Attachment 10

Results of modeling the pollutants dispersion

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A. Dispersion modeling of the distribution of conventional pollutants

A.1 Emission values of conventional air pollutants from PMF

The plasma melting facility (PMF) will be installed on the site of the auxiliary building-2 (AB-2). The waste gases from the PMF will be discharged into the atmosphere through the existing ventilation stack of AB-2.

The nominal waste gases volume from PMF is 1200 Nm^3/h.

The total waste gases volume from the AB-2 stack is 713710 Nm^3/h.

The ratio of waste gases from PMF and the total gas volume from the AB-2 stack is equal to 1200/713710=0.00168 **(≈ 0.17 %)**.

Hence the distribution velocity and the dispersion distance of the polluting substances discharged into the atmosphere from PMF will depend on the height and the diameter of the AB-2 stack, on the temperature and velocity of the total waste gases volume and from the meteorological conditions.

In the next table are given the maximum design concentrations of polluting substances in the waste gases at the PMF exit, before they reach the ventilation stack of AB-2 in **[mg/m^3]**.

Table A.1 Expected emission values at the PMF exit in Kozloduy NPP

Pollutant	**PMF Kozloduy NPP [55]** Average (1) daily values mg/m^3
Dust (practically only PM_{10})	< 1
CO	< 5
TOC	< 1
HCl	< 1
HF	< 1
SO_2	< 5
NOx	<100
Heavy (2) metals	
∑ Cd, Tl	0.005
Hg	0.005
∑ Sb, As, Pb, Cr, Cu, Mn, Ni, V, Sn	0.05
Dioxins (3) & furans	0.01 ng/m^3 (10^{-6}*0.01 mg/m^3)

(1) Conditions: 273 K, 101,3 kPa, 11 % O_2, dry gas
(2) Average values for a representative period of at least 30 min –maximum of 8 hours
(3) Average values for a representative period at least 6 hours – maximum of 8 hours

The off- gases from PMF are many time diluted in the ventilation stacks (1/0.00168 = 595 times) in comparison with the values indicated in Table A.1 e.g. from the point of view of limit emissions values (harmful substances concentrations) in point source emissions, the off-gases are many time lower from the limit values.

PMF is a facility without analogue in the country. Two diesel burners are used inPMF – one 300 kW and one 350 kW. Additionally during the melting process are generated up to 650 MWh per year in reference of 4000 h/annually of functioning.

The emissions (concentrations of conventional harmful substances) at the exit of the PMF comply with the requirements of: "ORDINANCE No. 1 for emission limit values of harmful substances (pollutants) emitted into the atmosphere from facilities and activities with stationary emission sources" - Annex No. 7.

The regulations regarding the permissible ground concentrations of harmful substances are given in: *Ordinance no. 11 of 14 may 2007 for permissible values of arsenic, cadmium, nickel and polycyclic aromatic hydrocarbons in ambient air; ordinance no. 12 of 15 july 2010 for permissible values of sulfur dioxide, nitrogen dioxide, fine particulate matter, lead, benzene, carbon oxide and ozone in ambient air.*

A.2 Preceding ambient air pollution from conventional pollutants in the region

The quality of ambient air in the area of emergency protective measures (30 km) is described in detail in chapter 3, p. 3.8.1. The concentration measurements of harmful substances have shown that no preparation of a program for pollutants mitigation is required in the area in accordance with Art. 30 and Art. 31 of the "Ordinance No. 7 for the ambient air estimation and control".

A.3 Local meteorological conditions in the region of Kozloduy NPP

In this study are used aggregated data from "Climate guide for Bulgaria" by Hydrology and Meteorology Dept. from 1982 and the studies "Local climate conditions in the region of "Kozloduy" NPP prepared by Consortium "MCE" - Sofia for the years 2009, 2010 and 2011 elaborated under Contract No. 280004 from 01.02.2008 to contractor "Kozloduy NPP" PLC.

A.4 Maximum ground concentrations for PMF in Kozloduy NPP

PMF will emit into the atmosphere pollutants from the existing discharge facility - the ventilation stack of AB-2.

In order to evaluate the maximum possible additional ground concentrations from the ventilation stack of AB-2, which are caused by PMF, the option 3 for model choice in the PLUME[1] software is used: *Maximum preceding pollution from existing discharge facilities.*

In this branch of the program is determined the maximum pollution from existing discharge facilities.

In the program the most unfavorable theoretically possible combination of meteorological conditions is searched, and a series of computations is automatically

[1] Calculations are performed using version 1.0 of the PLUME software developed in 1997 by the Geophysical Institute of BAS. In this version of the software the input data about emissions from the discharged facility are given in [g/s], and the ground concentrations are displayed in [mg/m^3].

performed, that covers in a wide range the possible variations in wind velocity and the respective possible stability classes as per Pasquil according the following table:

Wind velocity [m/s]	**Stability class**
1	**A , B**
2.5	**B , C , E**
4	**B , C , D , E**
5.5	**C , D**
7	**D**

In order to cover the emergency protective measures area (30 km) a square study area is adopted with dimensions 60x60 km, in the middle of which the investigated discharge facility is situated - the ventilation stack of AB-2.

The input data and conditions of the model are the following:

Number of steps in direction west-east	100
Number of steps in direction north-south	100
Step in direction west-east (m)	600
Step in direction north-south (m)	600
Type of ground surface	Rural area

The parameters of the discharge facility - the ventilation stack of AB-2, which are set in the computer program PLUME, are as follows:

- relative coordinates: X = 30000 m, Y = 30000 m;
- height: h = 150 m;
- diameter: d = 3.6 m;
- temperature: T = 65°C;
- gravitational deposition rate: Wg = 0 m/s for gaseous substances; Wg = 0.01 m/s for fine particulate matter (PM) with dimensions 5 to 10 µm;
- flow rate of waste gases from PMF: 1200 Nm^3/h (0.333 Nm^3/s);
- total flow rate of waste gases from the stack of AB-2: D = 713710 Nm^3/h (198 Nm^3/s).

The design quantity of the fine PM (PM_{10} and $PM_{2.5}$) is not specified, but given the high degree of purification of the output gases from PMF it is assumed that no particles with dimensions over 10 µm are discharged into the atmosphere.

The emissions of harmful substances from PMF, converted on the base of the average concentrations and the flow rate of the gases from PMF (0.333 Nm^3/s), and expressed in **[g/s]** are the following:

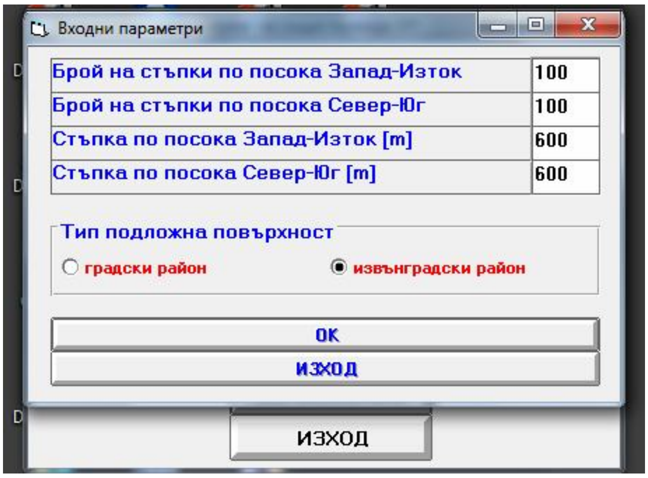
Table A.2 Emissions for PMF

Pollutant	E, g/s
PM_{10}	< 0.00033
CO	< 0.00166
TOC	< 0.00033
HCl	< 0.00033
HF	< 0.00033
SO_2	< 0.00166
NOx	< 0.03333
Heavy metals	
∑ Cd, Tl	0.000001665
Hg	0.000001665
∑ Sb, As, Pb, Cr, Cu, Mn, Ni, V, Sn	0.000016650
Dioxins & furans	$3.33*10^{-12}$

The input data for the parameters of the discharge facility for the individual pollutants are the following:

X [m]	Y [m]	h [m]	d [m]	T [^{O}C]	Wg [m/s]	D [m^3/s]	E [g/s]	
30000	30000	150	3.6	65	0.01	198	PM10	0.00033
30000	30000	150	3.6	65	0	198	CO	0.00166
30000	30000	150	3.6	65	0	198	TOC	0.00033
30000	30000	150	3.6	65	0	198	HCl	0.00033
30000	30000	150	3.6	65	0	198	HF	0.00033
30000	30000	150	3.6	65	0	198	SO_2	0.00166
30000	30000	150	3.6	65	0	198	NOx	0.03333
30000	30000	150	3.6	65	0	198	∑Cd,Tl	0.000001665
30000	30000	150	3.6	65	0	198	Hg	0.000001665
30000	30000	150	3.6	65	0	198	∑ Sb, As, Pb, Cr, Cu, Mn, Ni, V, Sn	0.000016650
30000	30000	150	3.6	65	0	198	Dioxins & furans	$3.33*10^{-12}$

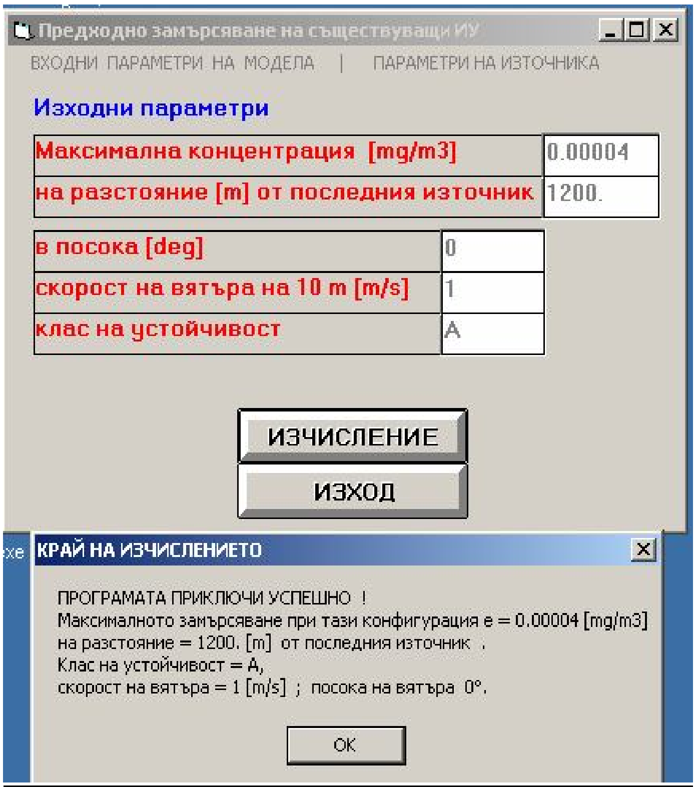
The parameters of the model are the following:



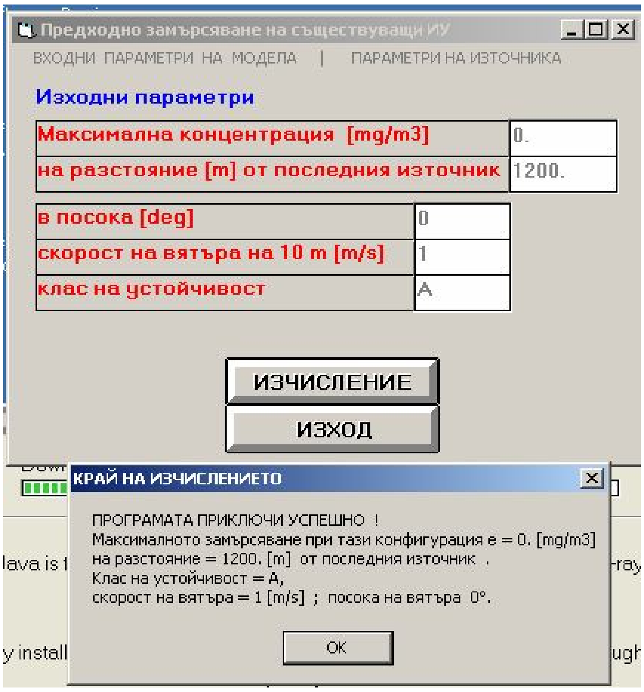
The computational results show that the maximum ground concentration is occurring in case of stability class A and wind velocity at 10 m height of 1 m/s. The distance from the ventilation stack is displayed where the maximum ground concentration is observed.

On the following figure is shown as an example the result for the ground concentration of NOx - 0.00004 mg/m^3 **(0.04 µg/m^3)**.

This is only the additional pollution, caused by the PMF.



For all other studied pollutants from the PMF the result output about maximum ground concentrations displays 0 mg/m^3 as shown in the following figure:



It has to be noted that according the reverence sources "Local meteorological conditions in the region of "Kozloduy" NPP of the Consortium "MCE" - Sofia for the years 2009, 2010 and 2011 in the region of "Kozloduy" NPP are predominating the cases with classes as per Pasquil D and E. The cases when the stability class is A are rare.

Therefore in the predominating cases the concentrations of harmful substances from PMF discharged by the ventilation stack of AB-2 will be even smaller.

The results for the maximum ground concentrations and the meteorological conditions, when they are occurring, are shown in **[mg/m^3]** in the following table.

Pollutant	Maximum ground concentration [mg/m^3]	Distance from discharge facility [m]	In direc-tion [deg]	Wind velocity at 10 m height [m/s]	Stability class
PM_{10}	0.0000004	1200	0	1	A
CO	0.0000020	1200	0	1	A
TOC	0.0000004	1200	0	1	A
HCl	0.0000004	1200	0	1	A
HF	0.0000004	1200	0	1	A
SO_2	0.0000020	1200	0	1	A
NOx	0.0000400	1200	0	1	A
∑ Cd, Tl	$1*10^{-9}$	1200	0	1	A
Hg	$1*10^{-9}$	1200	0	1	A
∑ Sb, As, Pb, Cr, Cu, Mn, Ni, V, Sn	$1*10^{-8}$	1200	0	1	A
Dioxins & furans	$1*10^{-15}$	1200	0	1	A

<u>Notes</u>: The software PLUME displays the maximum ground concentrations in a *fixed format* with only five significant digits after the decimal point. Because of that for any ground concentrations below 0.00001 mg/m^3 the result is displayed as 0 mg/m^3.

In the above given table are shown the maximum ground concentrations calculated as proportion from the NOx concentration - i.e. that substance from PMF, whose emission in air is the biggest (100 mg/Nm^3, respectively with a total quantity of 0.03333 g/s).

For the rest of the studied substances the maximum ground concentrations are less than 0.00001 mg/m^3 and the software displays for the maximum ground concentrations the number 0 in the output menus and in the output DAT-files (in the DAT-files the maximum concentration is denoted by **Max Concentration**).

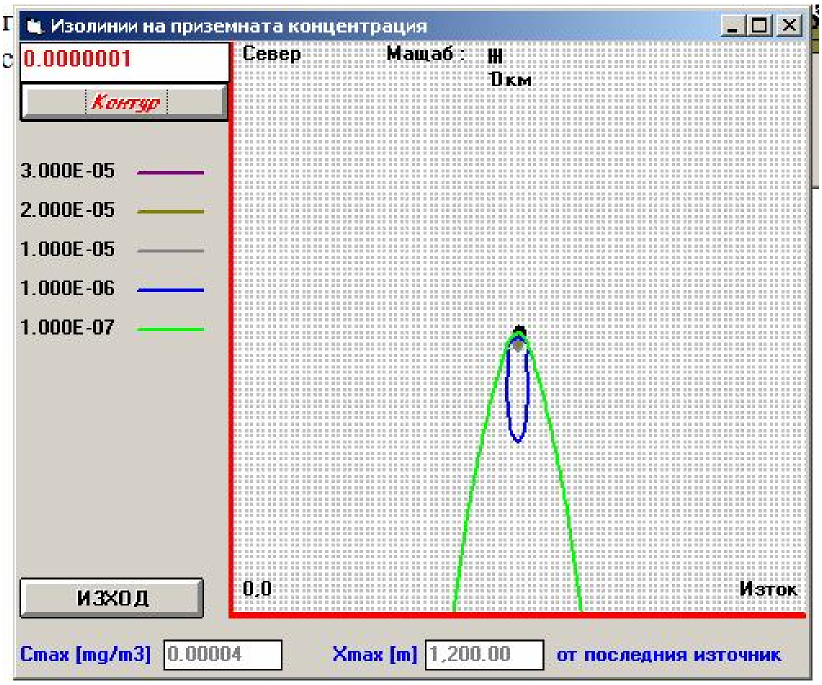
The ground concentrations at other locations in the studied area are displayed in a floating point format and with a decimal exponent, both in their graphical illustration and in the DAT-files.

The wind direction in the above table is conditional - though with a different probability for the different wind directions this maximum ground concentration may occur in any direction. The locus of the points with maximum ground concentration is a circle around the discharge facility.

The distance from the discharge facility to the location with maximum ground concentration is rounded to the step size - in this case to 600 m both along the X and the Y axes.

The graphical representation of the contours of the ground concentrations for NOx is shown on the following graphic obtained by means of the PLUME software using option 1 "Expected concentrations of harmful substances in the ground atmospheric layer", by introducing the most unfavorable theoretically possible meteorological conditions, which were obtained above using option 3 of the software and which are obtained at **wind velocity V=1 [m/s]** and class of **stability of the atmosphere A**.

Ground concentration contours of NOx



For the rest of the pollutants the contours have a similar character and are significantly below the permissible values.

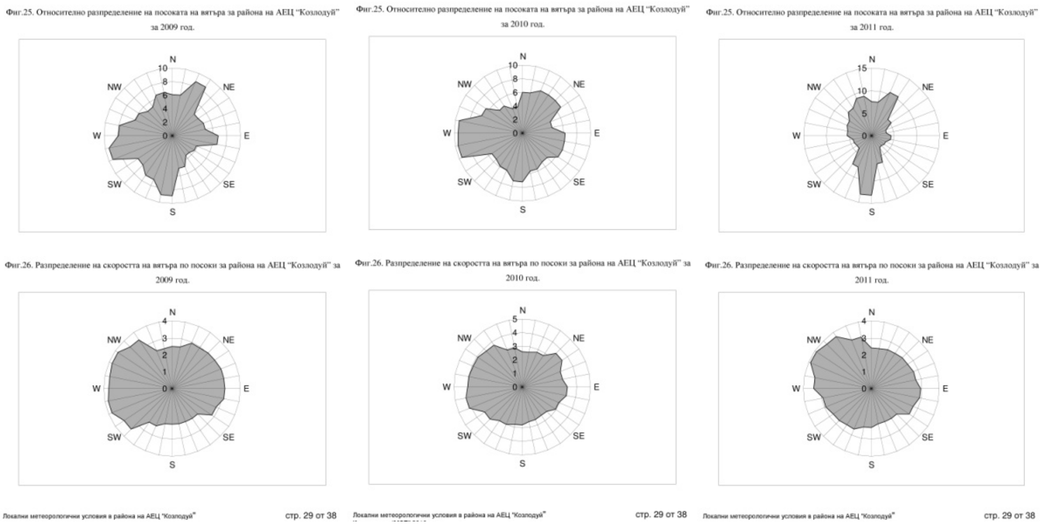
As examples are applied in electronic format the files with the output results from the maximum ground concentrations of NOx (file **NOx_max.dat**) and of PM_{10} (file **PM10_max.dat**).

A.5 Average annual ground concentrations for PMF in Kozloduy NPP

In chapter 3 are given some of the parameters of the field of wind in the "Kozloduy" NPP region from the studies "Local meteorological conditions in the region of Kozloduy NPP by Consortium "MCE" - Sofia for the years 2009, 2010 and 2011.

On the following figures are given the wind roses by frequency and velocity for the years 2009, 2010 and 2011.

These data represent the wind rose in 32 directions. They are different for each of the studied years, but the differences are within the climatic for the region.



In the software PLUME, as well as in the *"Climate Guide for Bulgaria" of the Hydrology and Meteorology Dept. from 1982* are given wind roses by frequency and velocity in the eight directions N, NE, E, SE, S, SW, W, NW.

It is impossible to implement directly the data from the above given graphics into the PLUME software.

The data from each meteorological station are different depending on the orography of terrain. For that reason are used aggregated data from the "Climate Guide" about the average annual wind roses obtained by measurements in two of the closest to Kozloduy meteorological stations situated on the bank of river Danube - "Lom" and "Oryahovo".

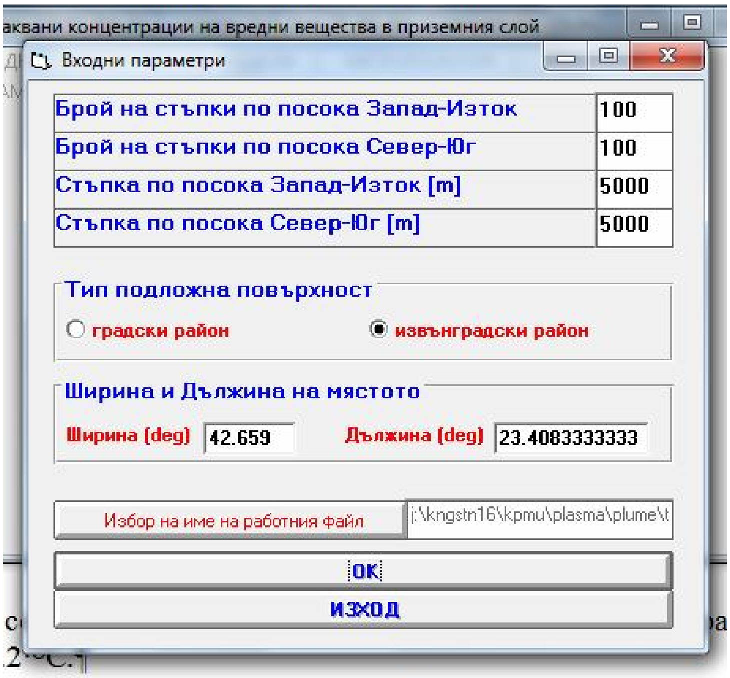
The wind rose used for the estimation of the average annual ground concentrations is given in the following table:

	Velocity [m/s]	**Frequency [%]**
N	2.1	3.1
NE	3.2	11.5
E	3.1	20.5
SE	2.2	7.2
S	2.1	3.8
SW	2.8	10.0
W	4.7	28.5
NW	4.2	15.4

The calculation is done with the average temperature for the year 2010 in the region of "Kozloduy" NPP 13.2°C.

For the investigation of the average annual ground concentrations is modeled an area of 500x500 km, in the middle of which is located the ventilation stack of AB-2.

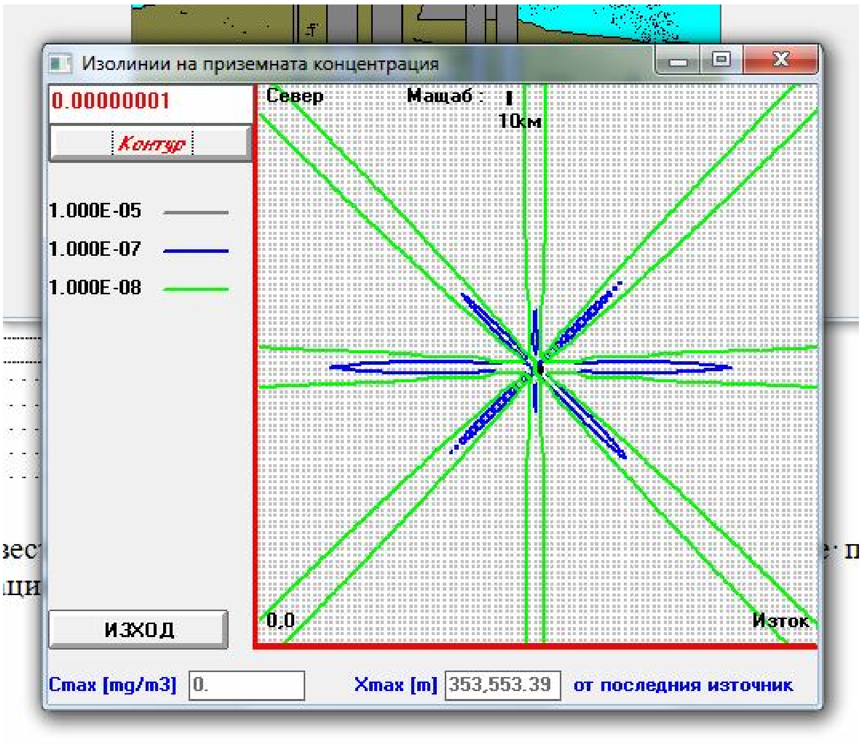
The parameters of the model are the following:



The ground concentrations are of the order of magnitude 10^{-8} mg/m^3, and the maximum average annual concentration (designated in the output file as Max Concentration) is again printed as zero. This is so because the ground concentrations from PMF are significantly smaller than the ones standardized as permissible in the regulations on quality of ambient air, and in the PLUME software is not provided an option for the print-out of such low order of magnitude (they are rounded to zero).

The concentrations of the rest of the substances from PMF are even smaller and are also printed out as zero by the PLUME software.

Some illustration can be provided by the isolines of the average annual ground concentrations of NOx are visualized:



A.6 Conclusion

The calculations for the conventional pollutants in the air made using the PLUME software are showing that the outgoing waste gases from the PMF are significantly diluted in the ventilation stack of AB-2 and are drawn by the total air flow at a significant height and with a significant velocity, and both the maximum momentary and the maximum average annual ground concentrations become insignificant as compared with the standardized permissible values for ambient air quality.

B. Modelling of radioactive effluent distribution

A N A L Y S I S
on the dose originating from gas aerosol and liquid releases to the environment from the Units 1-4 decommissioning process and the emissions from the plasma melting facility (PMF) operation, incurred by the public within the 30-km supervised area surrounding Kozloduy NPP, as per Project 5c

1. Input data – as per the programme proposed by the Consultant, EWN, Project 5c

- **Demographic data:**

– Bulgarian Side: Annual Report, KNPP Environmental Radiation Monitoring Results in 2010, № 11.РМ.ДОК.085 [1]

– Romanian Side: Letter from the Romanian Ministry of Environment and Forests, № 2830/RP/31-07-2012 [4]

- **Meteorological Data:**

Annual Report, KNPP Environmental Radiation Monitoring Results in 2010, № 11.РМ.ДОК.085 [1]

- **Emissions to air:**

Part 1. Annual Report, KNPP Environmental Radiation Monitoring Results in 2010, № 11.РМ.ДОК.085 [1]

Part 2. [1], Mean annual values over the entire decommissioning period, EIA-R for the decommissioning of units 1-4, П16Д08 rev 01.6_ДОВОС – Chapter 11 [2]

Part 3. [1], [2], EIA Input Data Report for the PMF, IBERDROLA, ID № I-650-RP-0009 [3]

- **Emissions to water:**

Part 1. Annual Report, KNPP Environmental Radiation Monitoring Results in 2010, № 11.РМ.ДОК.085 [1]

Part 2. [1], Mean annual values over the entire decommissioning period, EIA-R for the decommissioning of units 1-4, П16Д08 rev 01.6_ДОВОС – Chapter 11 [2]

1.1. Gas-aerosol emissions to atmosphere

1.1.1. **Part 1: Normal operation of KNPP, 2010, actual emissions through the stacks of EP-1 and EP-2, as per activity and nuclides distribution**

- Radioactive noble gases (RNGs): 6.43 TBq
- Long-lived aerosols (LLAs): 28.2 MBq

- I-131 (Iodine-131): 65.7 MBq
- H-3 total (tritium): 376 GBq
- Total C-14 (carbon-14): 519 GBq

1.1.2. Part 2: Mean annual values over the entire period of units 1-4 decommissioning

- **Long-lived aerosols: 20 MBq**

This value includes the emissions from the projects planned: Material Size Reduction and Decontamination Workshop, and Decay Storage Facility for Transitional Radwaste.

- **Radionuclide and activity distribution in aerosol releases**
  - as per the annual limits and control levels for total activity of liquid and gaseous releases from units 1-4 during their decommissioning.

Radionuclide	Stack-1	Stack-1	Stack-2	Stack-2
	%	A, MBq	%	A, MBq
Co-60	46	4,6	50	5,0
Sr-90	0,5	0,05	0,3	0,03
Cs-134	0	0	0,5	0,05
Cs-137	53	5,3	49	4,9
Pu-239, 240	0,2	0,02	0,1	0,01
Am-241	0,3	0,03	0,1	0,01
Total: 20 MBq		10		10

1.1.3. Part 3: Mean annual values under normal operating conditions of the plasma melting facility

- Long-lived aerosols: 6 MBq
- Radionuclide and activity distribution in aerosol releases

Radionuclide	Stack-1
	A, MBq
Mn-54	0,362
Co-58	0,181
Fe-59	0,0603
Co-60	3,44
Nb-95	0,0603
Ag-110m	0,362
Cs-134	0,362
Cs-137	1,21
Total:	6,04 MBq

– In accordance with Table 1, EIA Input Data Report for the PMF, IBERDROLA, ID № I-650-RP-0009

1.2. Liquid discharges to the Danube

1.2.1. Part 1: Normal operation of KNPP, 2010, actual emissions in the treated water discharges from EP-1 and EP-2, as per activity and nuclide distribution

- Nuclides (w/o H-3): 289 MBq
- Tritium (H-3): 22.7 TBq

1.2.2. Part 2: Mean annual values over the entire period of units 1-4 decommissioning

- Nuclides (w/o H-3): 120 MBq
- Tritium (H-3): 50 GBq

These values include the emissions from the projects mentioned above: Material Size Reduction and Decontamination Workshop, Decay Storage Facility for Transitional Radwaste, and all the activities associated with the decommissioning of units 1-4.

- **Radionuclide and activity distribution in the liquid discharges (w/o H-3)**

– as per the annual limits and control levels for total activity of liquid and gaseous releases from Units 1-4 during their decommissioning

Radionuclide	AB-1	AB-1	AB-2	AB-2
	%	A, GBq	%	A, GBq
Co-60	2	1,2	2	1,2
Cs-134	1	0,6	1	0,6
Cs-137	93	55,8	93	55,8
Sr-90	0,5	0,3	0,5	0,3
Pu-239, 240	0	0	0	0
Am-241	0	0	0	0
Ni-63	3	1,8	3	1,8
Fe-55	0,5	0,3	0,5	0,3
Total: 120 MBq		60		60

2. Input data – annual effective doses for the public within the 30-km supervised area around KNPP

2.1. Model used for dose assessment

Modelling programme code, based on the EU approved methodology CREAM (Consequences of Releases to the Environment Assessment Methodology) Radiation

Protection 72 –Methodology for Assessing the Radiological Consequences of Routine Releases of Radionuclide to the Environment.

- To assess the public dose due to liquid discharges - programme code DARR-CM, as adapted to the hydrology of the KNPP area and used for conservative evaluation of the dose exposure of a critical group of the public.
- To assess the public dose within the supervised area due to gas-aerosol discharges - programme code LEDA-CM, Normal Operation Shield, as adapted to the geographical and meteorological characteristics of the KNPP area. The methodology considers both the external and the internal impact of the radioactive releases and estimates the annual individual effective dose, the annual individual dose equivalent, and the critical group dose, as well as the collective dose for the population, per age groups.

The modelling programme codes used to estimate the individual and the collective effective doses to be incurred by the population from radioactive discharges to the environment, have been verified and validated.

2.2 Individual and the collective effective doses

2.2.1 Effective doses incurred by the population from gas-aerosol emissions

2.2.1.1 Part 1: Normal operation of KNPP, 2010

The ranges of the individual effective dose and the respective maximum values for the population within the 40-km area gas-aerosol emission around KNPP, taking into account the contribution of ^{3}H and ^{14}C, are as follows:

Max Dose RNGs+ LLAs+ ^{131}I, Sv/a	**Max Dose ^{3}H, Sv/a**	**Max Dose ^{14}C, Sv/a**	***Max Dose, Total, Sv/a**
$1,38.10^{-10}$ - $5,37.10^{-9}$	**$9,51.10^{-11}$ - $5,63.10^{-9}$**	**$6,81.10^{-9}$ - $7,88.10^{-7}$**	**$7,18.10^{-9}$ - $8,02.10^{-7}$**
$5.37.10^{-9}$	**$5.63.10^{-9}$**	**$7.88.10^{-7}$**	**$8.02.10^{-7}$**

** The dose estimate calculations used meteorological data for 2010.*

The annual effective collective dose was estimated at **$1,47.10^{-2}$ manSv/a**. The levellised annual effective collective dose from gas-aerosol emissions to the public within the 40-km area amounts to **$8,44.10^{-3}$ manSv/GW.a**. The assessments per emission components for KNPP are fully comparable with the data for a large number of PWRs worldwide (UNSCEAR–2000, 2008). The calculations used the population figures in the Bulgarian part (72 416 people). Taking into account the population in the respective part of Romania – another 75 150 people, the collective effective dose for the entire area can be approximately doubled.

2.2.1.2 Part 2: Mean annual values over the entire period of Units 1-4 decommissioning

The ranges of the individual effective dose and of the maximum values for the public within the 40-km area, generated from gaseous emissions from Units 1-4 decommissioning, are as follows:

Max dose, LLAs (externally), Sv/a	Max dose ^{3}H, Sv/a	Max dose ^{14}C, Sv/a	**Max dose, Total, Sv/a
5,58.10^{-11} - 1,37.10^{-9}	-	-	**1,47.10^{-10} - 2,46.10^{-9}**
1,37.10^{-9}	-	-	**2,46.10^{-9}**

** The dose estimate calculations used data for the micro climate in the region.*

The collective effective annual dose was estimated at **8,86.10^{-5} manSv/a**.

2.2.1.3. Part 3: Mean annual values under normal operational conditions of the plasma melting facility (PMF)

The ranges of the individual effective dose and of the maximum values for the public within the 40-km area, generated from gaseous emissions from the PMF operation, are as follows:

Max dose, LLAs (externally), Sv	Max dose ^{3}H, Sv/a	Max dose ^{14}C, Sv/a	**Max dose, total, Sv/a
1,46.10^{-11} - 3,60.10^{-10}	-	-	**3,36.10^{-11} - 5,47.10^{-10}**
3.60.10^{-10}	-	-	**5.47.10^{-10}**

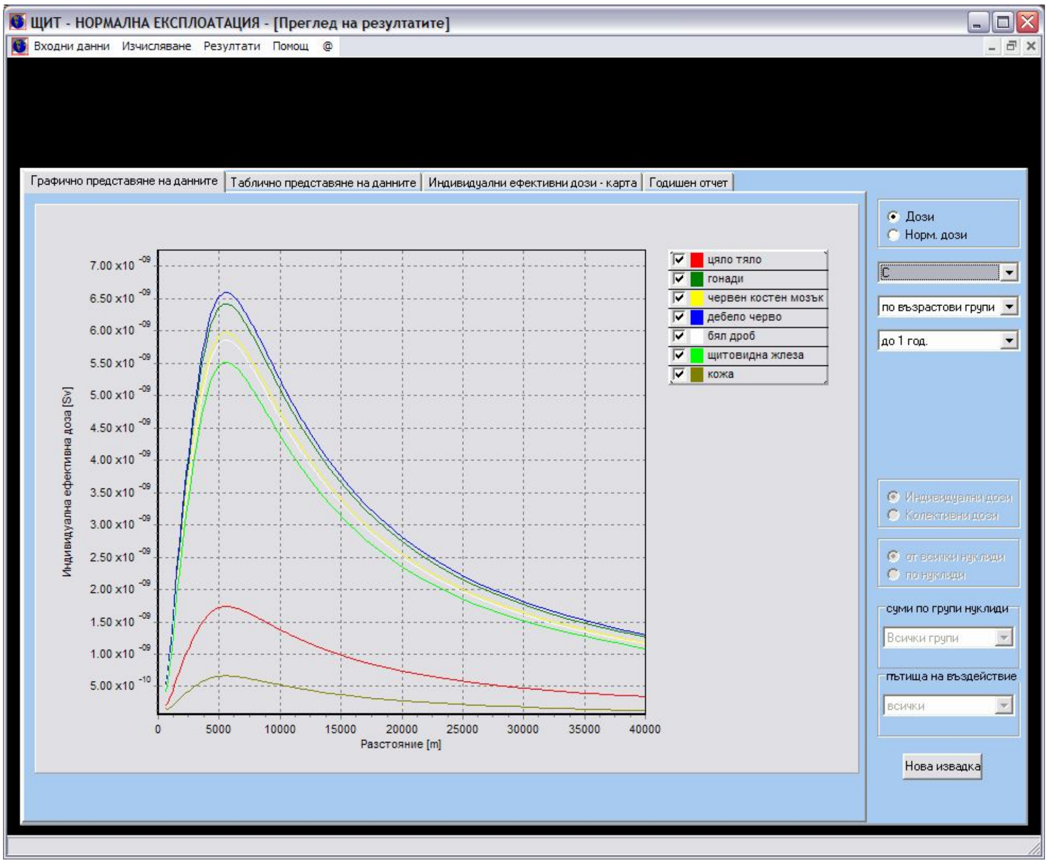
** The dose estimate calculations used regional micro climate data.*

The collective effective annual dose was estimated at **1.98.10^{-5} manSv/a**.

2.2.1.4. Distribution of the gas-aerosol emission doses for the public

Figures 1 and 2 show the dose distribution map for the population within the 40-km area and as a function of the distance to the emission source.

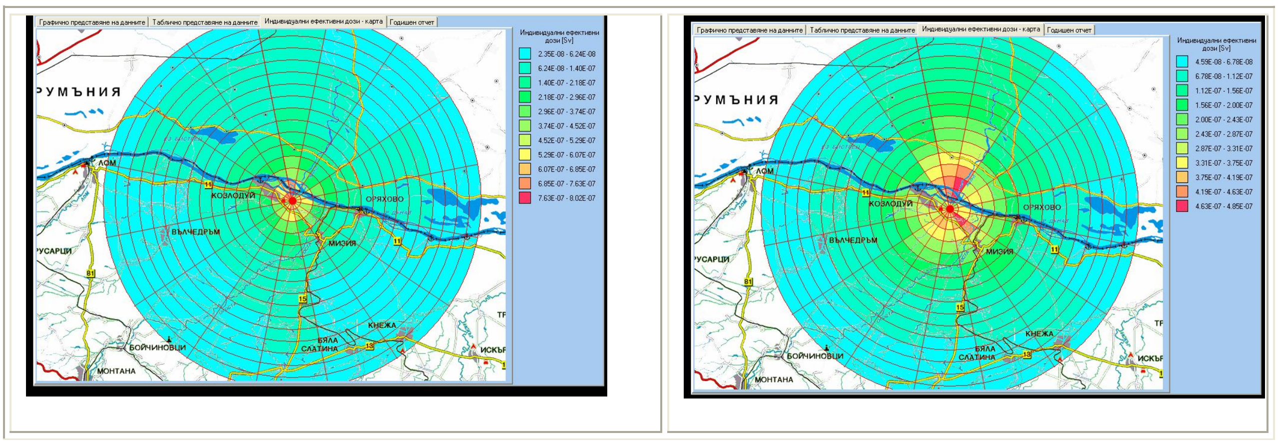
Fig. 1 Individual effective dose as function of the distance to the source



The maximum values of the individual effective dose were calculated within the 5-6 km maximum dose.

<u>Fig. 2</u> Distribution of the individual effective dose from external exposure to RNGs, LLAs, ^{131}I + (^{3}H, ^{14}C) within the area of Kozloduy NPP, 2010

a) <u>with meteorological data for 2010</u> b) <u>with micro climate data for 2001–2010</u>



2.2.2 Effective dose for the population from liquid emissions to the Danube River

2.2.2.1 Part 1: Normal operation of KNPP, 2010

The ranges of the individual effective dose and of the respective maximum values for the public within the 30-km area, generated from liquid emissions from the KNPP, are as follows:

Population	Max dose, w/o ^{3}H, Sv/a	Max dose, ^{3}H, Sv/a	Max dose, Total, Sv/a
30-km area	$1{,}40.10^{-11}$ - $8{,}96.10^{-10}$	$3{,}21.10^{-7}$ - $6{,}00.10^{-7}$	$3{,}22.10^{-7}$ - $6{,}00.10^{-7}$
Critical group	$4.43.10^{-9}$	$4.22.10^{-6}$	$4.23.10^{-6}$

The population critical group includes settlements located downstream along the Danube – the town of Oryahovo, and the villages Leskovets, Ostrov, and Gorni Vadin.

The estimated collective effective dose values for the Bulgarian side of the Danube, considering the above settlements, are as follows:

Population	Collective dose w/o ^{3}H, manSv/a	Collective dose, ^{3}H, manSv/a	Collective dose, Total, manSv/a
Critical group	$8{,}05.10^{-6}$	$4{,}42.10^{-3}$	$4{,}43.10^{-3}$

The levellised collective dose per unit of generated electrical energy amounts to **$2.54.10^{-3}$ man.Sv/GW.a**. The data are fully comparable with the results for a great number of PWRs worldwide (UNSCEAR–2000, 2008).

2.2.2.2 Part 2: Mean annual values over the entire period of units 1-4 decommissioning

The ranges of the individual effective dose and of the respective maximum values for the public within the 30-km area, generated from liquid emissions from the KNPP, are as follows:

Population	Max dose w/o ^{3}H, Sv/a	Max dose, ^{3}H, Sv/a	Max dose, Total, Sv/a
30-km area	$3.56.10^{-12}$ – $5.50.10^{-10}$	$7.07.10^{-10}$ – $1.32.10^{-9}$	$8.30.10^{-10}$ – $1.48.10^{-9}$
Critical group	$2.31.10^{-9}$	$9.30.10^{-9}$	$1.16.10^{-8}$

The population critical group includes settlements located downstream along the Danube – the town of Oryahovo, and the villages Leskovets, Ostrov, and Gorni Vadin.

The collective effective dose values for the Bulgarian part along the Danube, taking into account the population of the town of Oryahovo, and the villages Leskovets, Ostrov, and Gorni Vadin, are as follows:

Population	Collective dose w/o ^{3}H, manSv/a	Collective dose, ^{3}H, manSv/a	Collective dose, Total, manSv/a
Critical group	$5.01.10^{-6}$	$9.73.10^{-6}$	$1.47.10^{-5}$

2.3 Effective dose for the population – total incurred from liquid and gas-aerosol emissions

2.3.1 Cumulative effect from various sources of emissions

2.3.1.1 Individual effective dose

Description of source	Max dose from gas-aerosol emissions, Sv/a	Max dose from liquid emissions, Sv/a	Max dose, Total, Sv/a
Part 1. *KNPP-2010*	$7{,}18.10^{-9}$ - $8{,}02.10^{-7}$	$3{,}22.10^{-7}$ - $6{,}00.10^{-7}$	*** $5.03.10^{-6}$
	$8{,}02.10^{-7}$	*** $4{,}23.10^{-6}$	
Part 2. *KNPP-2010+Units 1-4 Decommissioning*	$7{,}33.10^{-9}$ - $8{,}04.10^{-7}$	$3{,}23.10^{-7}$ - $6{,}01.10^{-7}$	*** $5.04.10^{-6}$
	$8{,}04.10^{-7}$	*** $4{,}24.10^{-6}$	
Part 3. *KNPP-2010+Units 1-4 Decommissioning+PMF*	$7{,}36.10^{-9}$ - $8{,}05.10^{-7}$	$3{,}23.10^{-7}$ - $6{,}01.10^{-7}$	*** $5.05.10^{-6}$
	$8.05.10^{-7}$	*** $4.24.10^{-6}$	

**** The dose estimates apply to critical groups of the population within the 40-km area around KNPP*

2.3.1.2 Collective effective dose

Description of source	Collective dose from gas-aerosol emissions, manSv/a	Collective dose from liquid emissions, manSv/a	Collective dose, Total, manSv/a
Part 1. *KNPP-2010*	$1{,}47.10^{-2}$	$4{,}43.10^{-3}$	$1.91.10^{-2}$
Part 2. *KNPP-2010+Units 1-4 Decommissioning*	$1{,}48.10^{-2}$	$4{,}44.10^{-3}$	$1.92.10^{-2}$
Part 3. *KNPP-2010+Units 1-4 Decommissioning+PMF*	$1{,}49.10^{-2}$	$4{,}44.10^{-3}$	$1.93.10^{-2}$

The dose estimates obtained refer to the population of the Bulgarian side (72 416 people, year 2007). Taking into account the population in the respective part of Romania – another 75 150 people, the collective effective dose for the entire area can be approximately doubled. These are data fully comparable with the practice adopted for PWRs worldwide.

2.3.2 Conclusions drawn regarding the model dose estimates for the population dose resulting from the decommissioning of KNPP units 1-4 and the normal operation of the plasma melting facility (Project 5c)

- **The maximum annual effective dose per individual of the critical group of the population living within the 40-km area around KNPP, resulting from the liquid and gas-aerosol releases to the environment, was conservatively calculated at 5.05µSv/a, which is a much lower value than the quota of 250µSv/a for exposure from radioactive emissions from NPP (Ordinance on the Assuring of Safety of NPPs) and the norms determined for the population of 1mSv/a (ONRZ-2012, Basic Norms for Radiation Protection).**
- **The additional dose that might be incurred is about 500 times lower than natural radiation background (2.33mSv).**
- **The calculation of the cumulative effect added to the effect of KNPP normal operation, and due to emissions from the decommissioning of KNPP Units 1-4, and the normal operation of the plasma melting facility (PMF), Project 5c) results in a negligible increase of the maximum individual and collective effective doses by 0.5 to 1 %.**
- **The maximum annual effective dose of the population within the 40-km area around KNPP, and due to aerosol emissions only, 6MBq under normal operation of the plasma melting facility (PMF), was estimated at 5.47.10-10 Sv/a, which is barely 0.01 % from the total exposure resulting from all activities on the KNPP site.**
- **The comparisons of the collective effective dose values for the population around KNPP with the respective data for many other nuclear power plants with PWRs (WWERs) reactor type proved comparable with the practice worldwide.**