PJSC “Nuclear fuel production plant”

Nuclear fuel production plant

PROJECT

TOME 8.3

Environmental impact assessment
Transborder impact assessment
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CONTENTS

Appendices

The project has been developed on the order of the Private joint-Stock company “Nuclear fuel production plant” by the State Enterprise “Ukrainian research, project and prospecting institute of industrial technology” (SE “UkrNIPII promtehnologii”).

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The project is developed in compliance with the existing norms, rules. instructions, state and branch standards.

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INTRODUCTION

By the decrees of the President of Ukraine as of 15.06.2010 No. 692-16t/2010 “On the decision of the National security and defense Council”, as of 1 June 2010 “On providing for national interests in the sphere of provision of nuclear fuel for Ukrainian NPPs and creation of own nuclear fuel production in Ukraine”, “Energy strategy of Ukraine for the period until 2030”, approved by the decree of the Cabinet of Ministers of Ukraine of 15.03.2006 No. 145; “Nuclear fuel of Ukraine” state task economic program approved by the Decree of the Government of Ukraine as of 23.09.09 No. 1004; creation of nuclear fuel production in Ukraine for the VVER-1000 type reactors.

The “Nuclear fuel production plant” project has been developed by the State Enterprise “Ukrainian research, project and prospecting institute of industrial technology” (SE “UkrNIPII promtehnologii”) on the order of the PJSC “Nuclear fuel production plant” on the basis of the:

- decree of the CMU of 27.06.2012 No. 437-r “Issues of location, design and construction of a nuclear fuel production plant for the VVER-1000 reactors” approved by the Prime Minister of Ukraine N.Ya. Azarov.
- agreement between the SC “Nuclear fuel” and the OJSC “TVEL” of 27.10.2010;
- project statement and adaptations to the statement according to the Protocol GPU No. 21 of 29.03.2013 approved by the acting Director of the PJSC “Nuclear fuel production plant” Yu. F. Antipov and agreed with the Director-General of the SC “Nuclear fuel” T. V. Amosova and the Senior Vice-President of the OJSC “TVEL” P. I. Lavrenyuk;
- feasibility study approved by the decree of the CMU of 27.06.2012 No. 437-r.

This volume of the EIA (environmental impact assessment) has been developed according to the DBN A.2.2.-1-2003 “Composition and content of materials included in the environmental impact assessment in the process of designing and construction of enterprises, buildings and structures” and the Convention “On assessment of the environmental impact in the transborder context”

The objective of assessment of the nuclear fuel production plant environmental impact in the transborder context is the assessment of the impact on the territory of the neighboring states. Impact in the normal operating conditions and in case of emergencies are considered.

The assessment of the transborder impact of the Nuclear fuel production plant was approved at the meeting of the “Nuclear power complex” group of the research and development council of the Ministry of Energy and Coal Industry of Ukraine on 24.10.2013.

1 DESCRIPTION OF THE PLANNED ACTIVITY

The activity planned provides for construction and operation of a nuclear fuel production plant.

The nuclear fuel production plant site is situated on the territory of the Smolino settlement council of the Malovyskovsky region according to the ground lot sublease agreement of 27.12.2012.

The nuclear fuel production plant site is situated 2.5 km south-west of the Smolino urban settlement in the Malovyskovsky region of the Kirovograd Oblast of Ukraine. The distance from the Smolino urban settlement to the oblast center Kirovograd makes 72 km, to the region centre Malaya Viska – 25 km. The distance from the plant to the villages of Berezovka and Novopavlovka makes approximately 2,1 km; at the distance of 3.7 to 6 km there are the villages of Novopetrovka, Novogrigoryevka, Khmelevoye and Alexandrovka. In the physical and geographical respect, the region of location of the plant designed belongs to the Central part of Ukraine in the interfluves of Dnepr and South Bug, in the southern part of the Transdnepr upland.

The relief is flat land strongly rugged with gullies and ravines. The maximum region surface benchmarks reach 190 to 195 m at the watershed, the minimum ones – 140 to 165 m – at the bottoms of the rivers and gullies. The place of location of the plant is shown in Figure 1.1

Figure 1.1 – Location of the nuclear fuel production plant

Notation conventions

- nuclear fuel production plant

The distances from the nuclear fuel production plant (NFPP) to the nearest borders with the neighboring countries are given in table 1.

Table 1. Distances from the (NFPP) to the nearest borders with the neighboring countries

Neighboring country	Direction to the nearest border	Nearest frontier populated area	Distance from the NFPP to the nearest border
Belarus	N	Nizhniye Zhary	300 km
Poland	NNW	Dluzhnuv	559 km
Slovakia	W	Novaya Sedlitsa	637 km
Hungary	W	Tisobeg	620 km
Rumania	SW	Rominesht	307 km
Moldova	SWW	Broshten	166 km
Russia	SE	Grayvoron	368 km

The nearest state is the Republic of Moldova, the distance to which is 166 km.

The mainline production of nuclear fuel includes the processes of conversion of uranium hexafluoride into uranium dioxide (UDO), manufacturing of fuel pellets, manufacturing of component elements from a zirconium alloy and stainless steel, fitting out fuel elements (FE) and assemblage of fuel assemblies (FA). The mainline production is planned to be deployed within one building. The administrative and utility building, auxiliary manufacturing floors, warehousing, energy department and other supporting facilities of the enterprise will be deployed in free-standing buildings and structures.

Construction and commissioning of the nuclear fuel production plant will be performed in stages:

I stage of construction of the NFPP includes:

- manufacturing of the fuel elements (FE);
- manufacturing of the fuel assemblies (FA);
- manufacturing of the component parts from stainless steel;
- manufacturing of the component parts from zirconium;
- treatment of liquid and solid radioactive waste;
- plant infrastructure.

II stage of construction of the NFPP includes:

- manufacturing of the UDO powder;
- manufacturing of the pellets;
- treatment of liquid and solid radioactive waste;
- additional plant infrastructure.

Source material for production of the FA during the period of the I stage will be fuel pellets supplied from the Russian Federation.

Source material for production of the nuclear fuel during the period of fully developed production will be enriched uranium hexafluoride with enrichment by the U-235 isotope up to 5 % (mass).

The products manufactured are fuel assemblies (FA) for the reactors of the VVER-1000 type containing hazardous nuclear fissionable materials (natural uranium compounds with enrichment by the U-235 isotope up to 5 %). The FAs belong to the closed ionizing radiation sources.

The designed capacity of the NFPP provides for production of 800 FAs pieces per year for the VVER-1000 type reactors.

During production of the nuclear fuel, in the process of conversion of the uranium hexafluoride, a by-product is created, namely the hydrofluoric acid which is ~ 35 % water solution of the anhydrous hydrogen fluoride, in the amount of 504.6 t/year.

The nuclear fuel production plant, the technological process cycle of which includes radioactive substances (sources of ionizing radiation), belongs by the potential hazard for the population according to the OSPORBU (Basic sanitary rules for providing for the radiation safety of Ukraine) to the I category of enterprises for which a sanitary protection zone (SPZ) and a control area (CA) are established.

Taking into account all impact factors (radiation, chemical and physical ones) as well as subject to the requirements of DSP 173-96, a SPZ of 1100 m is established for the nuclear fuel production plant [1].

The boundary of the NFPP control area by the radiation parameters is established at the distance of 1500 m from the emission sources [1].

2 ALTERNATIVE OPTIONS OF THE PLANNED ACTIVITY

The “Nuclear fuel of Ukraine” state task economic program [2] provides for three options of solving the problem of provision of the nuclear power plants of Ukraine with nuclear fuel:

- first option – purchase of nuclear fuel on the world market;
- second option – creation of facilities for production of nuclear fuel by domestic enterprises and organizations;
- third option − creation of facilities for production of nuclear fuel and its elements in co-operation with other countries.

Today, countries such as Finland, Hungary, Czech Republic, Bulgaria, Slovakia, Ukraine provide their nuclear power stations with nuclear fuel by the first option. The drawback of this option is complete dependence on the foreign supplier.

Countries having the complete complex of nuclear technologies, including the technology of isotopic uranium enrichment, provide their nuclear power plants with nuclear fuel by the second option. Realization of such an option in Ukraine is not feasible due to the fact that development and implementation of the whole complex of the technologies required would call for considerable costs.

An optimum option for Ukraine is the third option, under which production of nuclear fuel will be established in Ukraine with acquisition from foreign firms and implementation of technologies of manufacturing component parts, fuel pellets and fuel assemblies as well as acquisition on the world market of services in conversion and enrichment of uranium for domestic production of nuclear fuel.

In 2010, a tender was carried out in Ukraine on selection of the technology of nuclear fuel production in Ukraine. The winner of the tender was the OJSC “TVEL” from Russian Federation.

On the basis of the government decisions on construction of a nuclear fuel production plant, a task team was created by the order of the acting Director-General of the SE “Nuclear fuel” No. 64 of 08.12.2010 for selecting a site for location of the nuclear fuel production plant in Ukraine. Three possible sites for location of the nuclear fuel production plant were defined by the task team on the basis of the proposals made by the local authorities (Protocol No. 1 of 24.12.2010):

- Kirovograd oblast (Smolino urban settlement);
- Dnepropetrovsk oblast (Zheltye Vody);
- Kiev oblast (Slavutych).

The sites proposed were considered for compliance with the requirements of the “Criteria and requirements to a production complex deployment site” document agreed by the State nuclear regulation inspection of Ukraine and approved by the Director-General of the SE “Nuclear fuel” on 20.04.2010.

The commission on selection of the site for deployment of the nuclear fuel production plant in Ukraine acknowledged that the site in the area of the Smolino urban settlement of the Malovyskovsky region of the Kirovograd Oblast complies with the criteria and requirements established for deployment of the Plant (Protocol No. 3 of 18.08.2011). The construction site was approved by the decree of the

CMU of 27.06.2012 No. 437-r “Issues of location, design and construction of a nuclear fuel production plant for the VVER-1000 reactors”.

Organization of a nuclear fuel production plant in Ukraine will provide for:

- production of the FAs in the quantities that will fully comply with the needs of the NPPs in Ukraine;
- development of the enterprises of the nuclear industry of Ukraine and stabilization of their financial position;
- additional creation of 454 new jobs;
- maximum use of local workforce, production, scientific and research and other resources;
- considerable increase in the level of energy security of the country.

Apart from that, another positive ecologic factor for the NFPP is the fact that the plant site is situated in an industrial area, within the limits of the Smolino mine ground allotment. So there is no need for additional ground allotment and its withdrawal from the agricultural cycle.

3 CHARACTERISTIC OF THE CONSIDERABLY IMPACTED ENVIRONMENTAL OBJECTS

The main impact of the activity planned will be on the air.

According to the data available on 1.01.2012, an amount of 15.2 thousand tons of pollutants was emitted into the atmospheric air on the oblast territory from the stationary pollution sources of the enterprises [4].

In the pattern of the total amount of emissions, substances in the form of suspended particles (22,4 %), carbon monoxides (31,6 %), sulfurous anhydride (9,2 %), nitrogen compounds (12,5 %), NMVOC (non-methane volatile organic compounds) (5,3 %) prevailed.

Apart from that, 1.8 million tons of carbon dioxide (carbonic gas) got into the atmosphere which contributes to the greenhouse effect.

Industrial complexes of Kirovograd, the Golovanovsky, Gayvoronsky, Petrovsky, Svetlovodsky, Novoukrainsky regions of the oblast hold a large share in the pattern of the general amount of the emissions,

In the region of location of the nuclear fuel production plant, the enterprise limiting the atmosphere pollution is the Smolino mine SE “VostGOK”.

The main pollutants emitted into the atmosphere air by the mine and limiting the atmosphere pollution, are the nitrogen dioxide, carbon monoxide, sulfurous anhydride, non-organic dust containing natural radionuclides (U_{nat}.; Ra-226; Th-230; Pb-210; Po-210).

Annual amount of pollutants in the mine emissions makes 251.32 t.

Content of pollutants in the atmosphere air on the territory of the industrial site of the mine complex and in its controlled-access zones according to the enterprise monitoring data [5] is given in table 3.1.

Table 3.1 – Content of pollutants in the atmosphere air on the territory of the industrial site of the Smolino mine, its SPZ and CA.

Name of the parameter	Mine industrial site	Sanitary protection zone	*Control area*
Ore dust, mg/m^3	0,48	0,328	*b.l.e.r*
Nitrogen dioxide, mg/m^3	b.l.e.r	b.l.e.r	*b.l.e.r*
Carbon monoxide, mg/m^3	b.l.e.r	b.l.e.r	*b.l.e.r*
Sulfurous anhydride, mg/m^3	b.l.e.r	b.l.e.r	*b.l.e.r*
$\Sigma\ \alpha$ activity, Bq/m^3	$14{,}38\cdot10^{-4}$	$8{,}954\cdot10^{-4}$	*$4{,}486\cdot10^{-4}$*
Natural uranium, Bq/m^3		0,0025-0,003	
Radium-226, Bq/m^3		*0,0027-0,0032*	

Note: b.l.e.r – below the limit of effective range.

Pollution of the air basin in the region of the Smolino urban settlement according to the data of the oblast hydrometeorology center is given in table 3.2.

Table 3.2 − Pollution of the atmosphere air in the Smolino urban settlement

Pollutant	Pollutant concentration in the atmosphere air in the region, mg/m^3	Maximum permissible concentration for populated areas, mg/m^3 [6]
Ferric oxide	0,016	0,04*
Manganese and its compounds	0,004	0,01
Nitrogen dioxide	0,008	0,2
Soot	0,06	0,15
Sulfurous anhydride	0,02	0,5
Carbon monoxide	0,4	5,0
Anhydrous hydrogen fluoride	0,008	0,02
Non-organic dust (SiO2 70-20%)	0,12	0,3
Emulsol aerosol	0,02	0,05**

* - average daily MPC, mg/m^3;

**- approximate safe impact levels, mg/m^3.

Pollution of the air basin with chemical and radioactive substances is lower than the maximum permissible values.

4 DESCRIPTION OF MODELS USED FOR CALCULATION OF POLLUTANTS SPREAD

For assessment of the impact of the plant on the air quality, calculation of dispersion of the chemical pollutants in the bottom layer of the atmosphere air is performed using the EOL-Plus software package recommended for use by the Ministry of Ecology and Natural Resources of Ukraine. With this software package, calculation of concentrations of pollutants contained in the enterprise emissions in the atmosphere air is performed using the OND-86 methodology.

For modeling the spread of contaminants in the atmosphere and forming the doses conditional on emissions of radionuclides, PC COSYMA software packages developed for emergency situations by the National Radiological Protection Board, England, and the CAP88 package for the enterprise normal operation developed in the Environmental Protection Agency, USA, have been used.

4.1 Brief description of the CAP88 model

CAP88 is a software package for assessment of compliance with the air purity law of 1988 being a set of computer programs and databases for evaluation of doses and the risk of emissions of radionuclides into the atmosphere. Description of the CAP88 package is given in the work [7,8]. The system is designed for assessment of doses and risks of emissions of radionuclides into the atmosphere and enables to calculate the following parameters:

- activity of radionuclides in the air;
- activity of radionuclides deposited onto the ground surface;
- activity of radionuclides in the foodstuffs (for calculation of the concentrations in the foodstuffs, vegetables, milk and meat consumed by people, ground food chain models recommended by the IAEA are used);
- activity of radionuclides getting into human organism with the foodstuffs produced in the area under consideration.

Assessments are performed for a circular distance and direction pattern with the radius of 80 km (50 miles) around the source.

The software package is not designed for peak emissions or emissions of highly active radionuclides as the dose and risk assessment is applicable only for low level chronic irradiation.

The database includes 825 radionuclides plus 13 decay chains. The dose coefficients and risk factors are based on the ICRP (International Commission on Radiological Protection) Publication № 72.

The CAP88 uses the modified Gauss equation for the emission tail for the assessment of the average dispersion of radionuclides emitted from several sources (up to six, yet all the sources are modeled in such a way as if they were located in the same point and the same supernatant tail formation mechanism was used for each source). Dry deposition is calculated using a source depletion model, and the wet deposition – using the wash-out coefficients. Concentrations on the ground

surface and in the soil are calculated for the accumulation time of 100 years taking into account the rate of radionuclides elimination from the soil making 2% per annum. In the CAP88, the time of irradiation during assessment of doses and risks is 50 years.

The dosage and risk are assessed in the process of combined impact of radionuclides incorporated by people due to inhaling, consumption of contaminated foodstuffs and external irradiation from radionuclides in the air and on the ground surface. The effective equivalent dose is calculated using weighting factors taken from the ICRP Publication No. 72.

Doses are calculated for 23 viscera. And the 24^{th} dose is the total effective equivalent dose for the whole body.

The Gaussian tail model used in the CAP88 is one of the most high-usage models in the radiation safety methodologies in many countries (also in Ukraine). It yields results complying with the experimental data as well as the results of other models, yet at the same time CAP88 is quite easy-to-use and compatible with the random nature of turbulence.

Mathematical models

Tail lift

The nature of emissions dispersion, apart from the weather factors, depends on the temperature, the emitted gas cleanup rate and the interaction of the wind current with the buildings located near the emission place. Overheating relative to the ambient air and dynamic pressure of the gases emitted result in the lift of the current over the emission point. The influence of the buildings comes to wind current distortions near them and to formation of a stable air circulation zone behind the buildings, the so called aerodynamic shadow. At the same time, the contamination emitted may get into the aerodynamic shadow zone and quickly reach the ground surface. As a result, a spatial contaminants source is formed behind the building. The degree of attraction of the contaminants emitted into the shadow zone depends on the place of location of the stack top. If the emission source is so high that the current lines going through the emission point do not get into the current shift zone, then a correct current is formed and the emissions will not drawn into the shadow zone. In case of lower sources, the emissions of which get into the current shift zone, part of the contaminants will be drawn into the aerodynamic shadow zone, whereas the other part will be realized in the form of lifted current.

CAP88 calculates the tail lift using the Rupp equation (pulse mode) or the Briggs equations (supernatant heated tail). In this work, the Rupp equation is used:

$$\Delta h = 1{,}5 \cdot v \cdot d / \mu,$$

where:

Δh is the tail lift added to the actual height of the smoke or ventilation stack h for determination of the effective stack height $h_{эфф}$, m;

v is the rate of emission from the stack, m/s;

d is the inner stack diameter.

Tail dispersion

Tail dispersion is modeled with the Gaussian equation for the tail:

$$A = \left(\frac{Q}{2\pi\sigma_y\sigma_z\mu} \right) \cdot \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y} \right)^2 \right] \times$$
$$\times \left\{ \exp\left[-\frac{1}{2}\left(\frac{z - h_{эфф}}{\sigma_z} \right)^2 \right] + \exp\left[-\frac{1}{2}\left(\frac{z + h_{эфф}}{\sigma_z} \right)^2 \right] \right\}, \quad (4.1)$$

Where A is concentration in the air at the distance of x meters leeward, y meters perpendicular to the wind direction and z meters above the ground, Cu/m^3;

Q is the rate of emission of the radionuclides from the stack, Cu/s;

μ is the wind speed, m/s;

σ_y, σ_z are the horizontal and vertical dispersion coefficients, m;

$h_{эфф}$ is the effective stack height, m.

The leeward distance x is included in the equation (4.1) through σ_y and σ_z, which are both functions of x and functions of the atmospheric stability class by Pasquill. CAP88 translates A from the Cu/m^3 units into the pCu/cm^3 units.

The equation (4.1) gives the following expression for the radionuclides concentration in the air at the ground level along the axial line of the effluent tail (with the y and z values set to zero):

$$A_{00} = (Q/\pi\sigma_y\sigma_z\mu)\cdot\exp[-1/2(h_{эфф}/\sigma_z)^2]$$

For calculation of concentration in the bottom layer averaged by the angular domain (22,5° around the tail axial line), following expression is used:

$$A_{cp} = f\cdot A_{00}, \text{ where}$$
$$f = \int^{\infty} \exp\left[-1/2\left(y/\sigma_y \right)^2 \right] dy / y_s = \sigma_y (\pi/2)^{1/2} / y_s, \text{ and} \quad (4.2)$$
$$y_s = \tan(11{,}5°)\cdot x.$$

With substitution of this expression, the concentration of nuclides in the air at the ground level averaged by the domain becomes:

$$A_{00} = (Q/0{,}15871\pi x\sigma_z\mu)\cdot\exp[-1/2(h_{эфф}/\sigma_z)^2].$$

This method of averaging by the domain compresses the tail within the limits of each sixteen interconnected 22.5-grade domains. For non-stable atmospheric stability classes by Pasquill, in which the horizontal dispersion is sufficiently high for considerably exceeding the limits of the domain, this method is not accurate.

As part of the input data, an average “upper limit” value is provided for the domain considered. It is assumed that the “upper limit” does not influence the tail until x (the leeward distance) becomes equal to $2x_L$, where $2x_L$ is the x value for

which σ_z = 0,47L (L is the height of the “upper limit”). For values more than $2x_L$, vertical dispersion is limited, and the radionuclides concentration in the air is considered the same from the bottom to the “upper limit”.

The average concentration between the ground and the “upper limit” which is the concentration in the air in the bottom layer for values more than $2x_L$, may be written as:

$$A_{cp} = \left(\int_0^{\infty} A dz \right) \Big/ L, \qquad (4.3)$$

where A is taken from the equation (1), the value of $h_{эфф}$ in this equation may be set to zero as A_{cp} is not function of the stack effective height.

The result of integration of the expression (2.3) is presented below:

$$A_{cp} = (Q/2{,}5066\sigma_y L\mu)\cdot\exp(-y^2/2\sigma_y^2) \qquad (4.4)$$

The concentration of the radionuclides in the bottom layer averaged by the domain may be obtained by substituting the exponential expression in (4.4) with f (equation (4.2)):

$$A_{cp} = Q/0{,}397825xL\mu \qquad (4.5)$$

It should be noted that, for the leeward distances exceeding $2x_L$ by the value, one should not consider any more that the distance (4.5) is described by the Gaussian equation. This model is simply a model of uniform distribution at the rectangle with the L dimension at 2x·tan (11,5 °). The presence of the force of gravity is processed by the program of determination of the downward list of the tail emitted from the stack (after its leveling at the height of $h_{эфф}$), deduction of $V_г \cdot x/\mu$ from $h_{эфф}$ in the tail dispersion equations. For CAP88, the value of $V_г$ is set, by default, to be zero, and can not be changed by the user.

Taking into account the recurrence of the wind directions for each of the atmosphere stability categories in the CAP88 is performed according to the formula:

$$A_i(x,z) = \sum_j f_{i,j} A_{i,j}(x,z),$$

where $f_{i,j}$ is the frequency of recurrence of the wind direction towards a specific domain (i) for the atmosphere stability category j; x is the distance from the source.

Dispersion coefficient

The horizontal and vertical dispersion coefficients σ_y and σ_z used for calculation of the dispersion and determination of the share of the radionuclides that get removed are different functions of the leeward distance x for each atmosphere stability class by Pasquill in the conditions of open terrains; they are given in table 4.1.

Table 4.1 – Horizontal and vertical dispersion coefficients as functions of the leeward distance

Stability class by Pasquill	σ_y	σ_z
A	$0{,}22x(1+0{,}0001x)^{-1/2}$	0,2x

Stability class by Pasquill	σ_y	σ_z
B	$0{,}16x(1+0{,}0001x)^{-1/2}$	$0{,}12x$
C	$0{,}11x(1+0{,}0001x)^{-1/2}$	$0{,}08x(1+0{,}0002x)^{-1/2}$
D	$0{,}08x(1+0{,}0001x)^{-1/2}$	$0{,}06x(1+0{,}0015x)^{-1/2}$
E	$0{,}06x(1+0{,}0001x)^{-1/2}$	$0{,}03x(1+0{,}0003x)^{-1}$
F	$0{,}04x(1+0{,}0001x)^{-1/2}$	$0{,}016x(1+0{,}0003x)^{-1}$

Tail depletion

The total content of the contaminants in the emission cloud as it moves with the average wind decreases as a result of: dry deposition, precipitation scavenging ("wet" deposition) onto the ground surface, radioactive decay and changes as a result of radioactive transformations in the parent radionuclides isobar chain. The first three processes are described with the so called depletion factor $F = Q'/Q$ which is the share of the number of emitted nuclides remaining in the cloud by the moment when it moves to the distance of x from the emission point. The result of action of the first two processes of washout from the atmosphere is formation of the flow of contaminants depositing onto the ground surface.

Dry deposition

Dry deposition is modeled in such a way that it is proportional to the radionuclides concentration in the bottom layer: $R_{сух} = V_г \cdot A$, where $R_{сух}$ is the rate of deposition of the radionuclides per area unit (pCu/(cm^2·s)); $V_г$ is the rate of deposition (cm/s); A is the concentration of radionuclides in the air in the bottom layer (pCu/cm^3).

As a rule, the proportionality constant $V_г$ is higher than the actual, i.e. measured rate of deposition of the radionuclides onto the ground surface. $V_г$ shall include radionuclides deposition caused by interception of the radioactive precipitation by the foliage, which afterwards falls to the ground and, thus, increases the value of radionuclides deposition. The default values for the deposition rate used by the CAP88 are $3{,}5 \cdot 10^{-2}$ m/s for iodine, $1{,}8 \cdot 10^{-3}$ m/s for aerosols and 0 m/s for gases.

Wet deposition

The share of particles deposited from the tail with the rain and snow is modeled with the following equation:

$$R_{вл} = \Phi \cdot A_{ср} \cdot L,$$

where $R_{вл}$ is the rate of deposition onto the surface (pCu/(cm^2·s)); Φ is the washout coefficient (s^{-1}); $A_{ср}$ is the average radionuclides concentration in the tail up to the "upper limit" (pCu/cm^3); L is the height of the "upper limit" (level of tropospheric mixing, height of the layer being mixed).

The washout coefficient is calculated with the CAP88 program by multiplying the annual precipitation share (in cm/year) by $1 \cdot 10^{-7}$ year/(cm·s).

Depletion factor

The share of radionuclides removed from the cloud (ratio of the decreased amount of radionuclides removed as a result of the above-mentioned factors Q′ to the initial amount of the radionuclides removed Q) for each leeward distance x consists in this case of three components:

$$F = Q'/Q = (Q'/Q)_{вл} \cdot (Q'/Q)_{сух} \cdot (Q'/Q)_{рас} = F_{вл} \cdot F_{сух} \cdot F_{рас}$$

The share of radionuclides removal due to precipitation for each leeward distance x makes:

$$F_{вл} = \exp(-\Phi t),$$

where Φ is the washout coefficient (s^{-1}); t is the time (s) required for the tail reaching the leeward distance x.

The share of radionuclides removed from the radionuclides tail due to dry deposition is obtained from (4.1) setting the value of z equal to zero (for concentrations at the ground surface) and deducting the value of $V_г \cdot x/\mu$ from $h_{эфф}$ for the tail having a certain list:

$$F_{сух} = \exp\left\{-(2/\pi)^{1/2} \cdot (V_{сух}/\mu)\int_0^x \left(\exp\left(-(h_{эфф} - V_г x/\mu)^2/2\sigma_z^2\right)/\sigma_z\right)dx\right\}$$

The values of the removed share for the cases where $V_г$ is zero are obtained with a separate CAP88 subroutine. The subroutine uses the values of the removed share calculated for the sequence of the radionuclides discharge heights and leeward distances using the Simpson rule on the following condition: $V_{вл}$ = 0,01 m/s and μ = 1 m/s for each stability class by Pasquill. The subroutine transforms these values using linear interpolation to the relevant value for the required wind direction, radionuclides discharge height and the stability class by Pasquill, and coordinates them with the actual deposition rate and wind speed.

For leeward distances exceeding $2x_L$ (equation (4.4)), removal of radionuclides from the tail is modeled with the following equation: $Q'_x / Q'_{2xL} = \exp\left[-(V_{сух}(x - 2xL)/L\mu)\right]$, which calculates the decrease in the shares of radionuclides discharged at the distances of x and 2xL respectively.

The share of decrease in the amount of radionuclides in the tail as a result of radioactive decay makes: $F_{рас} = \exp(-\lambda_г t)$, where $\lambda_г$ is the effective decay constant in the tail. $\lambda_г$ is not the real radioactive decay constant in all cases considered. For example, if the radionuclide is a temporary decay product in equilibrium with the long-lived parent isotope, then the effective decay constant will be equal to the real decay constant of the parent isotope.

For calculation of the decrease in the shares of radionuclides discharged as a result of radioactive decay and loss of radionuclides due to atmospheric precipitation, the CAP88 program uses an approximate calculation method establishing three wind speeds (1 m/s, average wind speed and 6 m/s) for modeling the real wind speed distribution specter for each separate wind direction and atmosphere stability class by Pasquill.

Concentration at the ground surface

Concentrations at the ground surface and in the soil are calculated for the radionuclides subject to dry deposition and washout. The accumulation time for the total deposition is taken to be 100 years. This value establishes 100-year time mark after the radionuclides emission, that is, it is assumed that during this period considerable internal radionuclides supply or external irradiation may occur as a result of their deposition onto the ground. After deposition, the radionuclides transport is represented by separate chamber soil and foodstuffs models.

Growth from the parent radionuclide is calculated using the decay product growth factor which is the ratio of the decay product concentration resulting from an individual share of the parent radionuclide deposited to the decay product itself correspondingly. These factors are calculated for a 100 year accumulation time assuming that the rate of the radionuclides removal from the ground (soil surface) is 2 % per annum.

Individual irradiation doses

For any way of irradiation, the individual dose is calculated using the general equation:

$$H = (E \cdot DF \cdot K)/P$$

where:

E is the exposure value (person-pCu/cm^3);

DF is the dose rate factor (mrem·year/(pCu·m^3);

P is the number of persons subject to irradiation;

K is the proportionality coefficient (10^{-3} nCu/pCu ·10^6 cm^3/m^3).

The coefficients included in this equation are described in detail in the papers of the ICRP Publication No. 72.

Collective irradiation doses

The collective population irradiation doses are obtained by summing up all the domain segments, shares of radionuclides supply with the foodstuffs and through inhaling and the exposure share, multiplied by the relevant proportionality coefficients for the dose (in person-rem/year).

4.2 Brief description of the PC COSYMA model

PC COSYMA (Code System for MARIA) is a software package for modeling the consequences of emergency radioactive substances emissions into the atmosphere. PC COSYMA was jointly developed by the National Radiological Protection Board (Great Britain) and the Forschungszentrum Karlsruhe (Germany) as a part of the MARIA (Methods for Accidental Radiation Impact Assessment) project of the European Commission.

Descriptions of the PC COSYMA package and its separate modules are set forth in the paper [9]. The system is designed for calculation of the radiation impact of emergency (brief) radioactive substance emissions into the atmosphere.

The system makes it possible to assess the following parameters and consequences:

- volumetric activity of the radionuclides in the bottom air level and the activity of particles deposited onto the ground surface in specific terrain points;
- expected individual and collective doses for selected time periods;
- number of people subject to the countermeasures (sheltering, evacuation, distribution of pellets with stable iodine, resettlement, deactivation, limitation of consumption of agricultural products) and the area of the territory covered by the countermeasures;
- amount of agricultural products prohibited for consumption;
- number of lethal and non-lethal diseases;
- economic cost of carrying out countermeasures and medical treatment.

The system can be used for deterministic and probabilistic assessments. The deterministic assessments enable to calculate the consequences of meteorological conditions for one installation, and the probabilistic ones take into account the probable spread of the meteorological conditions during the emergency.

Modeling the contaminants transport in the atmosphere is performed in the MUSEMET module. In this module, the segmented Gaussian spot model is used taking into account hourly wind speed and direction changes, atmosphere stability categories and the amount of precipitation influencing the substances discharged. The model assumes that the meteorological conditions are the same in the whole region of interest. The hourly changes in the meteorological conditions are taken into account only in case of probabilistic assessment. In case of deterministic assessment it is assumed that the meteorological conditions (wind speed and direction, atmosphere stability category and the amount of precipitation) remain unchanged during the whole period of interest. MUSEMET uses the height of the atmosphere layer being mixed, the horizontal and vertical dispersion coefficients which are functions of atmosphere stability. The dispersion coefficients have two parameter values – for even (agricultural regions) and irregular (cities) surfaces.

In this paper, deterministic assessments for one of the most unfavorable weather categories (critical approach) have been used.

Following ways of irradiation of the population may be taken into account in the system: external gamma-radiation from the radionuclides in the emission cloud; internal irradiation from the radionuclides inhaled from the emission cloud; external beta-radiation from the radionuclides deposited onto the skin and clothes; external gamma-radiation from the radionuclides deposited onto the ground surface; internal irradiation from the dust raised from the surface; internal irradiation from the radionuclide-contaminated foodstuffs consumed.

4.3 Description of basic approaches used for modeling

Meteorological parameters

In the calculations concerning normal (non-emergency) operation, meteorological conditions were used typical for the place of location of the NFPP obtained on the basis of distribution by the atmosphere stability categories [10] and the cli-

matic characteristic provided by the Department on the issues of emergency situations and protection of population from the consequences of the Chernobyl accident of the Kirovograd Oblast State Administration (Appendix A). The distribution system by the stability categories by Pasquill/Smith/Hosker has been used.

The choice of meteorological conditions for the emergency situation was performed based on the population irradiation doses calculations, i.e. the most unfavorable meteorological conditions were selected in case of which the doses are maximal (conservative approach). The most unfavorable atmosphere stability category was adopted − D. The height of the layer being mixed is 560 m. The wind speed is 2 m/s. Precipitation – 25 mm/h. It is assumed that the meteorological conditions do not change during the emission cloud movement.

Parameters used in the models

Distribution of the agricultural products on the territory is assumed to be uniform.

In the calculation of the individual doses, conservative assumption was taken that all products consumed were cultivated in the given area.

Calculation for the normal operation mode is performed for the period of one hundred years.

4.4 Brief description of the "Eol-Plus" automated system model for calculation of dispersion of the hazardous substances emissions in the atmosphere

At present, the only approved document on calculations of dispersion of hazardous substances emissions in the atmosphere air is the "Methodology of calculation of concentrations in the atmosphere of hazardous substances contained in the emissions of the enterprises. ODN-86"

The ODN-86 methodology is designed for forecasting the atmosphere air contamination. Modeling the contaminants dispersion with this methodology is based on solving the turbulent diffusion equation. ODN-86 establishes the requirements concerning calculation of concentration of the contaminants in the atmosphere air during deployment and designing of the enterprises, normalization of the emissions into the atmosphere from the existing enterprises and the enterprises under reconstruction as well as in the process of designing air intake installations.

The "OND-86 methodology" approved at the governmental level (as far back as the USSR times) is realized today in the form of the "Eol-Plus" software product. Included in the "Ecologist" workstation, this system is recommended by the Ministry of Ecology and Natural Resources for being used on the territory of Ukraine.

The criteria of assessment of the sanitary and ecologic state of the air are the maximum one-time MPCs of contaminants in the atmosphere air. In the absence of MPC standards, ASIL (approximate safe impact levels) values are used instead.

The "Eol-Plus" automated system for calculations of dispersion of hazardous substances emissions in the atmosphere air is designed for assessment of the impact of the hazardous emissions from the enterprises being designed and the exist-

ing enterprises (or being reconstructed) on the contamination of the bottom air layer.

The system makes it possible to calculate the contamination fields for a contaminants emission source point model with round or rectangular stack orifice, a linear model, two area source models (clearing pool models and models of a source consisting of a number of separate point sources located closely to each other, with the same values of the design and technological characteristics). At the discretion of the user, calculations during assessment of the impact of the enterprises being designed and the enterprises being reconstructed on atmosphere contamination may be performed taking into account the background (existing) concentrations.

During calculation of dispersion, the terrain relief, atmosphere stratification, contaminants deposition coefficient shall be taken into account.

The Eol-Plus automated system functions in the Microsoft Windows 3.x, 9.x and NT/

The calculation module is the principal part of the modeling process. Here automatic assessment of the modeled object (industrial site) impact on the air contamination at the points of calculation is performed.

Principal formula: $C = \text{Max}(\sum Ci)$, where

C is the maximum bottom concentration at the point of calculation (mg/m^3 or in MPC shares).

Ci is the concentration created by separate sources included in calculation.

Ci is a function of the sources characteristics, meteorological and geographic conditions in the region, wind speed, wind direction and location of the point of calculation and the emission source.

For determination of the risk of contamination of the bottom layer of the atmosphere air as a result of contaminants emissions, the highest concentration of these substances is calculated at the point of calculation corresponding to the most unfavorable conditions (when the wind speed reaches the dangerous value of $u_м$, intensive vertical turbulent exchange is observed).

Maximum concentration is the result of aggregating many concentrations created by the sources at different wind speeds and different wind directions.

Calculations determine the one-time concentrations of the contaminants belonging to the 20-30 minute averaging interval

Main distinctive features of calculations:

Support of extremal modeling of situations. The system automatically selects the most negative atmosphere contamination forecast within the framework of obtaining the maximum concentration at the design site.

Support of the relative atmosphere state assessment. The system supports calculation of the concentration in absolute units (mg/m^3) as well as in relative units (MPC (maximum permissible concentration) shares).

Two modeling stages. Modeling includes two stages:

Calculation of eventual impact of sources on the air contamination;

Calculation of concentrations at the points of calculation;

Such an approach enables to speed up the calculation process due to minimization of calculation iterations and the possibility of ignoring a part of emissions after the first stage.

Support of background assessment. It is possible to assess the existing background concentration levels known as the results of measurements without including all sources producing the background concentrations. If it is necessary to assess the existing source, it is possible to exclude the background impact on the concentration levels before the calculation.

5 Characteristic of possible types of impact on the environment objects

The strongest impact on the environment will be exerted after the full deployment of the enterprise. From the point of view of eventual transborder impact, emissions transport is assessed both for the normal conditions of operation of the plant and the emergency conditions. At that, impact on the air is assessed as a result of:

− non-radioactive emissions into the atmosphere (chemical impact);
− radioactive emissions into the atmosphere (radiation impact).

5.1 Impact in the conditions of normal operation

During operation of the NFPP, negative impact on the natural environment and the population is possible as a result of emission of radioactive and chemical contaminants from the processing equipment of the mainline and auxiliary productions located at the industrial site of the plant. Emission of contaminants will take place through the systems of local and general exhaust ventilation with mechanical drive.

The outgoing air mixtures are purified in the gas purification systems and then discharged into the atmosphere.

Chemical impact

The expected contamination estimate indicators [11] by all contaminants do not exceed the values of the maximum permissible concentrations both at the design SPZ boundary and beyond it, including the territory of the apartment block.

The maximum share of the emissions from the enterprise in the contamination of the atmosphere air with chemical substances in the conditions of normal operation at the SPZ boundary is forecast by the nitrogen dioxide and will not exceed 0.36 $MPC_{м.р.}$ shares. The maximum values of the calculated bottom contaminants concentrations taking into account the background contamination will not exceed: up to 0.51 $MPC_{м.р.}$ shares by xylene (I stage) and 0,43 $MPC_{м.р.}$ shares by zirconium and its non-organic compounds (full deployment), that is 1.9 to 2.3 times less than the permissible level.

The maximum contribution of the plant production complex to the atmosphere air contamination with chemical contaminants at the boundary of the nearest

residential area is forecast by the nitrogen dioxide and will not exceed 0.1 $МРС_{м.р.}$ shares. The expected maximum concentrations of contaminants taking into account the background contamination at the boundary of the nearest apartment block will not exceed 0,41 $МРС_{м.р.}$ shares (by zirconium and its non-organic compounds), that is 2.44 times less than the permissible level.

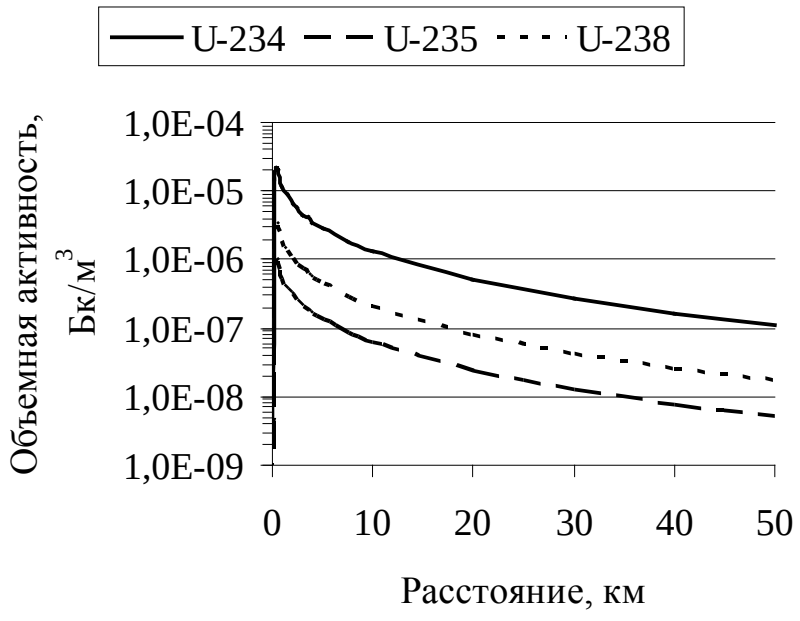
The zone of influence of the enterprise by chemical impact, the territory, on which the aggregate concentration due to the whole set of emission sources of this enterprise, including the low and not-organized sources, will exceed 0,05 $МРС_{м.р.}$ (OND-86), will be not more than 2.75 km after full deployment of the enterprise [11].

Consequently, the chemical impact of the gas and aerosol emissions of the nuclear fuel production plant at its normal operation on the neighboring countries (the distance to the closest one, the Republic of Moldova, making 166 km) will not exceed the normative values for contaminants concentrations in the atmosphere air for populated areas.

Radiation impact

Radiation impact of the nuclear fuel production plant on the natural environment and people is possible as a result of radioactive contaminants emissions into atmosphere from the mainline production. The main contributors are the U-234, U-235 and U-238 uranium isotopes.

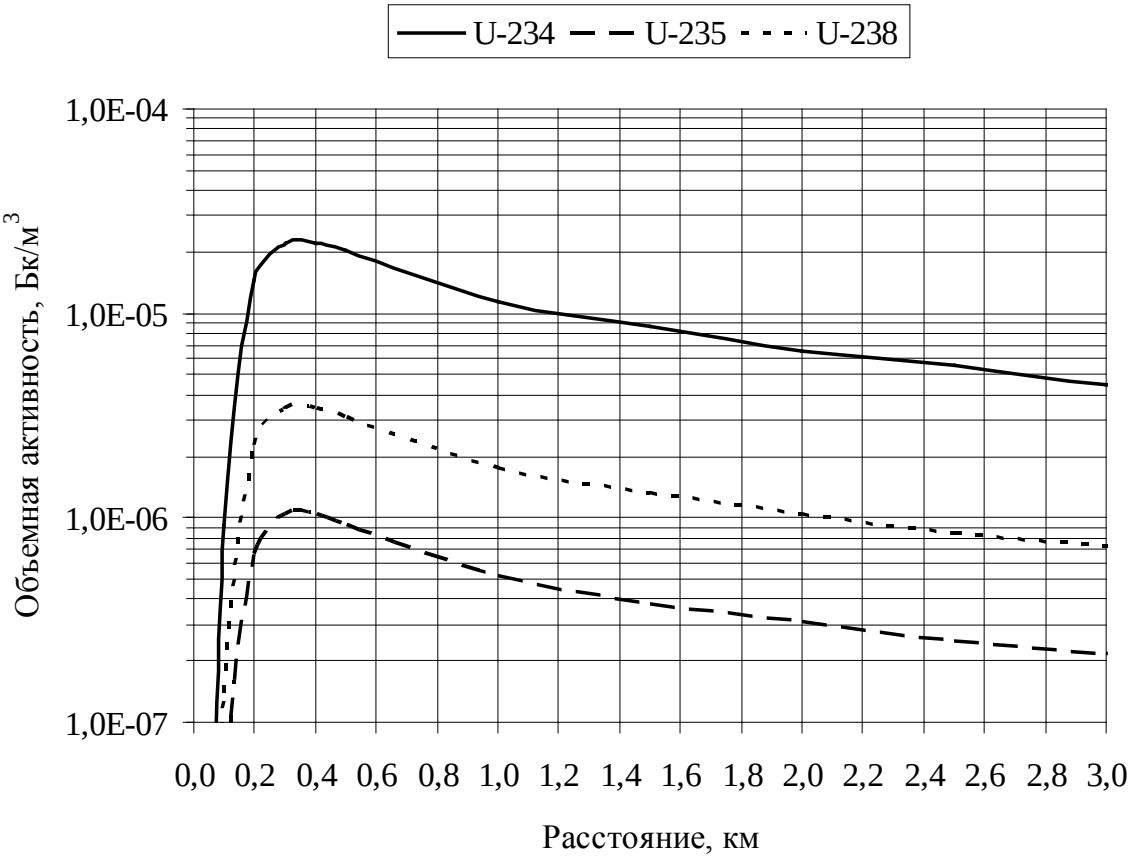
The results of calculations of volumetric activity of the uranium isotopes in the bottom layer of the atmosphere air [1] and precipitation density depending on the distance in normal operation mode after the full deployment of the enterprise are shown in Figures 5.1 and 5.2 as well as in the Appendix B.



Volumetric activity, Bq/m^3

Distance, km

a)



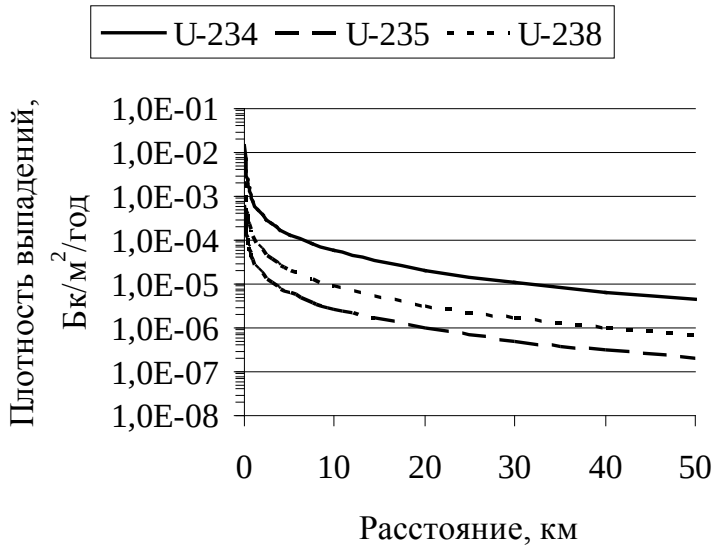
Volumetric activity, Bq/m^3

Distance, km

b)

Figure 5.1 – Dependence of the expected volumetric activity of the uranium isotopes in the atmosphere air bottom layer on the distance in the normal operation mode.

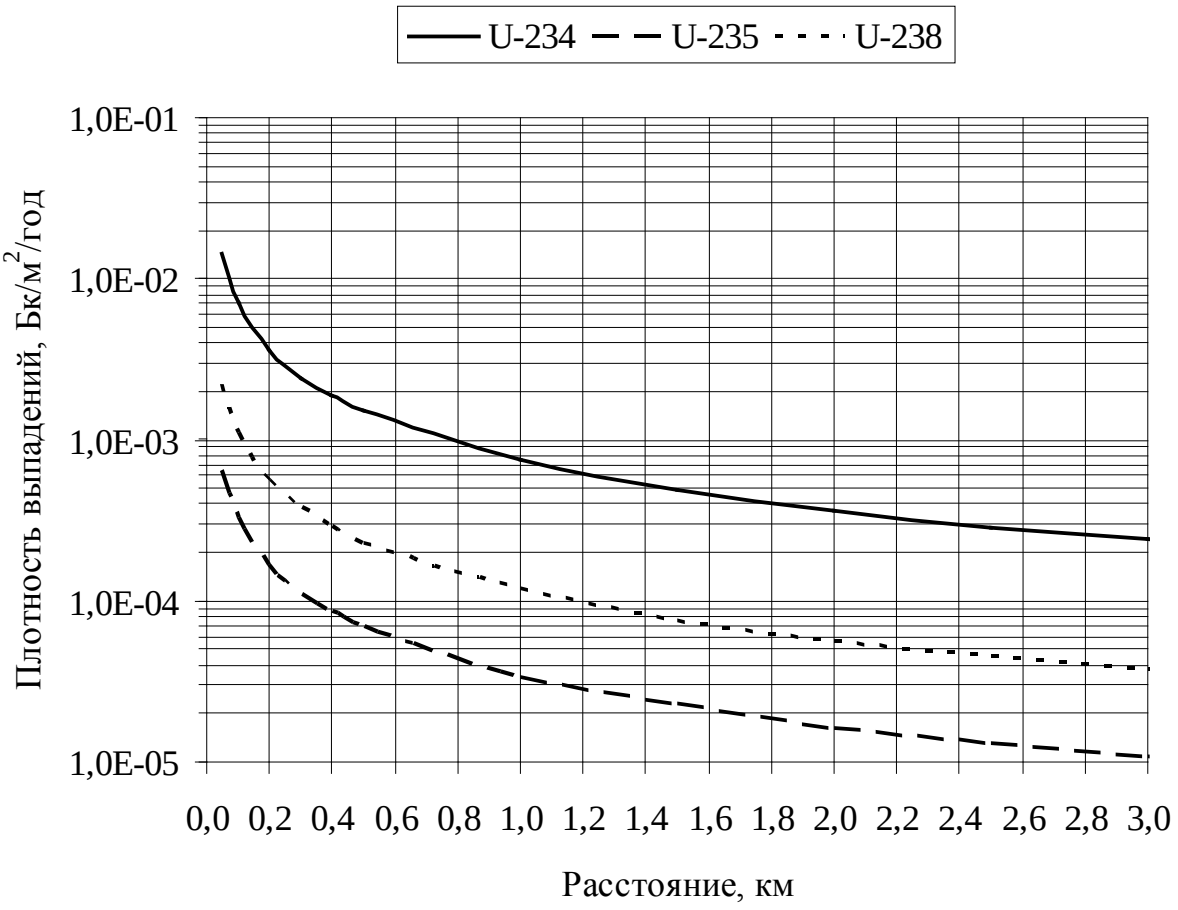
One can see that the maximum volumetric activities will be for the U-234 isotope: up to $2.3 \cdot 10^{-5}$ Bq/m^3 (after full deployment). This values are 2 and more tens of times less than the permissible levels for the V category (population) according to the NRBU-97 (Norms of radiation security of Ukraine) ($2 \cdot 10^{-3}$ Bq/m^3 for the U-234, and $3 \cdot 10^{-3}$ Bq/m^3 for the U-235 and U-238).



Precipitation density, Bq/m^2/year

Distance, km

a)



Precipitation density, Bq/m^2/year

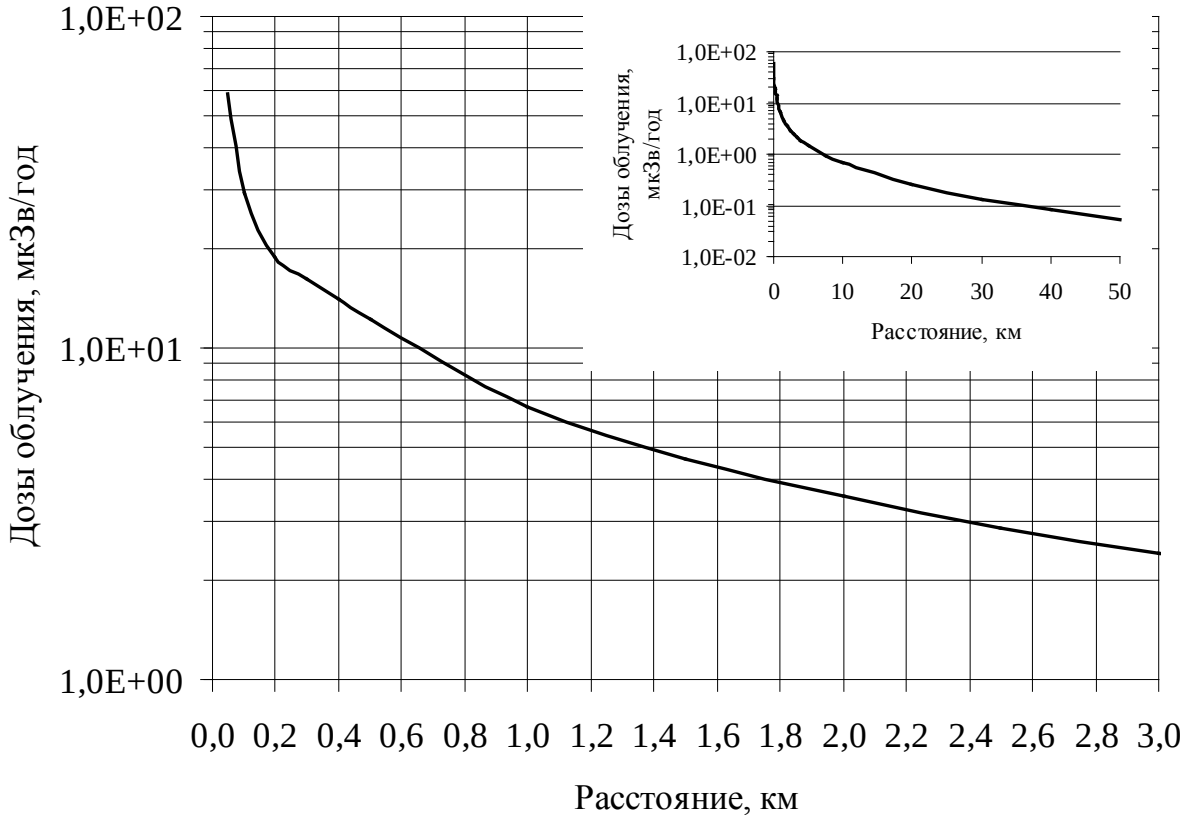
Distance, km

b)

Figure 5.2 – Dependence of the expected precipitation density of the uranium isotopes on the distance in the normal operation mode.

The maximum density of precipitation onto the ground surface is observed in case of the U-234 isotope: up to $1.43 \cdot 10^{-2}$ Bq/(m^2·year)

The results of calculations of the expected population irradiation doses [1] depending on the distance for the normal operation mode after full deployment are shown in Figure 5.3 and in the Appendix B. The figure shows the maximum doses (southward).



Irradiation doses, μSv/year

Distance, km

Figure 5.3 – Dependence of the expected population irradiation doses on the distance in the normal operation mode (full production deployment).

The figure shows that the dose limit quota for all ways of dose formation due to the plant RT equipment emissions – 0,1 mSv/year (100 μSv/year) according to the NRBU-97, – is not exceeded (irrespective of the place of residence of the critical population group). The maximum doses will be at the minimum distance from the emission source (50 m): up to 0.0582 mSv/year (after full deployment).

Analysis of the above material makes it possible to draw a conclusion that already at the distance of 50 km the value of the yearly individual effective dose will not exceed $5.34 \cdot 10^{-5}$ mSv/year (Appendix B), so the impact on the neighboring countries will be considerably less than the dose quotas established (for

Ukraine, according to NRBU-97, – 0.200 mSv/year, for most European countries it is higher) and the individual effective yearly dose limit of 1 mSv.

5.2 Impact in case of accidents

Apart from the impact of the contaminant emissions in the normal mode of operation of the nuclear fuel production plant, the project assesses the impact of the design and out-of-design accidents.

Following accidents are considered in the project:

1 Design accidents:

1.1 Spill of the uranium dioxide powder in case of drop of a container, during such accidents uranium compounds aerosols emissions are possible.

1.2 Seal failure of the pipeline with the uranium hexafluoride, in which case uranium compounds aerosols and anhydrous hydrogen fluoride emissions occur.

1.3 Seal failure of the hydrofluoric acid container; in case of such an accident hydrogen fluoride emissions may occur.

1.4 Electric power failure during which diesel power station are working emitting exhaust gases into the atmosphere.

1.5 Spill-out of hydrofluoric acid in the prepackage premises of the hydrofluoric acid storage site.

1.6 Spill-out of hydrofluoric acid at the hydrofluoric acid storage site.

2 Out-of-design accident:

2.1 Self-sustained chain reaction.

Time of liquidation of the accidents cited in 1.1, 1.2 and 1.3 will make 5 to 20 minutes according to the information of the OJSC "GSPI" (Moscow). In case of an accident cited in 1.4, the maximum time of operation of the reserve diesel power stations will make 24 hours. In case of accidents cited in 1.5 and 1.6, the time of liquidation of the emergency situations will make 0.2 to 0.5 hours correspondingly.

Chemical impact

Analysis of the dispersion calculations performed showed that the expected estimate indicators of contamination during accidents do not exceed by all contaminants the maximum permitted concentrations both at the SPZ boundary and beyond it.

During the period of emergency situations in the manufacturing building, the maximum calculated concentrations of contaminants, taking into account the background at the SPZ boundary, formed due to emissions from all enterprise sources, including the emergency emission, are expected to be in case of seal failure of the hydrofluoric acid container and anhydrous hydrogen fluoride getting into the air (Accident cited in 1.2).

At the same time, the maximum contribution share of the anhydrous hydrogen fluoride in the air contamination at the SPZ boundary will not exceed 0.47 $MPC_{м.р.}$ shares. The maximum values of the calculated bottom layer concentrations

of the anhydrous hydrogen fluoride taking into account the background contamination will not exceed 0.87 $MPC_{м.р}$ shares.

The expected maximum anhydrous hydrogen fluoride concentrations taking into account the background contamination during the accident under consideration at the boundary of the nearest apartment block will not exceed 0.6 $MPC_{м.р.}$ shares, i.e. 1,67 times less than the permitted level.

The work of the reserve diesel-generator power stations in case of the main electric power supply failure due to general causes will result in atmosphere air contamination (Accident cited in 1.4). The maximum contaminants concentrations taking into account background contamination will not exceed: at the SPZ boundary – 0,41 $MPC_{м.р}$ shares, at the boundary of the nearest apartment block – up to 0.403 $MPC_{м.р}$ shares.

The expected bottom layer contaminants concentrations during the work of the DPS are less than the permitted level: 2.43 times at the SPZ boundary, 2.48 times at the boundary of the nearest apartment block.

The maximum contribution share of the anhydrous hydrogen fluoride emissions in the atmosphere air contamination at the SPZ boundary in case of the accident cited in 1.6 will not exceed 0.37 $MPC_{м.р.}$ shares. The maximum values of the calculated bottom layer concentrations by the anhydrous hydrogen fluoride taking into account the background contamination at the boundary of the nearest apartment block in case of the Accident No. 5 will not exceed 0.42 $MPC_{м.р}$ shares, i.e. 2.39 less than the permitted level.

Thus, the degree of expected air contamination with chemical contaminants from the plant emission sources in emergency situations is within the limits complying with the requirements of the DSP 201-97 “State sanitary rules on protection of the atmosphere air of the populated areas”.

In view of the above, a conclusion may be drawn that in case of the design accidents, the impact on the neighboring countries (the nearest one is situated at the distance of 166 km) in consequence of chemical contaminant emissions will not exceed the standard values for populated areas as already at the SPZ boundary (1100 m) these requirements are met and the maximum contribution share of the contaminants emissions in the air contamination at the boundary of the nearest apartment block (2100 m) decreases considerably (3 to 19 times depending on accidents and substances).

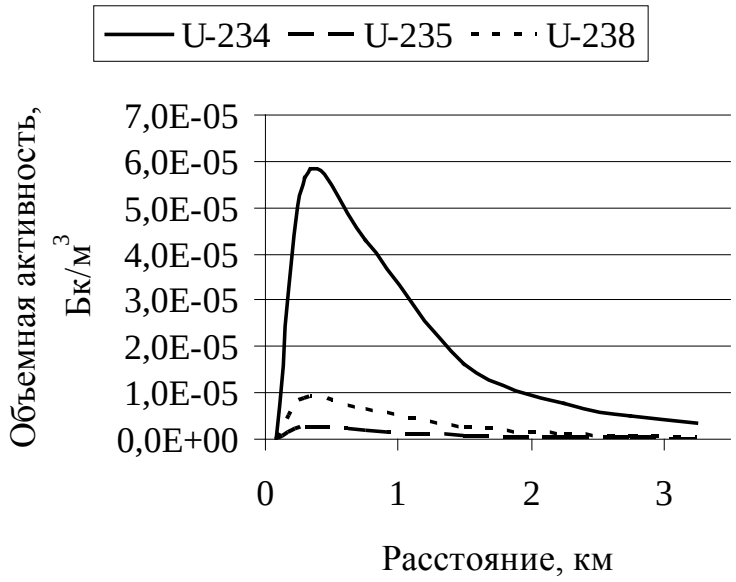
Radiation impact

Radioactive substances are emitted in case of design accidents cited in 1.1 and 1.2 as well as the out-of-design accident cited in 2.1.

In case of the design accident cited in 1.1, with drop onto the floor of the container (V=330 l, m=700 kg) with the UDO powder in the process of handling, removal of the substances that got into the air is performed with the general exhaust air after purification from the radioactive substances at the aerosol filters. Emission is performed through a stack 55 m in height and 3.6 m in diameter. Uranium isotopes emission which makes the largest contribution is: U-234 – 370.4 Bq; U-235 – 15.4 Bq; U-238 – 52.5 Bq [1, 12].

In case of the design accident cited in 1.2, with seal failure of the pipeline with the UHF before the automatic system actuation or manual shutdown, UHF evaporation occurs with its subsequent getting into the air of the UHF powder production area premises. Removal of the substances that got into the air is performed with the general exhaust air after purification from the radioactive substances at the aerosol filters. Emission is performed through a stack 55 m in height and 3.6 m in diameter. Uranium isotopes emission taking place during such an accident which makes the largest contribution is: U-234 – 17690 Bq; U-235 – 737 Bq; U-238 – 2506 Bq [1, 12].

The maximum design accident with emission of radioactive substances into the environment will be the accident cited in 1.2, during which seal failure of the pipeline with the UHF occurs. The results of calculations of uranium isotopes volumetric activity in the bottom layer of the atmosphere air depending on the distance are shown in Figures 5.3 and 5.4 and in the Appendix B.



Volumetric activity, Bq/m^3

Distance, km

Figure 5.3 – Dependence of the expected volumetric activity of the uranium isotopes in the atmosphere air bottom layer on the distance in case of accident 1.2

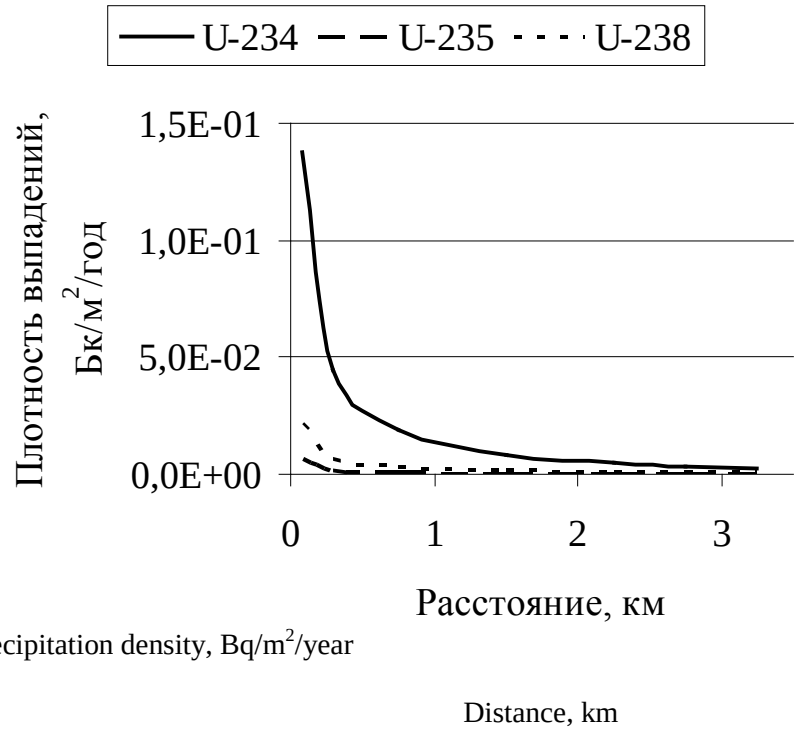


Figure 5.4 – Dependence of the expected precipitation density on the distance in case of accident 1.2.

The calculation results show that the maximum activities are expected at the distance of 250 m, and at 2100 m, where the nearest residential buildings of the local population are located, they decrease considerably. The maximum values are expected for U-234 – up to $5.7 \cdot 10^{-5}$ Bq/m^3, which is 35 times less than the permissible level for the category V (population) according to the NRBU-97 ($2 \cdot 10^{-3}$ Bq/m^3 for U-234).

The maximum precipitation activities are expected at the distance of 150 to 200 m. At the distance of 2100 m, where the local people reside, the activity decreases considerably. The maximum values are expected for U-234 – up to 0.14 Bq/m^2.

The results of calculations of the expected population irradiation doses [1] depending on the distance in case of this accident are shown in Figure 5.5 and in the Appendix B.

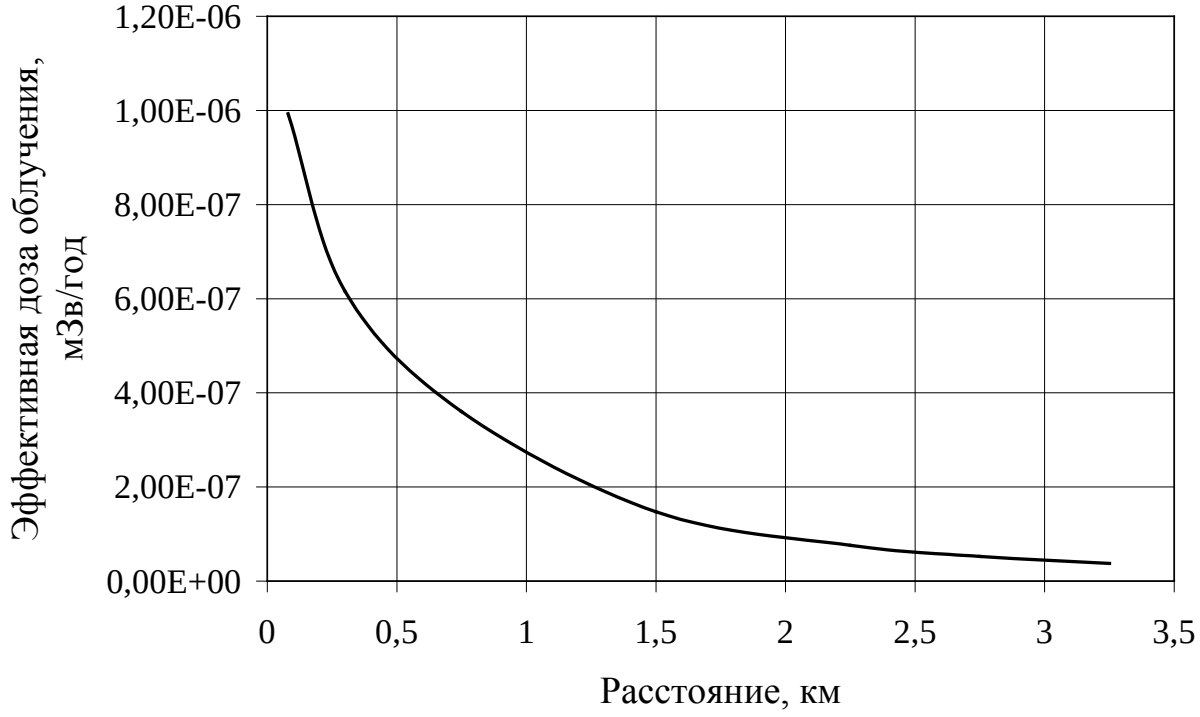


Figure 5.5 – Dependence of the expected effective population irradiation doses on the distance in case of accident 1.2.

The values of effective population irradiation doses in case of the accident 1.2 at the SPZ boundary (500 m) and the boundary of the nearest apartment block (2100 m) are $5 \cdot 10^{-7}$ mSv/year and $0.9 \cdot 10^{-7}$ mSv/year correspondingly which does not exceed the doze limit quota for all ways of formation of doses due to emissions – 0.1 mSv/year (100 μSv/year) according to NRBU-97.

In case of the out-of-design accident 2.1, according to the initial data of the OJSC “GSPI”, as a result of unaccounted occurrences spontaneous chain reaction takes place with the fissions number of 10^{18}.

Possible radionuclides emissions into the atmosphere during an accident are given in table 5.1.

Table 5.1 – Emission of radioactive substances into the atmosphere (out-of-design accident 2.1)

Nuclide	Emission into the atmosphere, Bq
Krypton-87	$3.3 \cdot 10^{11}$
Krypton-88	$2.3 \cdot 10^{11}$
Krypton-89* (rubidium-89)	$3.0 \cdot 10^{12}$ ($6.12 \cdot 10^{11}$)
Xenon-137* (cesium-137)	$1.3 \cdot 10^{13}$ ($3.13 \cdot 10^{6}$)
Xenon-138	$3.7 \cdot 10^{12}$
Iodine-131	$4.7 \cdot 10^{8}$
Iodine-133	$1.0 \cdot 10^{10}$
Iodine-135	$8.5 \cdot 10^{10}$
Antimony-130	$4.0 \cdot 10^{11}$
Tellurium-132	$1.5 \cdot 10^{8}$
Tellurium-133m	$4.0 \cdot 10^{11}$
Tellurium-134	$1.8 \cdot 10^{11}$
Strontium-90	$4.5 \cdot 10^{5}$
Strontium-91	$1.1 \cdot 10^{10}$
Strontium-92	$4.2 \cdot 10^{10}$
Cesium-137	$4.3 \cdot 10^{5}$
Barium-140	$4.0 \cdot 10^{8}$
Molybdenum-99	$5.4 \cdot 10^{8}$

* – As krypton-89 and xenon-137 are not biologically significant radionuclides due to their short half-life, their emission is taken into account through taking account of the activity of the relevant emissions of their daughter decay products (rubidium-89 and cesium-137).

According to the materials of the OJSC “GSPI”, radionuclides emission into the air may occur during 20 minutes.

During performing calculations it is assumed that the radioactive fission products are emitted through the ventilation system and the stack 55 m in height and 3.6 m in diameter.

According to the calculation results (Appendix B), maximum activities are expected at the distance of 250 m, and getting closer to the distance of 2100 m where the nearest buildings are located (beginning of the residential area), and where the local population resides, they decrease considerably. Maximum values are expected for the IRG, I-135 and Te-133m – up to 700 Bq/m^3.

Maximum precipitation activity is expected at the distance of 150 to 200 m. Maximum values are expected for the Sb-130 and Te-133m – up to $1{,}6 \cdot 10^6$ Bq/m^2. At the distance of 2100 m, where the local population resides, the activity decreases considerably.

The results of calculations of the expected population irradiation doses [1] depending on the distance in case of this accident are shown in Figure 5.6 and in the Appendix B.

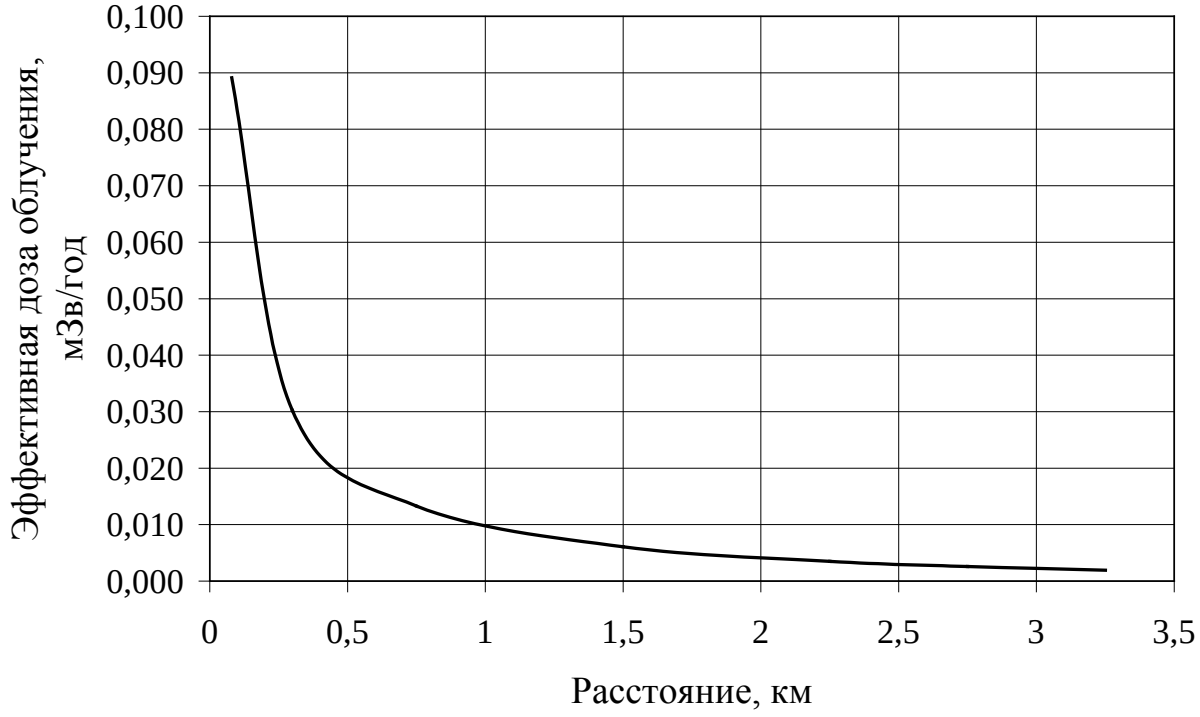


Figure 5.6 – Dependence of the expected effective population irradiation doses on the distance in case of the out-of-design accident 2.1.

The values of effective population irradiation doses in case of the accident 2.1 at the SPZ boundary (500 m) and the boundary of the nearest apartment block (2100 m) are $2.3 \cdot 10^{-2}$ mSv/year and $3.8 \cdot 10^{-3}$ mSv/year correspondingly which does not exceed the doze limit quota for all ways of formation of doses due to emissions – 0.1 mSv/year (100 μSv/year) according to NRBU-97.

5.3 Conclusions

1. Chemical impact of the gas and aerosol emissions of the nuclear fuel production plant in the normal operating mode and in case of accidents on the neighboring countries will not exceed the normative values of contaminants concentration in the atmosphere air for populated areas. At the boundary of the nearest apartment block (2.1 km) the value of the maximum contaminants concentration in the atmosphere air is considerably less than the maximum permissible values (up to 20 times – in the normal plant operating mode, and up to 19 times – in case of accidents).

2. Radiation impact of the gas and aerosol emissions of the nuclear fuel production plant in the normal operating mode is considerably less than the dose limits established for the population of the neighboring countries (this limitation varies for different countries, mainly within 0.2 to 0.3 mSv/year, WS-G-2.3). Already at

the boundary of the nearest apartment block (2.1 km) the value of the yearly individual effective dose will not exceed $3.5 \cdot 10^{-3}$ mSv/year, and at the distance of 50 km – $5.34 \cdot 10^{-5}$ mSv/year.

3. The basic criterion of limitation of population irradiation in Europe in consequence of anthropogenic sources is the individual effective dose limit (by all irradiation ways) which is established at the level of 1 mSv/year. The assessment performed showed that neither of the accidents considered will result in exceeding the individual yearly effective dose for the population at the boundary of the nearest residential building (2.1 km) and, consequently, in the neighboring countries it will not be exceeded, too, as the border of the nearest country (Republic of Moldova) is at the distance of 166 km.

4. In normal operating mode of the nuclear fuel production plant as well as in case of accidents, there is no environmental impact in the transborder context, i.e. on the territory of the neighboring countries, as the normative requirements to air contamination and dose limits for the population are not exceeded even on the territory of Ukraine, at the boundary of the nearest apartment block (2.1 km) they are considerably less than the permitted levels.

5. There is no considerable transborder impact of the planned activity and, according to the “On assessment of environmental impact in transborder context” convention, there is no affected party. For providing for the public availability of the information, it will be sufficient to place the materials on assessment of the environmental impact in the transborder context at the public resources in Internet, such as, for example, the sites of the state bodies concerned: the Ministry of Ecology and Natural Resources and the Ministry of Energy and Coal Industry.

6 Measures aimed at decreasing the adverse environmental impact

For minimizing the negative environmental impact in the process of economic activity of the plant, measures are provided for the basic ones of which are described below.

The resource-saving measures include the issues of use of the land, water and fuel and energy resources:

- location of the site on industrial land, within the limits of the Smolino mine ground allotment;
- location of the site at a sufficient distance from residential areas, mineral resources research development areas, woodlands, surface water bodies, nature protection fund, history and culture objects;
- treatment of the resulting waste and recovery of the valuable components to be used again in the technological processes;
- reuse of the regenerated water from the LRW (liquid radioactive waste) treatment installation;
- use of a circulating water consumption system.

Protective measures provided for in the project include the relevant architectural, building and layout solutions as well as measures aimed at decreasing the radiation and non-radiation environmental impact.

The design of industrial buildings and premises is based on the main hygienic principle – their distribution by zones depending on the character of technological processes, the nature and possible level of contamination of the premises with radioactive substances.

One of the most important measures is providing for tightness of the buildings and equipment where radioactive substances and media are processed and stored.

For decreasing the negative environmental impact, a number of layout measures are provided for:

- layout of the territory providing for prompt discharge of atmospheric precipitation;
- arrangement of watertight blind areas around the buildings;
- arrangement of security observation wells network;
- organization of a buffer area and observation zone;
- organization of physical protection and plant security;
- cleaning the rainfall runoff at the purification installations;
- planting of greenery on the undeveloped territory.

General technological protective measures providing for minimization of the negative impact from the plant activity on the environment and people include:

- observance of the technological parameters of the technological complexes operation;
- production electric power supply under the I reliability category;
- training of the personnel in safe work procedures and actions in emergency situations;

- purification of the outgoing gas and air compounds before their discharge into the atmosphere;

- use of systems of detection of liquid and gaseous substances (UF_6, HF, H_2) leakages which might result in discharge of radioactive and toxic substances to working premises and the environment;

- installation of reservoirs with liquids in drip pans preventing from their spilling out;

- organization of collection, treatment and utilization of industrial waste;

- availability of a technological accidents localization system.

Technical measures:

- use of leak-proof technological equipment;

- use of automated technological equipment with remote control;

- use of leak-proof certified containers for storage of source products, finished products and inter-operational transport operations;

- fitting the technological equipment out with ventilation suction units with a gas purification system before the gas discharge into the atmosphere;

- multi-stage gas purification before the discharge into the atmosphere;

- combination of the areas where radioactive substances are worked with within separate premises separated by walls from other premises;

- deactivation of the surfaces of equipment and premises;

- arrangement of sanitary locks at the entrances to premises with technological equipment;

- organization of a sanitary inspection room at the administration and utility building with a radiation control post;

- organization of an automated radiation control system;

- automated radiation situation control system at the SPZ and CA;

- control of radionuclides emissions into the atmosphere and the liquid waste discharge;

- complex of measures providing for nuclear safety in the process of plant operation and eliminating the possibility of self-sustaining chain reaction;

- organization of an emergency signalization system for the cases of nuclear accident (occurrence of self-sustaining chain reaction);

- automated nuclear security parameters control in the technological equipment, including control of nuclear materials (NM), NM concentration in solutions, accumulation of NM in the equipment and service lines.

Security measures provided for in the project include:

- functioning of a radiation situation control system at the plant site, in the SPZ and CA;

- functioning of a system for monitoring the state of the atmosphere air, surface and underground waters, geological processes and soil, vegetation and foodstuffs state;

- functioning of control and management systems at the plant;

- functioning of a fire-prevention system;

- functioning of a warning system.

LIST OF ABBREVIATIONS

AUB	Administrative and utility building
NPP	Nuclear power plant
VVER-1000	Water-moderated water-cooled power reactor
UHF	Uranium hexafluoride
UDO	Uranium dioxide
DPS	Diesel power station
CA	Control area
NFPP	Nuclear fuel power plant
IAEA	International Atomic Energy Agency
IRPC	International Radiologic Protection Commission
NMVOC	Non-methane volatile organic compounds
OJSC «GSPI»	Open joint-stock company “State Specialized Project Institute”
$MPC_{м.р.}$	Maximum permissible concentration, maximum one-time value for the residential area atmosphere
RT	Radiation technologies
SPZ	Sanitary protection zone
FA	Fuel assembly
FE	Fuel element

LIST OF TERMS AND DEFINITIONS

Radiation accident	Any event at any object with radiation or radiation nuclear technology when control over the source is lost and there is a possibility of irradiation of people connected with the loss of control over the source.
Gas and aerosol emission	Discharge into the atmosphere of radioactive substances from technological lines and ventilation systems of the enterprise.
Sanitary protection zone (SPZ)	Territory around the radiation nuclear object where the population irradiation level in the normal operation conditions may exceed the dose limit. In the SPZ, residence of people is prohibited, limitations are established for industrial activity not related to the radiation nuclear object, and radiation control is performed.
Control area (CA)	Territory, on which impact of radiation discharge and radiation nuclear object emissions is possible in case of technical accidents and anomalies, where monitoring of technological processes is performed with the view of providing for radiation security of the radiation nuclear object.
V category	All population.
Doze limit quota	Doze limit share for the V category apportioned for the normal operation mode of a separate industrial source (in this document, quota for a plant with radiotechnologies (RT plant) is used – 100 μSv for all emission dose formation ways).
Critical group	Part of the population which by their sex and age, social and professional conditions and the place of residence or by any other factors gets or may get the maximum irradiation dose from the given source.

Dose limit	The main radiation-hygienic normative aimed at limitation of irradiation of persons of the A, B, V categories from all industrial sources of ionizing radiation in the practical activity situations.
Radiation nuclear object	Any substances, equipment or installations that contain or may contain nuclear materials or ionizing radiation sources (energy, industrial, research, experimental reactors, devices, installations, stands, equipment, instruments, stores, vehicles as well as electric power plants, productions, technological complexes using such technical facilities, including the ones related to development, production, research, testing, processing, transportation, storage of nuclear explosive devices).
Parties	Contractual parties of the Convention on assessment of the environmental impact in the transborder context.
Transborder impact	Any impact, not only of global nature, in the region under the jurisdiction of some or other Party, caused by a planned activity, the physical source of which is situated fully or in part within a region being under the jurisdiction of another Party.

REFERENCE NORMATIVE DOCUMENTS

Designation of the document referenced	Number of the section, subsection, item, subitem, lists, appendices, documents under development including the reference
1	2
DBN A.2.2-1-2003 "Composition and content of materials related to environmental impact assessment (EIA) in the process of designing and construction of enterprises, buildings and installations". State Building administration of Ukraine, 2004.	Introduction
Convention “On assessment of the environmental impact in the transborder context.” Convention was ratified by the Law of Ukraine No. 534-XIV of 19.03.99.	Introduction Conclusions
Convention “On access to information, participation of the community in the decision taking process and access to justice in respect of issues relating to environment” (Arhus Convention) Convention was ratified by the Law of Ukraine No. 832-XIV of 06.07.1999 . With amendments of 27.05.2005.	Conclusions
OSPORBU Basic sanitary rules for providing for the radiation safety of Ukraine. Approved by the Ministry of Health Protection of Ukraine, order No. 54 of 02.02.2005. K: MHP of Ukraine, 2000. – 115 pp.	Section 1
NRBU-97 Norms of radiation Security of Ukraine. Series “Security of Ukraine”. K: MHP of Ukraine, 1997. – 127 pp.	Section 5

1	2
OND-86 Methodology of calculation of concentration in the atmosphere air of contaminants contained in the enterprises emissions. L., Gidrometeoizdat, 1987.	Section 4,5
SP 534-65 Sanitary rules of designing, equipping and maintaining stores for storage of strong toxic substances (STS). Approved by the Deputy Chief Sanitary Inspector of the USSR P. L. YARSKY 24 June 1965 No. 534-65	Section 1
ICRP Publication No. 72 ICRP72 International Commission on Radiological Protection, “Age Dependent Doses to Members of the Public from Intake of Radionuclides, Part 5. Compilation of Ingestion and Inhalation Dose Coefficients” ICRP Publication 72, Pergamon Press, Oxford, 1996	Section 4
No.WS-G-2.3 SAFETY STANDARDS SERIES REGULATORY CONTROL OF RADIOACTIVE DISCHARGES TO THE ENVIRONMENT. INTERNATIONAL ATOMIC ENERGY AGENCY VIENNA, 2000.	Section 5

APPENDIX A

Characteristic of the basic climate elements

UKRAINE

Kirovograd oblast state administration

DEPARTMENT ON THE ISSUES OF EMERGENCY SITUATIONS AND PROTECTION OF POPULATION FROM THE CONSEQUENCES OF THE CHERNOBYL ACCIDENT

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12 May 2011 No.18/07-081317 /

To First Deputy Head of the oblast state administration A. I. NIKOLAYENKO

On the characteristics of the Smoline urban settlement basic climate elements

By way of fulfillment of your assignment and according to the Agreement memorandum between the Kirovograd oblast state administration, Kirovograd oblast council and the State concern "Nuclear fuel" concerning deployment of uranium production in Kirovograd oblast as an indispensable part of the nuclear fuel cycle of Ukraine, we provide here the climatic characteristic of the Kirovograd oblast with the emphasis on the Maloviskivsky region, particularly the Smoline urban settlement, according to the information of the Kirovograd oblast hydrometeorology centre of 12 May 2011 No. 537 on the characteristics of the basic climate elements by the results of observation performed by the Novomirgorod meteorological station, the closest one to the Smoline urban settlement of the Maloviskivsky region, which is representative for this territory.

Data for the town of Novomirgorod

Months	1	2	3	4	5	6	7	8	9	10	11	12
1. Average monthly air temperature, ºC	-6.0	-3.5	0.3	8.7	15.1	18.2	19.6	18.9	14.2	7.9	2.1	-2.5
2. Aggregate precipitation per month in mm	35	35	33	38	45	80	79	55	40	30	41	47
3. Average yearly air temperature, ºC	+7.7											
4. Aggregate yearly precipitation in mm	558											
5. Average maximum air temperature in the warmest month – June, ºC	+25.4											
6. Average minimum air temperature in the coldest month – January , ºC	-8.9											
7. Repeatability (%) of the wind direction (wind rose) and calm during the year:												
Wind directions (rhumbs):	N	NE	E	SE	S	SW	W	NW	Calm			
Repeatability in %	18.2	15.1	11.3	12.5	12.6	11.2	9.3	9.8	20.5			
8. Stratification coefficient	A = 200											
9. Coefficient taking into account the terrain relief influence	1											

Wind speed probability by gradations (in % of the total number of cases)

month	**Speed in m/s, %**												
	0-1	**2-3**	**4-5**	**6-7**	**8-9**	**10-11**	**12-13**	**14-15**	**16-17**	**18-20**	**21-24**	**25-28**	**29-34**
January	31.7	21.3	18.6	12.9	9.0	4.1	0.9	0.8	0.4	0.2		0.1	
February	28.0	21.0	18.9	15.5	8.3	5.6	1.6	0.7	0.4	0.05			
March	29.0	20.8	19.1	13.4	10.0	4.2	1.6	0.8	0.7	0.4			
April	31.4	23.0	21.3	12.3	6.5	3.2	1.1	0.7	0.5				

May	31.5	23.8	21.0	10.9	8.0	3.5	0.6	0.4	0.3				
June	39.8	25.1	19.2	10.2	3.8	1.4	0.3	0.1	0.1	0.05			
July	44.1	25.9	17.3	7.9	3.1	1.3	0.2	0.03	0.1	0.03			
August	42.8	24.7	18.2	8.7	3.3	1.4	0.4	0.4	0.1	0.03			
September	43.4	24.7	17.9	8.3	4.1	1.0	0.3	0.2	0.1				
October	39.5	23.1	19.5	9.8	5.0	2.0	0.3	0.5	0.2	0.1			
November	29.5	23.7	21.2	13.8	7.5	2.9	0.5	0.5	0.4				
December	30.1	22.1	20.1	13.8	8.7	3.4	1.1	0.5	0.2	0.05			
Yearly	35.1	23.3	19.3	11.4	6.5	2.8	0.7	0.5	0.3	0.1		0.01	

Head of Department /SIGNATURE/ **G. DEMORATSKY**

APPENDIX B

Calculations on radiation impact

Table B.1 – Results of calculations of the maximum expected population irradiation doses after radiation accidents

Distance, km	Effective dose, Sv/year
Radiation accident 1.1 (design) - Drop of the container with the uranium dioxide powder	
0,08	2,08E-11
0,3	1,29E-11
0,75	7,54E-12
1,5	3,07E-12
2,25	1,59E-12
2,75	1,10E-12
3,25	7,88E-13
Radiation accident 1.2 (design) - Seal failure of the pipeline with the UHF with evaporation	
0,08	9,93E-10
0,3	6,16E-10
0,75	3,60E-10
1,5	1,47E-10
2,25	7,59E-11
2,75	5,25E-11
3,25	3,76E-11
Radiation accident 2.1 (out-of-design) - Self-sustained chain reaction	
0,08	8,91E-05
0,3	3,02E-05
0,75	1,33E-05
1,5	6,09E-06
2,25	3,51E-06
2,75	2,57E-06
3,25	1,94E-06

Table B.2 – Results of calculations of the maximum volumetric activity of the radionuclides in atmosphere air and maximum precipitation onto the ground surface after radiation accidents cited in 1.1 and 1.2

Distance, km	Volumetric activity of radionuclides in atmosphere air, Bq/m^3			Precipitation onto the ground surface, Bq/m^2/year		
	^{234}U	^{235}U	^{238}U	^{234}U	^{235}U	^{238}U
Radiation accident 1.1 (design) - Drop of the container with the uranium dioxide powder						
0,08	4,83E-10	2,23E-11	7,56E-11	2,88E-03	1,33E-04	4,50E-04
0,3	1,19E-06	5,47E-08	1,85E-07	9,24E-04	4,26E-05	1,44E-04
0,75	8,97E-07	4,14E-08	1,40E-07	3,92E-04	1,81E-05	6,11E-05
1,5	3,39E-07	1,56E-08	5,28E-08	1,80E-04	8,32E-06	2,81E-05
2,25	1,58E-07	7,31E-09	2,47E-08	1,05E-04	4,82E-06	1,63E-05
2,75	1,03E-07	4,78E-09	1,61E-08	7,68E-05	3,54E-06	1,20E-05
3,25	7,06E-08	3,25E-09	1,10E-08	5,80E-05	2,68E-06	9,05E-06
Radiation accident 1.2 (design) - Seal failure of the pipeline with the UHF with evaporation						
0,08	2,31E-08	1,07E-09	3,61E-09	1,38E-01	6,35E-03	2,15E-02
0,3	5,66E-05	2,61E-06	8,82E-06	4,41E-02	2,03E-03	6,88E-03
0,75	4,28E-05	1,98E-06	6,69E-06	1,87E-02	8,64E-04	2,92E-03
1,5	1,62E-05	7,44E-07	2,52E-06	8,60E-03	3,97E-04	1,34E-03
2,25	7,56E-06	3,49E-07	1,18E-06	5,01E-03	2,30E-04	7,78E-04
2,75	4,93E-06	2,28E-07	7,71E-07	3,67E-03	1,69E-04	5,73E-04
3,25	3,37E-06	1,55E-07	5,25E-07	2,77E-03	1,28E-04	4,32E-04

Table B.3 – Results of calculations of the maximum volumetric activity of the radionuclides in atmosphere air after radiation accident cited in 2.1

Distance, km	Volumetric activity of radionuclides in atmosphere air, Bq/m^3					
	^{87}Kr	^{88}Kr	^{138}Xe	^{131}I	^{133}I	^{135}I
1	2	3	4	5	6	7
Radiation accident 2.1 (out-of-design) - Self-sustained chain reaction						
0,08	2,81E-01	2,65E-01	2,83E-01	6,83E-04	2,75E-02	1,11E-01
0,3	7,28E+02	6,89E+02	7,03E+02	1,72E+00	6,97E+01	2,81E+02
0,75	6,17E+02	5,92E+02	5,47E+02	1,38E+00	5,64E+01	2,24E+02
1,5	2,81E+02	2,74E+02	2,17E+02	5,67E-01	2,36E+01	9,17E+01
2,25	1,59E+02	1,58E+02	1,07E+02	2,92E-01	1,23E+01	4,69E+01
2,75	1,18E+02	1,19E+02	7,22E+01	2,04E-01	8,61E+00	3,25E+01
3,25	9,14E+01	9,28E+01	5,08E+01	1,48E-01	6,31E+00	2,36E+01

Table B.3 continued

Distance, km	Volumetric activity of radionuclides in atmosphere air, Bq/m^3					
	^{89}Rb	^{130}Sb	^{132}Te	^{133m}Te	^{134}Te	^{140}Ba
1	8	9	10	11	12	13
Radiation accident 2.1 (out-of-design) - Self-sustained chain reaction						
0,08	5,61E-02	2,02E-01	2,14E-04	2,70E-01	9,28E-02	5,75E-04
0,3	1,31E+02	4,86E+02	5,25E+01	6,53E+02	2,23E+02	1,41E+00
0,75	9,03E+01	3,56E+02	3,97E-01	4,81E+02	1,63E+02	1,07E+00
1,5	2,89E+01	1,26E+02	1,49E-01	1,73E+02	5,78E+01	4,01E-01
2,25	1,16E+01	5,56E+01	7,00E-02	7,78E+01	2,56E+01	1,88E-01
2,75	6,81E+00	3,47E+01	4,56E-02	4,94E+01	1,61E+01	1,23E-01
3,25	4,17E+00	2,28E+01	3,11E-02	3,28E+01	1,05E+01	8,36E-02

Table B.3 continued

Distance, km	Volumetric activity of radionuclides in atmosphere air, Bq/m^3				
	^{90}Sr	^{91}Sr	^{92}Sr	^{137}Cs	^{99}Mo
1	14	15	16	17	18
Radiation accident 2.1 (out-of-design) - Self-sustained chain reaction					
0,08	6,47E-07	1,47E-02	4,67E-02	5,14E-06	7,69E-04
0,3	1,59E-03	3,61E+01	1,14E+02	1,26E-02	1,88E+00
0,75	1,20E-03	2,72E+01	8,56E+01	9,50E-03	1,43E+00
1,5	4,53E-04	1,02E+01	3,17E+01	3,58E-03	5,36E-01
2,25	2,12E-04	4,75E+00	1,47E+01	1,68E-03	2,51E-01
2,75	1,39E-04	3,11E+00	9,47E+00	1,10E-03	1,64E-01
3,25	9,44E-05	2,11E+00	6,39E+00	7,47E-04	1,12E-01

Table B.4 – Results of calculations of the maximum precipitation onto the ground surface after radiation accident cited in 2.1

Distance, km	Precipitation onto the ground surface, Bq/m^2/year					
	^{131}I	^{133}I	^{135}I	^{89}Rb	^{130}Sb	^{140}Ba
1	2	3	4	5	6	7
Radiation accident 2.1 (out-of-design) - Self-sustained chain reaction						
0,08	2,11E+03	8,53E+04	3,45E+05	3,34E+05	1,20E+06	3,42E+03
0,3	7,56E+02	3,07E+04	1,23E+05	1,02E+05	3,79E+05	1,10E+03
0,75	3,59E+02	1,47E+04	5,82E+04	3,94E+04	1,55E+05	4,65E+02
1,5	1,76E+02	7,32E+03	2,85E+04	1,55E+04	6,72E+04	2,14E+02
2,25	1,10E+02	4,61E+03	1,76E+04	7,64E+03	3,66E+04	1,24E+02
2,75	8,50E+01	3,60E+03	1,36E+04	5,05E+03	2,59E+04	9,12E+01
3,25	6,79E+01	2,89E+03	1,08E+04	3,43E+03	1,88E+04	6,89E+01

Table B.4 continued

Distance, km	Precipitation onto the ground surface, Bq/m^2/year					
	^{132}Te	^{133m}Te	^{134}Te	^{90}Sr	^{91}Sr	^{92}Sr
1	8	9	10	11	12	13
Radiation accident 2.1 (out-of-design) - Self-sustained chain reaction						
0,08	1,28E+03	1,61E+06	5,53E+05	3,86E+00	8,77E+04	2,79E+05
0,3	4,09E+02	5,09E+05	1,74E+05	1,24E+00	2,81E+04	8,89E+04
0,75	1,73E+02	2,10E+05	7,12E+04	5,25E-01	1,19E+04	3,73E+04
1,5	7,97E+01	9,26E+04	3,09E+04	2,42E-01	5,44E+03	1,69E+04
2,25	4,62E+01	5,13E+04	1,69E+04	1,40E-01	3,14E+03	9,67E+03
2,75	3,39E+01	3,67E+04	1,19E+04	1,03E-01	2,30E+03	7,04E+03
3,25	2,56E+01	2,69E+04	8,65E+03	7,77E-02	1,73E+03	5,26E+03

Table B.4 continued

Distance, km	Precipitation onto the ground surface, Bq/m^2/year	
	^{137}Cs	^{99}Mo
1	14	15
Radiation accident 2.1 (out-of-design) - Self-sustained chain reaction		
0,08	3,05E+01	4,58E+03
0,3	9,79E+00	1,47E+03
0,75	4,15E+00	6,22E+02
1,5	1,91E+00	2,87E+02
2,25	1,11E+00	1,66E+02
2,75	8,14E-01	1,22E+02
3,25	6,15E-01	9,20E+01

Table B.5 – Results of calculations of the expected population irradiation dose rate in case of normal operation mode (after full deployment of the enterprise), μSv/year

Direction	Distance, km						
	0,05	0,1	0,2	0,3	0,4	0,5	1
1	2	3	4	5	6	7	8
N	4,03E+01	2,03E+01	1,30E+01	1,11E+01	9,74E+00	8,42E+00	4,59E+00
NNW	4,02E+01	2,02E+01	1,29E+01	1,11E+01	9,70E+00	8,38E+00	4,57E+00
NW	4,00E+01	2,01E+01	1,29E+01	1,10E+01	9,66E+00	8,35E+00	4,55E+00
WNW	3,81E+01	1,92E+01	1,23E+01	1,05E+01	9,20E+00	7,95E+00	4,33E+00
W	3,62E+01	1,82E+01	1,17E+01	9,97E+00	8,73E+00	7,55E+00	4,11E+00
WSW	4,22E+01	2,13E+01	1,36E+01	1,16E+01	1,02E+01	8,82E+00	4,80E+00
SW	4,83E+01	2,43E+01	1,56E+01	1,33E+01	1,17E+01	1,01E+01	5,50E+00
SSW	5,33E+01	2,68E+01	1,72E+01	1,47E+01	1,29E+01	1,11E+01	6,06E+00
S	**5,82E+01**	**2,93E+01**	**1,88E+01**	**1,61E+01**	**1,41E+01**	**1,22E+01**	**6,62E+00**
SSE	4,48E+01	2,25E+01	1,44E+01	1,24E+01	1,08E+01	9,35E+00	5,10E+00
SE	3,14E+01	1,58E+01	1,01E+01	8,65E+00	7,58E+00	6,55E+00	3,57E+00
ESE	3,06E+01	1,54E+01	9,85E+00	8,43E+00	7,38E+00	6,38E+00	3,48E+00
E	2,98E+01	1,50E+01	9,59E+00	8,21E+00	7,19E+00	6,21E+00	3,39E+00
ENE	3,28E+01	1,65E+01	1,06E+01	9,05E+00	7,92E+00	6,85E+00	3,73E+00
NE	3,58E+01	1,80E+01	1,15E+01	9,88E+00	8,66E+00	7,48E+00	4,08E+00
NNE	3,81E+01	1,92E+01	1,23E+01	1,05E+01	9,20E+00	7,95E+00	4,33E+00

Table B.5 continued

Direction	Distance, km						
	1,5	2	2,5	3	3,5	4	5
1	9	10	11	12	13	14	15
N	3,22E+00	2,46E+00	1,97E+00	1,67E+00	1,44E+00	1,25E+00	1,00E+00
NNW	3,21E+00	2,45E+00	1,96E+00	1,66E+00	1,44E+00	1,25E+00	9,98E-01
NW	3,19E+00	2,44E+00	1,96E+00	1,66E+00	1,43E+00	1,24E+00	9,94E-01
WNW	3,04E+00	2,33E+00	1,86E+00	1,58E+00	1,36E+00	1,18E+00	9,46E-01
W	2,89E+00	2,21E+00	1,77E+00	1,50E+00	1,29E+00	1,12E+00	8,98E-01
WSW	3,37E+00	2,58E+00	2,07E+00	1,75E+00	1,51E+00	1,31E+00	1,05E+00
SW	3,86E+00	2,95E+00	2,36E+00	2,00E+00	1,73E+00	1,50E+00	1,20E+00
SSW	4,25E+00	3,26E+00	2,61E+00	2,21E+00	1,90E+00	1,65E+00	1,32E+00
S	**4,65E+00**	**3,56E+00**	**2,85E+00**	**2,41E+00**	**2,08E+00**	**1,81E+00**	**1,45E+00**
SSE	3,58E+00	2,74E+00	2,19E+00	1,86E+00	1,60E+00	1,39E+00	1,11E+00
SE	2,50E+00	1,92E+00	1,53E+00	1,30E+00	1,12E+00	9,73E-01	7,79E-01
ESE	2,44E+00	1,87E+00	1,49E+00	1,27E+00	1,09E+00	9,48E-01	7,59E-01
E	2,38E+00	1,82E+00	1,46E+00	1,23E+00	1,06E+00	9,23E-01	7,39E-01
ENE	2,62E+00	2,00E+00	1,60E+00	1,36E+00	1,17E+00	1,02E+00	8,15E-01
NE	2,86E+00	2,19E+00	1,75E+00	1,48E+00	1,28E+00	1,11E+00	8,90E-01
NNE	3,04E+00	2,33E+00	1,86E+00	1,58E+00	1,36E+00	1,18E+00	9,46E-01

Table B.5 continued

Direction	Distance, km					
	7,5	10	20	30	40	50
1	16	17	18	19	20	21
N	6,53E-01	4,67E-01	1,76E-01	9,36E-02	5,61E-02	3,70E-02
NNW	6,50E-01	4,66E-01	1,76E-01	9,32E-02	5,59E-02	3,68E-02
NW	6,48E-01	4,64E-01	1,75E-01	9,28E-02	5,57E-02	3,67E-02
WNW	6,16E-01	4,41E-01	1,67E-01	8,84E-02	5,30E-02	3,49E-02
W	5,85E-01	4,19E-01	1,58E-01	8,39E-02	5,03E-02	3,32E-02
WSW	6,84E-01	4,90E-01	1,85E-01	9,80E-02	5,88E-02	3,87E-02
SW	7,82E-01	5,60E-01	2,11E-01	1,12E-01	6,73E-02	4,43E-02
SSW	8,62E-01	6,18E-01	2,33E-01	1,24E-01	7,42E-02	4,89E-02
S	**9,43E-01**	**6,75E-01**	**2,55E-01**	**1,35E-01**	**8,11E-02**	**5,34E-02**
SSE	7,25E-01	5,19E-01	1,96E-01	1,04E-01	6,24E-02	4,11E-02
SE	5,08E-01	3,64E-01	1,37E-01	7,28E-02	4,37E-02	2,88E-02
ESE	4,95E-01	3,54E-01	1,34E-01	7,09E-02	4,25E-02	2,80E-02
E	4,82E-01	3,45E-01	1,30E-01	6,91E-02	4,14E-02	2,73E-02
ENE	5,31E-01	3,80E-01	1,44E-01	7,61E-02	4,57E-02	3,01E-02
NE	5,80E-01	4,16E-01	1,57E-01	8,32E-02	4,99E-02	3,29E-02
NNE	6,16E-01	4,41E-01	1,67E-01	8,84E-02	5,30E-02	3,49E-02

Table B.6– Results of calculations of the maximum average annual volumetric activity of the radionuclides in atmosphere air and maximum precipitation onto the ground surface in case of normal operation mode (after full deployment of the enterprise)

Distance, km	Volumetric activity of radionuclides in atmosphere air, Bq/m^3			Precipitation onto the ground surface, Bq/m^2/year		
	^{234}U	^{235}U	^{238}U	^{234}U	^{235}U	^{238}U
0,05	2,36E-09	1,11E-10	3,82E-10	1,43E-02	6,47E-04	2,19E-03
0,10	9,04E-07	4,17E-08	1,39E-07	7,02E-03	3,29E-04	1,10E-03
0,20	1,46E-05	6,60E-07	2,29E-06	3,62E-03	1,65E-04	5,59E-04
0,30	2,22E-05	1,04E-06	3,48E-06	2,41E-03	1,10E-04	3,84E-04
0,40	2,22E-05	1,04E-06	3,48E-06	1,86E-03	8,66E-05	2,96E-04
0,50	2,02E-05	9,38E-07	3,13E-06	1,54E-03	6,91E-05	2,30E-04
1,00	1,15E-05	5,21E-07	1,77E-06	7,46E-04	3,40E-05	1,21E-04
1,50	8,69E-06	3,82E-07	1,32E-06	4,94E-04	2,30E-05	7,68E-05
2,00	6,60E-06	3,13E-07	1,04E-06	3,62E-04	1,65E-05	5,70E-05
2,50	5,56E-06	2,50E-07	8,34E-07	2,85E-04	1,32E-05	4,50E-05
3,00	4,52E-06	2,15E-07	7,30E-07	2,41E-04	1,10E-05	3,73E-05
3,50	4,17E-06	1,88E-07	6,26E-07	1,97E-04	9,32E-06	3,18E-05
4,00	3,48E-06	1,63E-07	5,56E-07	1,75E-04	8,01E-06	2,74E-05
5,00	2,85E-06	1,32E-07	4,52E-07	1,32E-04	6,25E-06	2,08E-05
7,50	1,88E-06	8,69E-08	2,92E-07	8,34E-05	3,84E-06	1,32E-05
10,00	1,36E-06	6,26E-08	2,09E-07	5,70E-05	2,63E-06	8,99E-06
20,00	5,21E-07	2,40E-08	7,99E-08	2,08E-05	9,76E-07	3,29E-06
30,00	2,71E-07	1,25E-08	4,17E-08	1,10E-05	5,05E-07	1,75E-06
40,00	1,67E-07	7,65E-09	2,61E-08	6,58E-06	3,07E-07	1,03E-06
50,00	1,11E-07	5,21E-09	1,70E-08	4,39E-06	1,97E-07	6,80E-07

APPENDIX C

LIST OF PUBLICATIONS

1. Проект. Завод по производству ядерного топлива. Том 9. Санитарно-защитная зона и зона наблюдения ОПЯТ-00-000-000-00-СЗЗ. 2013 г./ Project. Nuclear fuel production plant. Tome 9. Sanitary protection zone and control area OPYAT-00-000-000-00-SZZ. 2013.
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3. Технико-экономическое обоснование строительства завода по производству ядерного топлива. Критерии и требования к площадке для размещения производственного комплекса". ДП "УкрНИПИИ-промтехнологии", 2011 г./ “Feasibility study of construction of the nuclear fuel production plant. Criteria and requirements to the site for location of the production complex”. SE “UkrNIPII promtehnologii”, 2011.
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9. J. A. Jones, P. A. Mansfield, S. M. Haywood et al. PC COSYMA (Version 2): An accident consequence assessment package for use on a PC. − Luxemborg: Office for Official Publications of the European Communities, 1996. − 59 pp.
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11. Проект. Завод по производству ядерного топлива. Том 8. Оценка воздействий на окружающую среду. ОПЯТ-00-000-000-00-ОВОС. 2013 г./

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12. Данные ОАО «ГСПИ» по производственному зданию, указанные в задании на разработку части «Охрана окружающей природной среды» (исх. № 049/М013/680 от 24.05.2013 с уточнениями от 31.05.2013, вх. № 729 от 27.05.2013)/ Data of the OJSC “GSPI” on the industrial building specified in the draft proposal for the “Natural environment protection” section (ref. No. 049/M013/680 of 24.05.2013 with corrections of 31.05.2013, inc. № 729 of 27.05.2013)
13. Гусев Н.Г., Беляев В.А. Радиоактивные выбросы в биосфере: Справочник. – М.: Энергоатомиздат, 1991. – 256 с./ N.G. Gusev, V.A. Belyayev. Radioactive emissions in the biosphere: Handbook – M.: Energoatomizdat, 1991. – 256 pp.