E+00	2,41E+01
^{135}I	4,12E+02	1,26E+04	2,28E-02	2,38E-02
^{85m} Kr	0,00E+00	2.92E+04	2,19E-04	2,19E-04
^{85}Kr	0,00E+00	2,69E+04	5,14E-06	5,14E-06
^{88}Kr	0,00E+00	4,82E+01	4,92E-06	4,92E-06
^{133}Xe	0,00E+00	4.54E+06	7.08E-03	7,08E-03
^{135}Xe	0,00E+00	2,81E+05	3.34E-03	3,34E-03
^{103}Ru	2,28E+01	1.63E+03	7.99E-02	1,37E-01
^{106}Ru	2,28E+00	1.63E+02	1,30E-01	4,20E-01
^{134}Cs	2,05E+01	1.47E+03	1,25E+01	7,82E+00
^{137}Cs	1,19E+02	9,11E+02	5,69E+01	3.79E+01
^{144}Ce	1,73E+00	1,24E+02	6,25E-02	2,26E-01
^{90}Sr	1,16E+00	8,32E+01	5,35E-01	9,66E-01
^{95}Zr	7,36E-01	5.27E+01	6.53E-03	1,08E-02
^{95}Nb	2,51E+00	1.80E+02	1,03E-02	1,37E-02
^{140}Ba	2,44E+01	1,75E+03	6,37E-02	2,12E-01
Total			**1,77E+02**	**6,83E+02**

Modifications register sheet

Modifications	Numbers of pages				Total amount of pages in the document	Document No. (permit)	Signature	Date
	modified	replaced	new	canceled				
1	-	All	-	-	40	33-11		25.01.11