CONSORTIUM

"DICON – ACCIONA ING."

ENVIRONMENTAL IMPACT ASSESSMENT REPORT

for Investment Proposal:

BUILDING A NEW NUCLEAR UNIT OF THE LATEST GENERATION AT THE KOZLODUY NPP SITE

CHAPTER 4: DESCRIPTION, ANALYSIS AND EVALUATION OF THE POTENTIAL SIGNIFICANT RADIATION AND NON-RADIATION IMPACT ON THE POPULATION AND THE ENVIRONMENT RESULTING FROM THE IMPLEMENTATION OF THE INVESTMENT PROPOSAL, THE USE OF NATURAL RESOURCES, THE EMISSIONS OF HARMFUL SUBSTANCES DURING NORMAL OPERATION AND IN EMERGENCY SITUATIONS, THE GENERATION OF WASTE AND THE CREATION OF DISCOMFORT

4.7. WASTE
4.8. HAZARDOUS SUBSTANCE
4.9. HARMFUL PHYSICAL FACTORS
4.10. HEALT AND HYGIENIC ASPECTS OF THE ENVIROMENT AND RISK TO HUMAN HEALTH
4.11. RADIATION RISK TO THE POPULATION IN THE EVENT OF RADIOACTIVE RELEASES
4.12. EXPECTED IMPACT ON SITES OF IMMOVABLE CULTURAL AND HISTORICAL HERITAGE

☒ original

☐ copy

PREPARED BY:	NELLY GROMKOVA – TL VERJINIA DIMITROVA – PM	VERSION: 03
VALIDATED BY:	TZVETANKA DIMITROVA – TQ CONTROL EXPERT	DATE: AUGUST 2013

CONTENTS

LIST OF FIGURES

LIST OF TABLES

4 DESCRIPTION, ANALYSIS AND EVALUATION OF THE POTENTIAL SIGNIFICANT RADIATION AND NON-RADIATION IMPACT ON THE POPULATION AND THE ENVIRONMENT RESULTING FROM THE IMPLEMENTATION OF THE INVESTMENT PROPOSAL, THE USE OF NATURAL RESOURCES, THE EMISSIONS OF HARMFUL SUBSTANCES DURING NORMAL OPERATION AND IN EMERGENCY SITUATIONS, THE GENERATION OF WASTE AND THE CREATION OF DISCOMFORT

4.7 WASTE

4.7.1 NON-RADIOACTIVE WASTE (NRAW)

4.7.1.1 IMPACT DURING THE CONSTRUCTION

The assessment for the construction phase is made in accordance with the Waste Management Act (promulgated SG, No. 53/2012) and the secondary legislation thereto.

During the construction phase – Domestic and construction waste generated by construction operations and equipment installation within the site boundaries and excavated soil mass. During the most intensive period the Domestic waste will be generated by about 4000 workers and employees. The construction of NNU is planned to take about 5 years. Non-hazardous industrial waste and hazardous waste will also be generated.

Quantitative characteristics of the expected waste is indicative, as the investment proposal is at an early stage of the survey for site selection and options for selection of reactor types with certain capacities. The waste is of different quantities, since it depends on the location of the sites, topography, the size of the area that is not to be built-up, etc. Waste is classified in accordance with Regulation No. 3 on Waste Classification (promulgated SG, No. 44/ 25.05.2004, amended and supplemented, No. 23/20.03.2012).

4.7.1.1.1 Domestic waste

Generated by the daily life activities of workers and employees taking part in the construction of NNU.

4.7.1.1.2 Mixed Domestic waste

- Waste description and application – expected to be generated in the process of daily life activities of working personnel during the construction of facilities covered by the Investment proposal (IP) – about 2500 employees, workers and specialised personnel.

- Source – generated by life activities of working personnel at separate sites included in the IP.
- Quantity (expected volume) – 800 – 1000 m^3/year – for construction phase of five years or about 4000-5000m^3
- Period/periods of waste generation – throughout the whole year
- Analysis (including test methods) – NA
- Bulgarian classification code – 20 03 01.

4.7.1.1.3 Biodegradable waste

- Waste description and application – originates from leafs, bushes, branches, etc. during the excavation works and terrain cleaning.
- Quantity – for the construction phase.
- The quantity of biodegradable waste differs for different sites because it is related to the built-up degree, the land areas, etc. The quantity will be specified at the next design stages.

According to the preliminary assessment the expected quantities of biodegradable waste for separate sites during the construction of NNU are as follows:

- ✓ Site No.1 – about 5 t/y up to 25 tonnes for the entire construction phase;
- ✓ Site No.2 – about 2 t/y up to 10 tonnes for the entire construction phase;
- ✓ Site No.3 – about 3.5 t/y up to 16 tonnes for the entire construction phase;
- ✓ Site No.4 – about < 0.5 t/y up to 1.5-2 tonnes for the entire construction phase;

- Period/periods of waste generation – mainly during general construction works (most intensive during the summer period).
- Analysis (including test methods) – NA
- Bulgarian classification code – 20 03 01.

For Kozloduy community there is a planed implementation of composting installation.

4.7.1.1.4 Construction waste

The management of the construction waste will be carried out according to the requirements of the Regulation for construction waste management and recycling of construction materials (published SG No.89/13.11.2012).

- Soil (including contaminated excavated earth), stones and excavated soil – code 17.05;
- Excavated earth mass – code 17 05 06, other than the mentioned in 17 05 05;
- Soil and stones with code 17 05 04, other than the mentioned in 17 05 03;
- Waste description and application – excavated soil from the civil works;

- Source – the waste is generated during the excavation works at the industrial site erection of buildings and infrastructure, concrete drains/sewers, etc.
- Quantity (m^3) – the waste will be used for filling negative forms, terrain levelling, reclamation, etc. *(The quantity will be specified at the next design stages.)*

The quantity of unnecessary earth masses differs for the different sites because it is related to the amount of the performed excavation and filling works, the built-up degree, the existence of buildings and facilities, etc. The earth masses balance will be determined at the next design stages.

According to the preliminary assessment the expected the quantities of unnecessary earth masses for the separate sites during the construction of NNU (100% humus utilisation is envisaged) are as follows:

- ✓ Site 1 – no unnecessary earth masses (humus 210 000 m^3 – 100% utilisation);
- ✓ Site 2 – 178 000 m^3 unnecessary earth masses for the entire construction phase of 5 years (humus 220 000 m^3 – 100% utilisation)
- ✓ Site 3 – no unnecessary earth masses (humus 210 000 m^3 – 100% utilisation);
- ✓ Site 4 – no unnecessary earth masses as well as humus.

- Period/periods of waste generation – mainly during general construction works (most intensive during the summer period).
- Analysis (including test methods) – NA
- Bulgarian classification code – 17 05 06.

4.7.1.1.5 Concrete unfit for recycling

- Waste description and application – concrete unfit for utilisation in civil works, generated as waste during the 5 year period of NNU construction.
- Source – the waste is generated during the construction works of the NNU sites.
- Quantity (m^3) during the construction phase – expected volume of about 600-700 m^3 for the entire construction phase *with appropriate control and management of the material supply and the construction process (the quantities will be specified at the next design stages).*
- Period/periods of waste generation – mainly during general construction works at the industrial sites, erection of buildings, concrete constructions of separate facilities, infrastructure, drains/sewers and other concrete works, etc. (peak load during the summer season);
- Analysis (including test methods) – NA
- Bulgarian classification code – 17 01 01.

*4.7.1.1.6 Mixture of concrete, bricks, faience and terracotta products, other than 17 01 06**

- Waste description and application – generated in the process of construction works;
- Source – the waste is generated during the construction works of the NNU sites.
- *Quantity (m^3) during the construction phase – expected volume of about 100 m^3 (the quantities will be specified at the next design stages) generated by new construction;*
- Period/periods of waste generation – mainly during general civil works at the industrial sites, erection of buildings, etc. (peak loading during the summer season);
- Analysis (including test methods) – NA
- Bulgarian classification code – 17 01 07.

4.7.1.1.7 Mixed construction and demolition waste other than mentioned in 17 09 01, 17 09 02 and 17 09 03 and with code 17 09 04

- Waste description and application – mixed construction waste;
- Source – the waste is generated by buildings and facilities demolition, during the construction works on the NNU sites.
- Quantity (m^3) during the construction phase – expected volume of about 3.0 thousand m^3 for Site 4 and about 1.2 thousand m^3 for Site 2. The quantity for Site 1 is max. 50 m^3 and for Site 3 - max. 100 m^3*(the quantities will be specified at the next design stages) according to the NNU site selection and options for selection of reactor type, the facilities layout, and the degree of utilisation of the existing on-site facilities and communications;*
- Period/periods of waste generation – mainly during general construction works at the industrial sites, erection of buildings, etc. (peak loading during the summer season);
- Analysis (including test methods) – NA
- Bulgarian classification code – 17 01 04.

The presented assessment is preliminary. Before commencement of NNU construction the site will be prepared by cleaning of the demolished structures and obsolete equipment. At the next design stages, following the selection of site and type of the reactor, a layout plan for the new facilities and auxiliary buildings will be designed as well as recommendations for demolition of the major part of the now existing facilities. Besides the waste quantities classified as non-hazardous (no need of radiation control) are going to be assessed and the means for their treatment (stockpiling/landfilling, submission for further treatment by authorised companies – recycling, etc.) will be specified.

At the preparation phase for construction of sites 2 and 4, the older buildings will be demolished according to the preliminary assessment.

4.7.1.1.8 Industrial non-hazardous waste

4.7.1.1.8.1 *Iron and steel waste*

- Waste description and application – a reinforcement and reinforced mesh, shuttering, support fixings and fasteners, sheet steel, ferrous metal scrap, etc.
- Source – the waste is generated in the process of civil and installation works at the construction phase.
- Quantity in tonnes for certain construction phase

- the expected waste quantities generated by new construction and demolishing of buildings at Site 4 thereof range about maximum 2 000 t;
- the expected waste quantities generated by new construction and from demolished buildings at Site 2 thereof range about maximum 800 t;
- the expected waste quantities generated by new construction at Site 1 thereof range about maximum 5.0 t;
  - the expected waste quantities generated by new construction and from demolished buildings at Site 3 thereof range about maximum 10.0 t.
  - Period/periods of waste generation – no periodicity.
  - Analysis (including test methods) – NA
  - Bulgarian classification code – 17 04 05.

4.7.1.1.8.2 *Ferrous metals – Shavings, cuttings and scrap*

- Waste description and application – shavings, cuttings and scrap of ferrous metals, waste reinforcement, etc.
- Source – cold metal mechanical processing – generated by installation of main and auxiliary equipment.
- Quantity in tonnes for certain construction phase – maximum 10 t.
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 12 01 01.

4.7.1.1.8.3 *Nonferrous metals –Shavings, cuttings and scrap*

- Waste description and application – Shavings, cuttings and scrap of non-ferrous metal;
- Source – cold metal processing.
- Quantity in tonnes for the entire construction phase – maximum 2 t.
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 12 01 03.

4.7.1.1.8.4 *Obsolete auto tyres*

- Waste description and application – worn-out tyres and transportation belts unfit for further usage, etc.
- Source – transportation and construction vehicles – quantity up to 20 t for the entire construction phase.
- Period/periods of waste generation – construction phase.
- Analysis (including test methods) – NA
- Bulgarian classification code – 16 01 03.

4.7.1.1.8.5 *Packing of wooden materials*

- Waste description and application – wood packing.
- Source – equipment packing, etc.
- Quantity – up to 6 t for the entire construction phase.
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 15 01 03.

4.7.1.1.8.6 *Waste paper – paper and cardboard packing (including separately collected waste Domestic packing)*

- Waste description and application – paper packing of construction materials.
- Source – paper packing of construction materials – plaster, cement, terracol, etc.
- Quantity – up to 5 t for the construction phase.
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 15 01 01.

4.7.1.1.9 Waste from the local water treatment plant (for Domestic wastewater)

4.7.1.1.9.1 *Residues from screens and sieves*

- Waste description and application – course matter, residues from screens (*sie*ves).
- Source – residues from screens (*sie*ves) from the local water treatment plant (LWTP).
- Quantity – up to 50 m^3/y for the entire construction phase.
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 19 08 01.

4.7.1.1.9.2 *Waste sediments from the sand trap*

- Waste description and application – *sand sediments from the sand trap*.

- Source – waste sediments from the LWTP sand trap.
- Quantity – up to 50 m^3/y for the construction phase.
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 19 08 02.

4.7.1.1.9.3 *Sediments from wastewater treatment in LWTP*

- Waste description and application – *Sediments from biological wastewater treatment in LWTP* – aerobically stabilised.
- Source – *sediments from biological wastewater treatment in LWTP*
- Quantity – up to 20 t/y (67 m^3/y) humidity 70%, up to 330 m^3 for the entire construction phase.
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – tested on application.

- Bulgarian classification code – 19 08 05.

4.7.1.1.10 Hazardous waste[1]

The construction of NNU is expected to generate hazardous waste: Obsolete luminescence and mercury lamps and rechargeable batteries, chemical substances, mixtures and packing supplied to Kozloduy NPP-EAD in tanks, drums and containers, waste oil products generated in the process of treatment of oil contaminated wastewaters in the local water treatment plant.

4.7.1.1.10.1 *Non-chlorinated hydraulic oils, mineral-based*

- Waste description and application – spent oil.
- Source – generated by machine oil change.
- Quantity (m^3) – about 0.1 m^3/y for specific construction phase and 0.5 m^3 for the entire construction phase.It's not recurring at regular intervals and depends on the amount of works executed, the mode of operation and accident proneness of the facilities.
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 13 01 10*.

4.7.1.1.10.2 *Fluorescent lamps and other waste containing mercury*

- Waste description and application – obsolete *fluorescent* and mercury lamps.
- Source – replacement of obsolete local lightning fixtures/lamps. Quantity 0.5 t/y during the construction phase (2.5 t for the entire construction phase).
- Period/periods of waste generation – no periodicity.

[1] Regulation 3/2004 ã. Waste classification, designated with symbol (*)

- Analysis (including test methods) – NA
- Bulgarian classification code – 20 01 21*.

4.7.1.1.10.3 *Lead acid rechargeable batteries*

- Waste description and application – unfit lead acid batteries.
- Source – replacement of unfit lead acid batteries of construction and transportation equipment.
- Quantity up to 10 t/y; for the entire construction phase -50 t.
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 16 08 01*.

4.7.1.1.10.4 *Packing of paints and varnishes*

- Waste description and application – packing of paints and varnishes containing residues from hazardous substances or contaminated by hazardous substances.
- Source – architectural arrangement, industrial design, etc.
- Quantity – up to 0.1 t for the entire construction phase.
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 15 01 10*.

4.7.1.1.11 Waste from Sludge and Oil Retainer (SOR)

4.7.1.1.11.1 *Mixture of fats and oils from the oil separation other than mentioned in 19 08 09*

- Waste description and application – mixture of fats, oils and oil products separated in SOR during wastewater treatment.
- Source – wastewaters generated by washing of motor vehicles and other machines – separation of oils, fats, oil products, etc. in the upper layer of SOR.
- Quantity up to 50-60 m^3/y during the entire construction phase – 250 m^3.
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 19 08 10*.

4.7.1.1.11.2 *Sediments formed in SOR*

- Waste description and application – sediments containing hazardous substances (fats, oils, oil products, etc.) separated during wastewater treatment in SOR.
- Source – wastewaters generated by washing of motor vehicles and other machines – separation of insoluble substances, oils, fats, oil products, etc. in the SOR sediments.
- Quantity – up to 50 m^3 for the entire construction phase.

- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 19 08 13* – sediments containing hazardous substances from other type of industrial wastewaters treatment.

Compared to the presently generated waste in Kozloduy NPP it is expected the waste quantity to raise in the 5 years construction period:

- ✓ Domestic waste – about 10 to 15%,
- ✓ industrial non-hazardous waste – about 20 to 30%,
- ✓ industrial hazardous waste – about 20 to 30%.

4.7.1.2 IMPACT DURING OPERATION

During the operation of New Nuclear Unit (NNU) is expected generation of Domestic, construction, industrial and hazardous waste, as every year at the work premises and sites during various operating activities, repairs, reconstruction of buildings and premises, etc. are created conditions for generation of various types and quantities of non-radioactive waste. According to article 7. of Waste Management Act [2], persons whose activities generate waste and holders of waste shall either treat it independently or shall submit it for collection, transportation and disposal to entities that are authorized to carry out such activities in accordance with this Act.

Construction waste – Generated as a result of the repair activities. Will be collected separately and submitted to specialised company in accordance to the requirements of the Regulation for management of construction waste and utilisation of recycled construction materials[3].

Domestic waste – Generated by the life activities of workers and employees that take part in NNU operation and all sites related to the plant activity, in all work rooms of administration and production buildings, canteens, cafeterias, as well as at the cleaning of plant site of leaves and branches etc. The waste of the NNU operational personnel will be transported and stockpiled in regulated depot – Non-radioactive Domestic and Industrial Waste Depot (NHIWD), after compulsory dosimetric control (the waste of sites outside the plant will be transported to regional depot in Oryahovo).Regarding biodegradable waste the Community of Kozloduy will be required to present information about its separate collection. It's planned to submit the biodegradable waste for composting or anaerobic decomposition. (The Community of Kozloduy foresees construction of installation for treatment of biodegradable waste).

Industrial non-hazardous waste

[2]Waste Management Act, SG No. 53/12.07.2012

[3] Regulation for management of construction waste and utilisation of recycled construction materials, SG No. 89/ 13.11.12).

The greater part of industrial waste at Kozloduy NPP consists of metal scrap (old worn-out machine components, worn-out steel ropes, etc.). These are not directly related to the production activity but result from repair of equipment on the work sites. Brass waste is generated further to metal waste during maintenance of brass components.

The industrial non-radioactive waste consists of:

- → metal waste not directly related to the production activity but result from repair of equipment; these will be stockpiled at specific sites within the plant and in well organised outdoor temporary storage;
- → sediments from the wastewater treatment station for purification of Domestic wastewater outflow from the new nuclear unit;
- → sediments from neutralisation pits – facilities for neutralisation of wastewater from production of chemically desalted water.

Hazardous waste – generated by burnt out luminescent and mercury lamps, sediments of sludge and oil retainers, laboratory or industrial chemical substances and mixtures with expired shelf life, packing of oil and lubricants, oil soiled rags, tows and sawdust. Waste will be stockpiled separately in specially arranged temporary storages at Kozloduy NPP site. After accumulation of certain amount of such waste it is going to be submitted to specialised companies for further treatment according to the requirements of WMA.

The quantitative characteristics of the expected waste are indicative, as the investment proposal is at an early stage of the survey for site selection and options for selection of reactor types with certain capacities. Waste is classified in accordance with Regulation No. 3 on Waste Classification (promulgated SG No. 44 / 25.05.2004, amended and supplemented, No. 23/ 20.03.2012).

Table 4.7-1 presents the types *non-radioactive waste*, expected to be generated by New Nuclear Unit operation at Kozloduy NPP.

TABLE 4.7-1: NON-RADIOACTIVE WASTE, EXPECTED TO BE GENERATED BY NEW NUCLEAR UNIT OPERATION AT KOZLODUY NPP

Name	Code according to Regulation No. 3	Quantity tonnes/year	Note
Domestic waste			
Mixed Domestic waste	20 03 01	600-1000	
Glass	20 01 02	to 2 -3	Waste glass generated by repair works.
Medical products other than those mentioned in 20 01 31	20 01 32	0.05 – 0.1	
Wood materials other than those mentioned in 20 01 37	20 01 38	20-50	
Plastics	20 01 39	0.1-0.6	
Other fractions nowhere else mentioned (sediments from	20 01 99	0.5-2.0	Scheduled periodical cleaning

Name	Code according to Regulation No. 3	Quantity tonnes/year	Note
Cold Channel cleaning and the intake Chambers of the CPS)			
Biodegradable waste	20 02 01	up to 10	
Soil and stones	20 02 02	0.5-4.0	
Waste from sewerage systems cleaning	20 03 06	1.0 – 5.0	
Paper and cardboard	20 01 01	5.0 -25	
Batteries and acid lead batteries other than those mentioned in 20 01 33	20 01 34	up to 0.5	
Obsolete electrical and electronic equipment other than those mentioned in 20 01 21, 20 01 23 and 20 01 35	20 01 36	-	
Spatial waste	20 03 07	-	
Industrial waste			
Bran, wood shavings, cuts, pieces, timber materials, chip board panels and veneer, miscellaneous as mentioned in 03 01 04	03 01 05	0.5 – 2.0	
Shavings, cuttings and scrap of ferrous metal	12 01 01	2.0-2.5	
Shavings, cuttings and scrap of non-ferrous metals	12 01 03	0.07-0.15	
Paper and cardboard packing	15 01 01	0.05-0.1	
Plastic packs	15 01 02	0.05-0.1	
Metal packs	15 01 04	0.05-0.1	
Glass packs	15 01 07	0.05-0.1	
Absorbents, filter materials, towels and protective clothing other than those mentioned in 15 02 02	15 02 03	0.5-1.5	The filters are exchanged according to specific schedule and pipeline transmittance check up.
Obsolete auto tyres	16 01 03	3-5	
Components removed from obsolete equipment other than that mentioned in code16 02 15	16 02 16	3-25	The quantity depends on the size and the type of the equipment that is changed.
Inorganic wastes other than that mentioned in 16 03 03	16 03 04	0.5-2.0	
Organic wastes other than that mentioned in 16 03 05	16 03 06	0.2-1.5	
Sharp tools	18 01 01	-	

Name	Code according to Regulation No. 3	Quantity tonnes/year	Note
Wastes collection and making harmless whereof is not subject to special provisions aimed to prevent infections	18 01 04	-	
Sediments from physical-chemical treatment other than that mentioned in 19 02 05	19 02 06	0.5 – 1.7	
Infiltrate from waste landfills other than that mentioned in 19 07 02	19 07 03	30- 45	
Residues from screens and sieves	19 08 01	up to 2.5	
Sediments from urban wastewater treatment	19 08 05	up to 25	
Ferrous metals	19 12 02	3.5-5	
Non-ferrous metals	19 12 03	5-30	
Photographic films and paper containing silver or silver compounds	09 01 07	<0.01	
Photographic films and paper free of silver or silver compounds	09 01 08	< 0.05	
Obsolete vehicles free of liquids or other hazardous components	16 01 06	-	The quantity depends on the size and the type of the specific equipment that is changed.
Obsolete equipment other than that mentioned in odes from 16 02 09 to 16 02 13	16 02 14	2.5-20	
Components removed from obsolete equipment other than that mentioned in code16 02 15	16 02 16		
Antifreeze liquids other than those mentioned in 16 01 14	16 01 15	-	
Alkaline batteries (except for 16 06 03)	16 06 04		
Other batteries and rechargeable batteries	16 06 05		
Construction waste			The quantities depends on the executed construction, installation and repair works
Concrete	17 01 01		
Excavated earth masses other than those mentioned in 17 05 05	17 05 06		
Insulation materials other than those mentioned in 17 06 01 and 17 06 03	17 06 04		
Combined waste from civil works and demolition other than those mentioned in 17 09	17 09 04		

Name	Code according to Regulation No. 3	Quantity tonnes/year	Note
01, 17 09 02 and 17 09 03			
Hazardous waste			
Spent greases and lubricants	07 06 99*	up to 0.1	
Water-based developer and activator solutions	09 01 01*	up to 0.02	
Fixing solutions	09 01 04*	<0.01	
Non-chlorinated hydraulic oils, mineral-based	13 01 10*	up to 0.1	
Non-chlorinated motor, lubrication and gear transmission oils, mineral-based	13 02 05*	2.5 – 8	
Non-chlorinated insulation and heat-transfer oils, mineral-based	13 02 07*	1.5-8	
Sediments from oil trap shafts (collectors)	13 02 03*	4	
Oil from oil-water separators	13 02 06*	0.6 -8 (p.3)	
Gas oil, boiler and diesel fuel	13 07 01*		
Other emulsions	13 08 02*		
Waste, mentioned nowhere else (spent greases and lubricants)	13 08 99*		
Packing containing residues from hazardous substances or polluted by hazardous substances	15 01 10*	0.6 – 1	
Absorbents, filter materials, towels and protective clothes contaminated by hazardous substance	15 02 02*	0.1 – 1.0	The filters are exchanged according to specific schedule and pipeline transmittance check-up.
Obsolete motor vehicles	16 01 04 *	0.1 – 80	
Oil filters from motor vehicles	16 01 07 *		
Antifreeze liquids containing hazardous substances	16 01 14 *		
Transformers and capacitors containing PCBs			
Obsolete equipment containing hazardous components (3) other than mentioned in codes 16 02 09 to 16 02 12			
Inorganic waste containing hazardous substances			
Organic waste containing hazardous substances			

	Name	Code according to Regulation No. 3	Quantity tonnes/year	Note
	Gases in pressurised vessels (including halons) containing hazardous substances			
	Lead acid batteries			
	Ni – Cd batteries			
	Sediments from physical chemical treatment containing hazardous substances			
	Solvents			
	Photographic chemical substances and solutions			
	Fluorescent tubes and other waste containing mercury			

(*) Waste containing hazardous substances (flammable, irritating, harmful, toxic, carcinogenic, corrosive, mutagenic, etc.) is classified as hazardous and its designated by star symbol.

According to Art. 7of the WMA[4], persons whose activities generate waste and holders of waste shall either treat it independently or shall submit it for collection, transportation and disposal to entities that are authorized to carry out such activities in accordance with this Act. Art.8. of WMA[5],the handover and reception of industrial construction and hazardous waste will be done only under written contract basis with persons in possession of permit, complex permit or registration document as per the Art. 35 of WMA for the corresponding activity and code designated waste repository site, according to Regulation 3 (2004) for waste classification.

Assessment during the operation of the NNU is elaborated in accordance with the Waste Management Act (SG, No. 53/2012) and the bylaws thereto.

4.7.1.3 IMPACT DURING NNU DECOMMISSIONING PHASE

During decommissioning of various sites related to the operation of NNU will be exercised strict control and effective management of the generated waste including non-radioactive waste. Reclamation of disturbed areas will be carried out periodically – by stages. Until the completion of decommissioning, the utilities serving the employees on the site (water supply, sewage, wastewater treatment, etc.) will be retained. The characteristic of the expected waste generated at this stage is indicative and more specific information can be provided in subsequent design phases.

The following kinds of generated waste are expected:

[4]Waste Management Act, SG, No. 53/12.07.2013.

[5] Waste Management Act, promulgated SG, No. 53/12.07.2012

- Domestic waste generated by about 300 production personnel.
- Construction waste – the quantity will be evaluated at the next design phase on the base of more detailed data for decommissioning phase.
- Non-hazardous industrial waste – waste from the local water treatment plant (LWTP), metal waste, defective/worn out auto tyres, rubber conveyor belt, etc. (The quantity will be specified at the next design phase.)
- Hazardous waste – non-chlorinated mineral insulation oils, fluorescent tubes and other mercury containing waste, obsolete lead acid accumulators (the quantity will be specified at the next design phase.)

4.7.1.3.1 Mixed domectic waste

- Waste description and application – generated in the process of daily domestic activities of working personnel during the decommissioning phase of NNU.
- Source – working personnel during the decommissioning phase of NNU
- Quantity (m^3)– expected volume – maximum 50 m^3/y
- Period/periods of waste generation – throughout the entire year
- Analysis (including test methods) – NA
- Bulgarian classification code – 20 03 01.

4.7.1.3.2 Construction waste

4.7.1.3.2.1 *Mixture of concrete bricks, faience and terracotta products, other than 17 01 06**

- Waste description and application – generated by decommissioning activities;
- Source – generated by cleaning of the site of old buildings and facilities.
- Quantity (m^3) during decommissioning phase – expected volume – will be specified at the next design stages.
- Period/periods of waste generation – mainly during decommissioning phase of the industrial sites, etc.
- Analysis (including test methods) – NA
- Bulgarian classification code – 17 01 07.

4.7.1.3.3 Industrial non-hazardous waste

4.7.1.3.3.1 *Obsolete auto tyres*

- Waste description and application – obsolete tyres and transportation belts unfit for further usage;
- Source – transport and other construction machines used for NNU decommissioning.
- Quantity – the expected quantity will be specified at the next design stages;
- Period/periods of waste generation – operational period;

- Analysis (including test methods) – NA
- Bulgarian classification code – 16 01 03.

4.7.1.3.3.2 *Ferrous metal waste – Iron and steel*

- Waste description and application – a reinforcement structures and reinforcing mesh, ferrous cuttings, etc.;
- Source – execution of certain type of dismantling works during the decommissioning phase;
- Quantity – the expected volume and quantities will be specified in the next design stages;
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 17 04 05;
- Ferrous metals – ferrous grit/shavings and cuttings;
- Waste description and application – mainly obsolete equipment, etc;
- Source – mainly waste metal reinforcement, discarded obsolete equipment;
- Quantity in tonnes for certain period – quantity – the expected quantity and volume will be specified in the next design stages;
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 12 01 01.

4.7.1.3.4 Waste from the local wastewater treatment plant (LWTP) (urban domestic wastewater)

4.7.1.3.4.1 *Residues from screens and sieves*

- Waste description and application – course matter from domestic wastewater (residues from screens and sieves).
- Source – residues from screens and sieves from the local wastewater treatment plant (LWTP).
- Quantity – up to 3 m^3/y during the decommissioning phase of separate sites
- Period/periods of waste generation – no periodicity
- Analysis (including test methods) – NA
- Bulgarian classification code – 19 08 01.

4.7.1.3.4.2 *Waste sediments from the sand trap*

- Waste description and application – sand sediments, separated by sand trap
- Source – waste sediments from the LWTP sand trap
- Quantity – up to 3 m^3/y during the decommissioning phase of the separate sites
- Period/periods of waste generation – no periodicity

- Analysis (including test methods) – NA
- Bulgarian classification code – 19 08 02.

4.7.1.3.4.3 *Sediments from domestic wastewater treatment in the LWTP*

- Waste description and application – sediments from domestic wastewater treatment in the LWTP – aerobically stabilised.
- Source – biological wastewater treatment waste generated by LWTP.
- Quantity – up to 5 t/y (17 m^3/y); humidity 70%; during the decommissioning phase
- Period/periods of waste generation – no periodicity
- Analysis (including test methods) – tested on application.

4.7.1.3.5 Hazardous waste

4.7.1.3.5.1 *Non-chlorinated mineral insulation oils*

- Waste description and application – spent transformer oils.
- Source – generated by machine oil change
- Quantity (m^3) up to 1.0-2.0 m^3 /y – not recurring at regular intervals
- Period/periods of waste generation – no periodicity
- Analysis (including test methods) – NA
- Bulgarian classification code – 13 03 07*

4.7.1.3.5.2 *Fluorescent tubes and other mercury containing waste*

- Waste description and application – obsolete luminescence and mercury lamps
- Source – replacement of obsolete local lightning fixtures/lamps at the entire site.
- Quantity up to 200 pcs.
- Period/periods of waste generation – no periodicity
- Analysis (including test methods) – NA
- Bulgarian classification code – 20 01 21*

4.7.1.3.5.3 *Lead acid batteries*

- Waste description and application – obsolete lead acid batteries.
- Source – replacement of old lead acid batteries
- Quantity up to 100 pcs./y. during the entire decommissioning phase
- Period/periods of waste generation – no periodicity
- Analysis (including test methods) – NA
- Bulgarian classification code – 16 06 01*

4.7.1.3.6 Waste deposits from Sludge and Oil Retainer (SOR)

4.7.1.3.6.1 *Oils and fat mixture from the oil separation other than those mentioned in 19 08 09*

- Waste description and application – oils and fat mixture and oil products separated in SOR during wastewater treatment.
- Source – wastewaters generated by washing of motor vehicles and other machines – separation of oils, fats, oil products, etc. in the SOR upper layer.
- Quantity – up to 10 m^3/y for the NNU decommissioning phase.
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 19 08 10*.

4.7.1.3.6.2 *Sediments formed in SOR*

- Waste description and application – sediments containing hazardous substances (fats, oils, oil products, etc.) separated in SOR during wastewater treatment.
- Source – wastewaters generated by washing of motor vehicles and other machines – separation of insoluble substances, oils, fats, oil products, etc. in the SOR sediments.
- Quantity – up to 10 m^3/y during the NNU decommissioning phase.
- Period/periods of waste generation – no periodicity.
- Analysis (including test methods) – NA
- Bulgarian classification code – 19 08 13* – sediments containing hazardous substances from other type of industrial wastewater treatment.

4.7.1.3.7 Collection, transportation, stockpiling and disposal of non-radioactive waste

Non-radioactive waste shall be collected, transported and treated in conformity with the WMA requirement. The non-radioactive waste management will be performed in conformity with "Instructions for non-radioactive waste collection, transportation, temporary storage and utilisation in Kozloduy NPP EAD" under strict control of their classification as non-radioactive waste. Kozloduy NPP has adopted good practice for waste management and control. Non-radioactive waste generated by the new unit during construction and operation phases will be subject of effective control ensuring minimum impact on the regional environmental components and population.

Kozloduy NPP EAD has permission to collect waste, transport, utilize and safely dispose it. The Permit is issued by RIEW-Vratsa, that also exercises control on the activities performance.At present, part of the waste is collected separately but such collection has still not been organized for the remaining waste. The latter includes used grease and lubricants, small batteries, sodium and other lamps with metal halogenides, packing of chemical substances and compounds.

Subject to separate collection and treatment is:

- Waste that because of their specific characteristics and / or requirements of the regulations are defined as hazardous;
- Industrial waste, hazardous and utilizable industrial waste are stockpiled temporary in specified locations on the Plant Site, and further on they are sold or transferred to persons with license, complex license or registering document as per the WMA or to organization for utilization. A site of NHIWD is set with Decision 05-ДО-72-01/12.06.2008 of RIEW-Vratsa for temporary storage of waste before disposal, regulating the composition and quantities of waste whereof such storage is allowed. Activities for safe waste disposal in specially designed repository, are allowed on that site – code D5[6]. The permit complements the provisions of Decision 05-ДО-72-00/24.01.2006 and has been in force since 31.12.2010 with last amendment in force till 31.12. 2015[7]. During separate NNU implementation stages the waste management will take into account the quantities of additionally generated non-radioactive waste.

Transportation of waste is carried out by plant-own specialized or all-purpose vehicles or by machines of outside companies operating under contract on the Site.

Radiation control is performed in the protected zone of Kozloduy NPP at locations with waste generation and collection in compliance with standard requirements and on the basis of company documents.. Containers for domestic and non-utilizable small-size industrial waste are subject to daily dosimetric control.

Since the beginning of 2001, Kozloduy NPP EAD has used its own Depot for non-radioactive domestic and industrial waste (DNHIW) compliant with the current applicable standards. Non-radioactive solid household waste and non-utilizable industrial small-size building debris are stockpiled in the DNHIW. Construction and operation of the Depot cover two stages on total stockpiling area of a little more than 11 ha. The design capacity of the facility is 45 000 m3 with operation lifetime of 9 years for the first stage and 15 years for the second stage. The Depot is located at about 3.7 km to South of the Danube River midstream opposite to the 693rd kilometer of the river. According to the Principal data in DNDIW only 85% of the unit for the first phase is occupied (from 2001 to 2011).

Waste stockpiling whereof Kozloduy NPP EAD is in possession of a permit valid till 31.12.2015 is foreseen also upon realization of the IP. Should new waste subject to categorisation be generated at the realization of new nuclear unit, such waste shall be characterized as well.[8] When necessary, should the waste not comply with the depot class, such waste shall have to be treated before disposal[9] (pH adjustment, thickening, disinfection, etc.). Kozloduy NPP EAD has a Program for own monitoring of the non-radioactive household and industrial waste depot aimed to identify and ensure

[6] Waste Management Act, promulgated SG, No. 53/12.07.2012

[7] Letter from Kozloduy NPP EAD Safety and Quality Directorate, out. Ref.No.190/8.02.13.

[8] Manual for waste characterisation and application of criteria for waste acceptation in different depot types, MEW, Sofia 2011.

[9] Manual for preliminary waste treatment before deposition, MEW, Sofia, 2005.

organization of efficient own monitoring of the depot for non-radioactive household and industrial waste (DNRDIW) at Kozloduy NPP.

4.7.1.3.7.1 *During construction phase*

4.7.1.3.7.1.1 Non-hazardous waste

Domestic waste – Generated by workers, employees and the entire specialised personnel working on construction of specific NNU sites. The Domestic waste shall be collected in containers located in specified locations on the site. The waste shall be powdered with hydrated or chlorinated lime for disinfection.

The waste generated in the protected zone is envisaged to be regularly transported to Kozloduy NPP DNHIW and the waste generated outside this zone to be transported to Oryahovo regional depot.

Domestic waste includes also waste from wastewater mechanical treatment in LWTP (course matter screened by sieves and sand sediments from the sand trap).

Construction waste – During the investment proposal (IP) construction the construction waste is of limiting amount (earth masses, generated by excavation works and terrain preparation for consecutive civil works, construction waste – concrete, etc.). By elaboration of earth mass balance and effective waste management, they can be optimally used for: improvement of the temporary technological route; backfilling; site ground levelling; construction of embankment along the rivers; terrain reclaiming.

The soil generated during the construction and excavation works will be temporarily stockpiled at specific on-site locations and will be completely used again for terrain cultivation. Biodegradable waste will be stockpiled or used for composting of solid domestic waste.

Generated industrial non-hazardous waste – mostly metal waste from welding works, production of construction reinforcement, installation of facilities, machines, devices etc. (ferrous and non-ferrous metal waste) will be collected at specific locations and submitted under contract for recycling to authorised companies. Paper and wooden waste packs will also be collected temporarily at specific locations according to the regulatory requirements, and will be submitted to authorised companies for further utilisation. Obsolete or worn out tyres, etc. (compromised transport conveyor belt, etc.) will be submitted to entities that are authorized to carry out disposal.

Non-hazardous industrial waste – aerobically stabilised sediment from the local water treatment plant and washed sand from the sand trap is recommended to be treated the following way: the aerobically stabilised sediment from the local water treatment plant will be dehydrated and sent to DNDIW in Kozloduy NPP, to be used later for reclaiming and filling of disturbed terrains etc. The opportunity for implementation of facilities for composting and agricultural exhausted soil nutritional enrichment, etc. will be precisely specified.

Sand deposits from LWTP sand trap (after washing) can be used for land filling in DNDIW.

Stockpiling/landfilling – The construction waste generated in construction phase and later repair works will be stockpiled in locations specified by the Community or will be reused after appropriate treatment (crushing) for filling of disturbed terrains, road construction, etc., or will be mixed with other waste, for different purposes. The opportunity for mixing it with overburden will be specified at the operation phase.

The Domestic waste will be stockpiled at DNDIW of Kozloduy NPP. It is not allowed to deposit hazardous waste generated during the construction and operational stages in DNDIW, because it contradicts to the regulatory requirements; it will aggravate the environmental conditions in the region and create risk for the site workers health.

The Domestic waste can be used after certain treatment (composting, terrains reclaiming, etc.).

4.7.1.3.7.1.2 Hazardous waste

Obsolete lead acid accumulators – will be submitted under contract to authorised recycling companies – this obligation is bound to the companies (construction and transportation) that operate the site.

Luminescent and mercury lamps – the obsolete luminescent and mercury lamps will be collected specific protected storages and submitted to authorised companies for recycling.

Spent compressor and engine oils – it is planned the spent oils to be collected in 100 l containers; the spent oils will be stored in specific locations according to the regulatory requirements and will be submitted under contract to authorised companies for recycling.

Paints and varnish packages – submitted to authorised company for recycling.

Oils separated in SOR – ubmitted to authorised company for disposal.

SOR sediments – submitted to authorised company for disposal.

4.7.1.3.7.2 *During operation*

At the operation phase the generated waste include:

Domestic waste – Generated by the site personal related to NNU operation, auxiliary personnel and visiting personnel (facilities control and maintenance); the waste will be collected in containers, powdered with hydrated or chlorinated lime for disinfection and regularly transported to DNHIW of Kozloduy NPP. Treated as the domestic waste generated during construction phase.

Construction waste – Generated only during the repair works. Treated as the construction waste generated during construction phase.

The domestic and construction waste will be treated as the waste generated during the construction phase.

Non-hazardous industrial waste – It is recommended aerobically stabilised sediments from LWTP, sand deposits from the sand trap and other non-hazardous industrial waste to be treated as those generated during the construction phase.

Hazardous waste: Obsolete lead acid accumulators, defective luminescence and mercury lamps, spent oils, SOR sediments and oils separated in the upper layer will be treated as during the construction phase.

4.7.1.3.7.3 *During decommissioning phase*

Domestic waste generated by 300 workers will be collected in containers located in appropriate locations on the site. The waste will be powdered with hydrated or chlorinated lime for disinfection. The waste shall be regularly transported to the communal depot for non-radioactive waste. For that purpose the Principal shall conclude a contract with company authorised to carry out such activities.

Construction waste – Can be optimally used for: backfilling; ground levelling of the site; construction of embankment along the rivers; terrain reclaiming, etc.

Domestic and construction waste will be treated as the waste generated during the construction and operation phase.

The generated *non-hazardous industrial waste* – It is recommended aerobically stabilised sediments from LWTP, sand deposits from the sand trap and other non-hazardous industrial waste to be treated as those generated during the construction phase.

Stockpiling/landfilling – It is done by analogy with construction and operation phases or waste will be used after additional treatment.

Hazardous waste – Obsolete lead acid accumulators, defective luminescence and mercury lamps, spent oils, SOR sediments and oils separated in the upper layer will be treated as during the construction and operation phases.

4.7.1.4 ASSESSMENT OF THE ENVIRONMENTAL IMPACT FORECAST FOR WASTE GENERATED BY INVESTMENT PROPOSAL IMPLEMENTATION AND THE WAY OF ITS TREATMENT

The specified methods for collection, transportation and disposal of waste generated by *investment proposal implementation* are appropriate and environmentally friendly and deterioration of environmental situation in the region is not expected.

In compliance with the proposed measures for reduction to reasonable minimum of the generated waste quantities and under strict control and effective management, the summarized impact of the 'Waste factor' during the construction of various sites of IP, their commissioning, operation and decommissioning, is expected to be as follows:

Territorial scope of impact: Within the boundaries of the respective site, within the area provided for temporary waste storage and disposal in conformance with the regulatory requirements.

Mode and degree of impact: In compliance with all the measures for effective management of non-radioactive waste, significant negative impact on the individual components of the environment is not expected.

Duration of exposure: Long term, over the entire construction phase, operation, decommissioning, including after its lifetime.

Frequency of exposure: Continuous, for the entire construction phase, operation, decommissioning, including after its lifetime.

Cumulative impact: Increase in specific types of non-radioactive waste is expected:

during the construction period of 5 years – excess of earth masses is expected only on site 2 of about 180 thousand m^3 for the entire construction period. T The majority of non-hazardous, non-radioactive waste will be utilized.

during operation – the different types of non-radioactive waste is expected to increase to the period of operation of the remaining reactors at the site.

during decommissioning – cumulative effect is not expected.

Transboundary impact: Not expected.

4.7.2 RADIOACTIVE WASTE

There are several hundred radioactive nuclides generated in the nuclear reactor (self-existing isotope splitting). Most of them are with short half-life and decayed fully or to very low specific activity before they enter the waste. The total number radionuclides of potentially concentrations that can be found in nuclear reactors is about 100.

The primary source of radionuclides is the nuclear reactor. Depending on the degree of tightness, and corrosion of the fuel elements in the respective reactor, the waste can be expected to vary in content of radioactive fission products and corrosion products of activation. The ratio between these radionuclides and their concentrations in RAW determines the waste category and ultimately the type and size of the facilities for processing, storage and disposal of conditioned RAW.

The radionuclides in RAW are classified into three groups depending on the way they are generated:

- ✓ activation products – ^{3}H, ^{14}C, ^{55}Fe, ^{59}Ni, ^{60}Co, ^{63}Ni;
- ✓ fission products – ^{90}Sr, ^{129}I, ^{134}Cs, ^{137}Cs;
- ✓ actinides – ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{241}Am.

Of the large number radionuclides that can be found in waste relatively small part are of key importance for the different management phases. The main properties of RAW that depend on the radionuclides contained in it are:

- ✓ emission of heat at high radionuclides concentration;
- ✓ necessity of biological protection;
- ✓ criticality (probability for chain fission reaction);
- ✓ radiotoxicity.

On the basis of the above-mentioned and some other additional criteria, as critical for the long-term safety of RAW disposal, the following radionuclides are considered **^{3}H, ^{14}C, ^{36}Cl, ^{55}Fe, ^{59}Ni, ^{60}Co, ^{63}Ni, ^{79}Se, ^{90}Sr, ^{99}Tc, ^{126}Sn, ^{129}I, ^{134}Cs, ^{135}Cs, ^{137}Cs, ^{152}Eu, ^{235}U, ^{238}Pu, ^{239}Pu,**

^{240}Pu, ^{241}Pu, ^{241}Am, ^{242}Cm. Depending on the type of the disposal facility, there are limits for their maximum activity in the corresponding RAW management facility.

The history of reactor core operation is of utmost importance for irradiative properties of RAW. However for waste physical and chemical properties the extreme importance have preparation and implementation of reactor repair and maintenance activities and it's auxiliary facilities, as well as the technologies used for deactivation of radionuclide contaminated gases, liquids and solids.

The new nuclear unit foresees use of ionizing radiation sources for the purposes of metal control, calibration of dosimetric and radiometric equipment, in fire alarm installations, for process measurement and control. After discarding them, they also will be treated as radioactive waste.

The adopted by IAEA "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management" and the Regulation on the Safe Management of Radioactive Waste of NRA define the international criteria and national regulatory requirements in all aspects of activities associated with RAW. By virtue of the Regulation of NRA from 2004 are set three (3) categories of solid RAW depending on their activity – Ist, IInd and IIIrd category, called also low-, medium-and high-level radioactive waste. The liquid RAW are classified according to the characteristics of the solid radioactive waste, which is expected to be obtained after conditioning them.

In connection with the processing of radioactive waste and in accordance with Art. 5 of the Regulation on the Safe Management of Radioactive Waste, three categories of solid RAW are defined:

- ✓ **Category 1:** transitional waste that can be cleared from regulatory control after appropriate processing and/or temporary storage for a period not longer than five years, during this period their specific activity decreases below control exemption levels;
- ✓ **Category 2:** low and intermediate level waste containing radionuclides in concentrations, not requiring special measures for heat removal during its storage and disposal; this RAW category is additionally divided to:
  - Category 2a – low and intermediate level waste, short-lived, containing mainly short-lived radionuclides (half-life period, shorter or equal to the half-life period of ^{137}Cs), and long-lived alpha-active radionuclides with specific activity, less or equal to 4.106 Bq/кg for each packing and less or equal to 4.105 Bq/кg in the entire RAW volume;
  - Category 2b – long-lived low and intermediate level waste, containing long-lived alpha-active radionuclides (with half-life period longer than the half-life of ^{137}Cs) with specific activity exceeding the category 2a limits;
- ✓ **Category 3:** high level waste with such a concentration of radionuclides that heat generation shall be considered during storage and disposal.

4.7.2.1 AP-1000

The systems for radioactive waste management are systems that treat liquid, gaseous and solid waste that may contain radioactive materials.

For AP-1000 reactor there are several approaches providing for lower radioactive emissions from the source [10]. These approaches are as follows:

✓ **Burn up fraction of TOE**

The fuel economy is closely related to the quantity of the spent fuel.

Both are optimised when burn-up cycle is designed in such way that the fuel is released from reactor as close as it is rational up to the licensed burn-up limitation.

The active Westinghouse fuel licensing limitation is 62.000 MWD/MTU with respect to the maximum burn-up of the heavy element. Usually it is achieved average burn up of about 50000 MWD/MTU per batch.

✓ **Operation cycle**

Reactor AP-1000 can be operated at different operation cycle lengths (for example annual or 18 months). If the main task is to decrease the average number of spent fuel cartridges per year then the annual cycle of reactor AP-1000 will burn averagely less cartridges in comparison with 18 months cycle (40% compared to 43%). However, depending on the price of the additional planned annual overhaul (PAO) in every 3 years, the price of the substitute power during PAO, the impact of PAO length on the average coefficient of utilisation of the installed power, etc. from economy view point this may not be the most effective solution for core operation. The majority of Westinghouse customers have chosen the longer 18 –months operational cycle.

✓ **Tramp Uranium (accidental uranium)**

The samples show insignificant uranium contamination sometimes called Tramp uranium (accidental uranium) of external surface of TOE, made by Westinghouse.

✓ **Specific features of TOE/ TOE containment**

The TOE containment is of metal-ceramics – at operational temperatures and pressure the high density uranium dioxide fuel demonstrates insignificant reaction with the active zone. In case of containment defects the high resilience of uranium dioxide to water protects fuel from deterioration even if it is possible limited fuel erosion to occur. The consequences of containment defects are reasonably lower due to the uranium dioxide potential to detain the fission products, including the gaseous and highly volatile products. The selection of material called ZIRLO minimizes defect formation that can lead to radioactive out throw to the primary coolant.

Compared to the previous type the fuel type that is going to be used in reactor AP-1000 is improved and has lower level of cartridge vibrations. This fuel type is already been used in

[10] UKP-GW-GL-790, Rev. 4, "UK AP1000 Environmental Report," Westinghouse Electric Company LLC

some power plants. Since the introduction of 17x17 RFA (stableTOK) of Westinghouse in 1998, the total percentage of leakages for this model that includes all Westinghouse technical solutions for protection from fuel particles is 0. The total percentage of leakages, in relation to TOE number, for standard RFA, including models that do not use all means for protection from fuel particles, is less than 10E-05[11].

✓ **Material selection**

To decrease formation of Co-60 by activating of Co-59, the latter is limited to under 0.05 weight % in reactor internal structures and under 0.2 weight % in main and auxiliary materials. Through wear and tear resistance and corrosion stability testing for overlay welding or other applications, alloys with the law or zero cobalt contain are specified instead of the formerly used cobalt alloys. The corrosion testing specifies the alloy corrosion stability in the primary coolant. Among the wear resistant cobalt free alloys considered for this application are the developed alloys qualified for utilisation in nuclear industry programs.

The use of cobalt alloy (for example Stellite®) is limited to applications where its hardness, low friction coefficient and wear resistance ensure highest reliability in relation to critical operational activities. The examples include applications on guiding surfaces of motor driven parallel faced gate valves and seat surfaces of pneumatic ball valves where tight sealing and endurance are required.

The parts of control and protection system (CPS) drive and the parts along the CPS drive route, exposed to primary coolant effect are made of metals resistant to the coolant corrosive effect. Only three types of metal are used: stainless steels, nickel-chrome-iron alloys and in limited applications – cobalt alloys. These materials give ensured many years effective operation of such CPS drives. In relation to the stainless steels only austenite and martensite stainless steels are used. In AP-1000 project the cobalt alloys are brought to minimum.

Co-58 is formed at activation of Ni-58. Because of that nickel alloys are used in the system of coolant recirculation only when the component reliability can be compromised if other materials are used. The main application of nickel alloys in the coolant recirculation system is in the steam generator tubing made of INCONEL.

As engineering safety measures there are common restrictions on application of copper, lead and antimony as well as other metals with low melting point. Beside this the project criteria for main recirculation pump completely restrict application of antimony in main recirculation pump and it bearings.

✓ **Minimising of leakage routes**

The reactor AP-1000 is designed with less valves and components (less sealed passages, total reduction of KCK, shifting of reasonable part of the volume control system and boron

[11] PPE-11-18, "17x17 RFA Overall Leakage Rate," Westinghouse Electric Company LLC, February 2011

control in the containment area) in comparison with prior nuclear plants, which leads to less leakage routes and less RAW as a whole.

✓ **Control of primary coolant water chemical conditions**

The coolant recirculation system contains boron acid for long term control of the core reactivity. The control of primary circuit water chemical conditions (WCC) is intended to minimise corrosion by addition of chemicals by means of volume control system and boron control. The following chemical substances are added to the borated coolant recirculation system:

→ *Lithium-7 hydroxide* (Li7OH) used for pH control of coolant recirculation system and was selected because of its compatibility with borated WCC, stainless steel and zirconium materials. The effective pH control reduces formation of radioactive corrosion products that can be expelled as liquid waste. Usage of Li7OH, with enriched Li-7 isotope, prevents as well an important mechanism for tritium formation. The Lithium-7 neutron absorption cross-section is five times less than Lithium-6 and the application of Li7OH considerably reduces the possibility for tritium formation related to the neutron absorption of Lithium-6, present in natural Lithium hydroxide.

→ *Hydrazine* is added as oxygen cleaning agent at unit cold start to reduce the formation of corrosion products related to dissolved oxygen.

→ The dissolved *Hydrogen* is added to coolant recirculation system during loaded operation for elimination of the free oxygen generated by radiolysis in the active zone and for prevention of ammonia generation.

→ The Zink acetate is initially added at hot functional tests and operation activities for minimization of corrosion and reduction of cobalt and activated nickel concentrations.

The coolant recirculation system WCC are routinely analysed, to ensure their adequacy and that particles formed by corrosion products are under specified limits.

✓ **"Grey"** OP of control and protection system (CPS) and OP with burnable absorber

The active zone reactivity is controlled by means of chemical absorber (boron acid) dissolved in coolant, CPS cluster arrays, "grey" OP of CPS and burning neutron absorbers. The „grey" OP of CPS are used at manoeuvrability mode of unit operation and ensure mechanical compensative reactivity control thus eliminating the necessity of chemical compensative reactivity control, ensured by change of soluble boron concentration. Separate rods with burnable absorber, integrated TOE with burnable absorber or both types can be used for ensuring of partial control of the excess reactivity during the fuel cycle. Thus the rods with burnable absorber reduce necessity of dissolved boron in coolant at the beginning of the fuel cycle. The reactor control secured by grey OP of CPS and burnable absorber rods, reduce the necessity of boron concentration change in coolant recirculation system. This way it is possible to reduce the primary coolant volume

extracted by means of volume control and boron control systems and treated as liquid RAW.

✓ **Reactor coolant circuit boundaries**

The atmospheric ejection can be limited by restriction of primary coolant leakages. Reactor coolant circuit boundaries secure barrier against release of reactor generated radioactive emissions. Reactor coolant circuit boundaries are the vessels, pipelines, pumps and valves, part of primary coolant circuit or connected to it, including the following:

→ The final shutoff valve of the containment area system pipelines that penetrate the containment area.

→ The second of the two valves of the system pipelines not penetrating the containment area that are closed during normal operation.

→ Valves for primary circuit pressurization protection.

The reactor coolant circuit boundaries are designed to contain the cooler at operation temperature and pressure and restrict leakages (and release of radioactivity) in containment area. The establishing of leakages within the coolant circuit boundaries is performed by variety of methods including level, flow and radioactivity measurements.

✓ **Primary coolant treatment**

The system for volume control and boron control perform primary coolant treatment aimed to reduce its activity. The treatment installation of the volume control and boron control system consists of two backup unit demineralizer systems (UDS) with mixed ion exchange columns, recurrently used UDS with cation exchange column, two backup UDS with cation exchange columns and two primary coolant filters. The UDS with mixed ion exchange columns serve for elimination of ion corrosion products and certain ion fission products. The UDS act also as coarse filters for incidental large particles. The fine filtration is provided by primary coolant filters located downstream to UDS to filter particles and fine resin fractions. They are designed to retain 98% of the particles smaller than 0.10 μm with adequate filter permeability to maintain differential pressure of 0.30 MPa. It is expected at the time of unit start up and testing, and probably during the initial several cycles, filter cartridges with larger micron size to be needed (to extend the filters life and replacement of filtering cartridges).

In normal operation one of the ion exchange columns is operational and the second UDS acts as backup in case the operational column depletes during the operation. Each UDS and filter has capacity ensuring their operation for one fuel cycle at least; usually at fuel cycle end the operational UDS is replaced, regardless of the conditions and chemical exposure history during the cycle. It is expected the UDS with mixed ion exchange and cation exchange columns to have reasonable unused capacity and to be capable to manage the primary loop treatment during the activities of unit suspension.

Incident or unexpected events or transitional processes related to contamination could prematurely force the suspension of the mixed ion exchange column of primary circle volume control and boron control system. In this case the backup ion exchange column of

volume control and boron control system can be put in operation without being necessary to enter the containment zone.

UDS with mixed ion exchange columns of the volume control and boron control system has limited capacity for boron removal. At every moment the operational decontaminating mixed ion exchange column will be completely boron equalised. The designated as "backup" UDS with mixed ion exchange column of the volume control and boron control system (which is still not operational) has the potential to remove about 70 ppm at the end of the fuel cycle. If the backup ion exchange column is used for boron removal in primary coolant only at the end of the cycle, it can be appropriately used as purifying mixed ion exchange column in the next fuel cycle

When there are defects in the fuel the operational UDS with mixed ion exchange column can be supported by incident introduction of UDS with cation exchange column for additional purification. in such case the cation resins remove mainly isotopes of Lithium and Caesium. UDS with cation exchange column sufficient capacity to support Caesium 136 concentration in primary coolant under 1.0 μCi/cm^3 in case of project fuel defects. Each UDS with mixed ion exchange and cation exchange columns has potential to process the maximum flow during the treatment.

The ion exchange in volume control and boron control system removes as well radioactive Iodine from the primary coolant. The removal of noble gases from the primary circuit usually is not necessary because the quantity of gases will not rise to unacceptable levels when the fuel defects are within the normally expected limits. If it is necessary to remove noble gases due to their high concentration in the primary circuit the system for volume control and boron control can work together with degasing installation of the liquid RAW system to eliminate gases.

By keeping low activity in the primary circuit the radioactive ejections related to coolant leakage from primary circuit to the containment zone atmosphere are reduced.

- ✓ **Systems for liquid waste management**

The systems for liquid waste management include the following systems:

- → Steam generator blowndown system
- → Drainage system for radioactive waste
- → System for liquid RAW

The systems for collection and treatment of liquid wastes are closely related to a volume and boron control systems. The systems for steam generator blowdown controls and supports WCC in the steam generator secondary circuit. The blowdown is usually recycled in the condenser by the means of electronic system for ion exchange, but in case of high radiation the blowdown is routed to the liquid RAW system. This allows for reasonable simplification of steam generator blowdown system without additional equipment in the liquid RAW system.

The system for liquid RAW uses ion exchangers for treatment and removal of all primary circuit waste. For increasing of ion exchange efficiency the system for liquid RAW is split in

two treatment channels for separation of borated coolant from low quality liquid waste. Based on conservative limits regarding fuel defects and ion exchange efficiency and in conformance with User Requirements Document (URD), no evaporators are needed.

The degasing station of vacuum type catches radioactive gases in the liquid ejection from primary circuit and transfers them to the system for gaseous RAW. The degasing installation eliminates the necessity of buffer gases or membrane in the tanks for waste containment.

The following table summarises the annual average mass flow that is going to be treated in the liquid RAW system or ejected in the environment during normal operation.

The expected operational liquid RAW, generated by reactor AP-1000, is presented in **Table 4.7-2**[12].

TABLE 4.7-2: EXPECTED OPERATIONAL LIQUID RAW GENERATED BY SYSTEM OPERATION

System	Waste description	Waste category	Physical/Chemical description	Expected quantities			Radioactivity
				Normal daily volume (m^3)	Maximum daily volume (m^3)	Total volume for entire period of plant operation (m^3)	
System for steam generator blowdown	Steam generator blowdown	Low level waste	Secondary coolant	4.22	42.24	2.22E+06	Included here as RAW but can be non-radioactive
Volume and boron control system	Dilution of boron concentrate at the end that the fuel campaign	Low level waste	Borated primary coolant	6	26	2.52E+02	100% primary coolant
and boron control system	Primary circuit heating	Low level waste	Borated primary coolant	85	170	4.08E+03	100% primary coolant without radiogas
System for liquid RAW	Compensative blowout of volume and boron control system (liquid)	Low level waste	Primary circuit coolant/diluted boron acid	1.65	2.94	4.17E+04	100% primary coolant
System for liquid RAW	Equipment leakages	Low level waste	Diluted boron acid	0.34	54.5	1.07E+04	100% primary coolant
System for liquid RAW	Drain water (contaminated waste)	Low level waste	Diluted boron acid	4.54	21.8	1.01E+05	0.1% primary coolant
System for liquid RAW	Sampling system drain	Low level waste	Diluted boron acid	0.76	3.79	1.73E+04	100% primary coolant
System for liquid RAW	Wash-basins/Showers in control	Low level waste	Wastewater	0.76	7.57	4.64E+04	10E-07 µCi/cc (0.037 MBq/m^3)

[12] UKP-GW-GL-790, Rev. 4, "UK AP1000 Environmental Report," Westinghouse Electric Company LLC

System	Waste description	Waste category	Physical/Chemical description	Expected quantities: Normal daily volume (m^3)	Expected quantities: Maximum daily volume (m^3)	Expected quantities: Total volume for entire period of plant operation (m^3)	Radioactivity
	room						
System for liquid RAW	Equipment and land deactivation	Low level waste	Surfactant containing waste	0.15	1.51	9.28E+03	0.1% primary coolant
System for liquid RAW	Chemical waste	Low level waste	Processed samples containing analytical chemicals	0.03	0.05	7.10E+02	≤ primary coolant
System for liquid RAW	Deactivating fluids	Low level waste	Liquid containing deactivating chemicals	0.0023	0.0047	6.20E+01	1 µCi/cc (37000 MBq/m^3)

✓ System for gaseous RAW

The system for gaseous RAW is continuous floors system with temperature equal to the temperature of surrounding environment and activated carbon column. The system for gaseous RAW consists of draining vessel, gas cooler water separator, preliminary activated carbon column and two main columns with activated carbon. The system for gaseous RAW includes also subsystem with oxygen analyser and subsystem for gas sampling. Gaseous fission products entering the gaseous RAW system are transferred by hydrogen and nitrogen. Source of the main influx is the degasing installation of liquid RAW system. Degasing installation extracts hydrogen as well as gaseous fission products from the drainage line of volume and boron control system.

The expected quantity of operational gaseous RAW[13] is presented in **Table 4.7-3**.

TABLE 4.7-3: EXPECTED OPERATIONAL GASEOUS RAW GENERATED BY AP-1000 SYSTEMS OPERATION

System	Waste description	Waste activity	Physical/Chemical description	Expected quantities: Normal volume		Maximum volume		Total volume for entire period of plant operation	
				cm^3/min	m^3/h	cm^3/min	m^3/h	ft^3	m^3
System for gaseous RAW	Discharge to drainage tank for primary coolant	Low level waste	Hydrogen Nitrogen and gaseous fission products	0	0	1.05	0.000063	1170	33.14
System for gaseous RAW	Compensative blowout of volume and boron control	Low level waste	Hydrogen Nitrogen and gaseous fission products	45.7	0.002742	81.6	0.004896	50904	1441.44

[13] UKP-GW-GL-790, Rev. 4, "UK AP1000 Environmental Report," Westinghouse Electric Company LLC

system (gas)

✓ System for solid RAW

The system for solid RAW is design for collecting and accumulating spent ion exchange resins and thick layer filtering elements, spent filtering cartridges, dry active waste and mixed waste generated as a result of normal operation including expected failures to observe operational norms. The system for solid RAW is located in the special building and in RAW facilities.

The standard AP 1000 solid RAW system is specially designed for flexibility in relation to solid RAW treatment, because the customer and regulatory requirements differ significantly in the separate countries and markets. The treatment and packing of waste can be accomplished by mobile systems in railroad transport corridor of the special building and the facility for mobile systems inside RAW building, each of them has its own service interfaces covering number of potential equipment types (compressed air, water, electrical power). Use of mobile system for treatment purposes allows for application of latest technologies, eliminates the issue related to obsolete installed equipment for RAW treatment and provides needed flexibility related to conformance with the constantly developing regulatory requirements. The most appropriate and effective systems can be used immediately after they become available. The installation of systems for solid radioactive waste treatment is implemented in many other projects for pressurised water reactor AP-1000 (generation of less than 50 m^3 low and intermediate level waste) mostly based on the site specific conditions than to unit specific requirements for maximum efficiency. The implementation of such systems (i.e. for solidification) could be discussed at later stage.

TABLE 4.7-4: SUMMARISED PRESENTATION OF MAIN SOLID RAW GENERATED BY REACTOR AP-1000

Waste description	RAW classification	Frequency	Normal volume per unit frequency (m^3)	Maximum volume per unit frequency (m^3)	Total volume for entire period of plant operation (m^3)
TOE	High level waste	40%/18 months	13.7		549
Ion exchange resin	intermediate level/low-level waste	Annually	7.8	15.6	561
"Grey"OP of CPS	Intermediate level waste	Every 200 years	1.7		5.1
CPS cluster array	Intermediate level waste	Every 20 years	5.6		16.9
Dampened granulated carbon	Intermediate level/low-level waste	Annually	0.6	1.1	41
Filtering cartridge – Metal cylinder	Intermediate level/low-level waste	Annually	0.2	0.4	13.7
Compactable paper, tape,	Low level waste	Annually	135	206	8924

Waste description	RAW classification	Frequency	Normal volume per unit frequency (m^3)	Maximum volume per unit frequency (m^3)	Total volume for entire period of plant operation (m^3)
clothing, plastics, elastomers					
Non compactable metal elements, glass, wood	Low level waste	Annually	6.6	10.6	455
Heating system filter, ventilation and conditioning – non-compactable fiberglass/metal	Low level waste	Differs			761
Spent resins from condense treatment	Low level waste	Annually	3.9	7.7	69.3
Dry granulated carbon	Low level waste	Annually	0.3	3.3	54.3
Heating system filter, ventilation and conditioning – granulated activated carbon	Low level waste	Every 10 years	4.9		29.1
Shrinkable hard plastics – seals, valve packing, insulation	Low level waste	Differs			7.6
Installation for electrodeionisation – resins/membrane module	Low level waste	Every 12 years	1.7		10.8
Heat exchangers insulation	Low level waste	Every 60 years	8.4		8.4
filter – corrugated polyester	Low level waste	Annually	0.1		5
Dampened granulated particles – sludge	Low level waste	Annually	0.03	0.1	2.4
spent oil	Low level waste	Every 5 years	0.15		1.8

4.7.2.2 AES-92

- ✓ **Forecast RAW quantities generated during operation**

According to Status Report for Advanced Nuclear Reactor Designs – Report 93. VVER–1000 (V-466B) IAEA Last update: 21-07-2011, forecast annual emission of radioactive waste after treatment does not exceed 50 m^3 per unit. This quantity does not include waste generated during repair and technical maintenance.

It is possible to make reference to KudanKulam NPP where the forecast annual emission is about 350 m^3 solid waste for two units ,that could be reduced after treatment to 250 m^3/year. This case includes repair activities and technical maintenance. The solid radioactive waste is generated from: waste cotton, paper, rags, plastics, equipment components, filters from spent resins, filter screens cartridges, filter sludge, etc.

- ✓ **RAW management to its final burying or exempt from regulatory control**

The systems needed for radioactive waste management differs depending on radioactive waste condition: liquid, gaseous or solid.

✓ **System for liquid radioactive waste management**

The system for liquid radioactive waste management is designed for management of liquid radioactive waste generated during nuclear plant operation. Liquid radioactive waste include resins and salt concentrates (evaporate concentrate).

Following generation the radioactive waste is temporarily stored for consequent treatment. Usually the temporary storage is necessary because of the short lived radionuclides. The procedure for treatment of such type radioactive waste usually passes through its solidification using different methods whereat waste changes from liquid to more stable solid form.

✓ **System for collection and treatment of gaseous radioactive waste**

Gaseous waste is treated differently in two subsystems depending on the treated gas. In case of hydrogen it is combusted in hydrogen combustion system. The radioactive products are treated in the system for radioactive process treatment.

Treatment system is connected to ventilation for reduction of ejections in the environment from processing of air coming from different plant premises.

✓ **System for solid radioactive waste treatment**

The system for solid radioactive treatment is designed for management of solid radioactive waste generated during nuclear plant operation. It also serves for temporary storage of such type radioactive waste.

Depending on activity and composition of the solid radioactive waste it is categorized for consecutive treatment. Then it is sealed in drums/containers and transferred for processing to the treatment and storage building.

Volume of low and intermediate level solid radioactive waste can be reduced by pressing, fragmentation and incineration (conventional or plasma). High level solid radioactive waste is transported in special containers for high level waste.

✓ **Forecast impact of gaseous RAW (KudanKulam NPP)**

The only data on forecasted radioactive impact caused by ejection of gaseous aerosols through ventilation tube of power plant operating with B-412 reactor can be found in Environmental Impact Assessment of Nuclear Power Plant KudanKulam – **Table 4.7-5**.

TABLE 4.7-5: GASEOUS AEROSOL EJECTIONS FROM SINGLE NUCLEAR UNIT IN KUDANKULAM NPP

Radionuclides	Rated values of ejection of gaseous aerosols through ventilation tube	Dimension
Noble gases from fission products	1.14E10	Bq/day
I-131	2.48E5	Bq/day
Long-living aerosols	2.62E5	Bq/day
Sr-90	2.03E1	Bq/month
Sr-89	4.68E3	Bq/month

Cs-137	2.41E5	Bq/month
Co-60	1.44E4	Bq/month
Mn-54	2.72E3	Bq/month
Cr-51	3.96E3	Bq/month

Source: *National Environmental Engineering Research Institute (NEERI). Comprehensive Environmental Impact Assessment of Nuclear Power Plant (Units 1 & 2), KudanKulam. January 2003. (http://npcil.nic.in/pdf/Comprehensive_EIA_of_KKNPP1_2.pdf.*

4.7.2.3 AES-2006

Technological systems for radioactive management are located in reactor building, auxiliary buildings and in building for radioactive waste storing and treatment[14].

Solid and liquid radioactive waste are classified as follows (**Table 4.7-6**):

TABLE 4.7-6:SOLID AND LIQUID RAW CLASSIFICATION

Category	Dose level Gamma rays mSv/h	Specific activity, kBq/kg		
		Beta radioactivity	Alpha ray emitters (except transuranian)	Transuranium
Low level	10^{-3} to 0.3	< 10^3	< 10^2	< 10
Intermediate level	0.3 to10	10^3 to 10^7	10^2 to 10^6	10 to 10^5
High level	> 10	> 10^7	> 10^6	> 10^5

- ✓ **Forecast data for RAW quantities generated during operation**

According to Report 107. VVER–1200 (V-392M) IAEA. Last update: 01-08-2011, the forecasted annual quantity of radioactive waste after treatment is not exceeding 50 m^3 per unit.This quantity does not include waste generated during repair and reactor refueling.

Total quantities of low and intermediate level radioactive waste for LNPP-2 (two units) is under 90 m^3 according to Information summary regarding environmental impact at construction and operation of second stage of Leningrad NPP-2, results of environmental impact assessment for the LNPP-2 second stage.

- ✓ **RAW management to its final burial or exempt from regulatory control**

The systems needed for radioactive waste management differs depending on RAW condition: liquid, gaseous or solid.

- ✓ **System for liquid RAW management**

[14] Justification of Investments into Nuclear Power Station Construction in the Republic of Belarus. Book 11. Assessment of Impact on the Environment. 1588. Part 8. EIE Report. Part 8.1 NPS Description (Edition 06.07.2010)

The system for liquid RAW management is designed for management of liquid RAW generated during plant operation. The liquid RAW includes: resins, evaporate concentrate, sediments, etc.

Liquid RAW is generated and stored and consequently treated. Usually the storage is necessary for decay of short lived radionuclides. The typical procedure for treatment of such RAW type passes through its solidification using different methods whereat waste changes from liquid to more stable solid form.

The liquid radioactive waste is treated by evaporation whereat pure condensate is obtained, re-used in the plant, and concentrated salts (evaporate concentrate) which is also considered as liquid radioactive waste.

- ✓ **Liquid RAW temporary storage and consequently treatment includes the following subsystems:**
  - → System for temporary storage of concentrated salts and used sorbents (ensures storage for at least 3 months needed to reduce the level of radioactivity caused by decay of short lived radionuclides);
  - → Special filters for water purification: ion exchange filters, special water treatment systems – sludge tanks;
  - → Conditioning and solidification system;

To obtain solidified product for final burying after mixing with cement the liquid RAW is stored in special, concrete containers. These containers are designed for temporary storage and consecutive transportation to burial facilities. By application of technologies for waste minimisation the expected quantity of solidified liquid radioactive waste is 30 m^3 per year.

- ✓ **System for collection and treatment of gaseous radioactive waste**

Gaseous waste is treated differently in two subsystems depending on the treated gas. In case of hydrogen it is combusted in hydrogen combustion system. In case of radioactive gases they are treated in gas cleaning system. This system is connected to the ventilation system of different unit premises to reduce radioactive injections in the environment.

The radioactive gas cleaning system is designed for reduction to acceptable levels the activity of gas emissions resulting from equipment blowout.

Systems are equipped with high efficiency cleaning aerosol and iodine filters.

Besides the above mentioned radioactive gases there are radioactive gases and aerosols incoming from reactor vessel when upper reactor block is removed during its refuelling, as well as gases from radiochemical laboratories with local exhaust system.

- ✓ **System for solid radioactive waste treatment**

System for solid radioactive waste treatment in solid RAW storage building is designed for management of solid radioactive waste generated during unit operation. Building also serves as temporary RAW storage.

Depending on activity and composition solid radioactive waste is classified according to its future treatment and later is packed in drums or containers.

- Low level waste are stored in special containers and consecutively treated to minimise the waste. The treatment includes: cutting incineration and pressing.
- intermediate level waste are stored in transport containers and then transported to storage and treatment building. In case the size such solid RAW is too big it is cut and/or fragmented. Intermediate level waste is stored in special protective containers.
- High level RAW is stored in special cells. It is transported in containers for high level RAW. Equipment designed for storing high level solid waste ensures safe high level RAW management thereof.

Most solid RAW are product of solidifying of liquid RAW- **Table 4.7-7** summarises radioactive waste treatment and storage.

TABLE 4.7-7: QUANTITY OF SOLID RAW GENERATED FROM TWO UNITS ENTERING STORAGE AND TREATMENT BUILDING

RAW	Point of generation	RAW quantity from 2 units m^3/y *(normal operation maintenance repair and incidents)*	Note
	Low level RAW		
Flammable gases	controlled zone access	220 (110/110)	
Non-flammable, pressurable	controlled zone access	130 (65/65)	
Metal	controlled zone access	20 (5/15)	50% for decay
TEN	RAW	1.0 (1/-)	50% for decay
	filters		
Non-flammable, pressurable	controlled zone access	32	once in two years
Flammable gases	controlled zone access	36	once in two years
Solidified waste	Normal operation of premises for technological and control system and special building	9.4	
	Intermediate level RAW		
Metal	controlled zone access	10 (10/-)	90% for treatment
	Other wastes		
Flammable gases	controlled zone access	23 (11.5/11.5)	90% for treatment

RAW	Point of generation	RAW quantity from 2 units m^3/y *(normal operation maintenance repair and incidents)*	Note
nonflammable	controlled zone access	54 (54/-)	90% for treatment
	filters		
nonflammable	controlled zone access	75	Once for the entire operation period – 50 years
Flammable gases	controlled zone access	87	Once for the entire operation period – 50 years
Solidified waste	Normal operation of premises for technological and control system and special building	25.7	
Solidified waste from special washing and incineration installation	RAW storage and treatment building	16.8	
	High level RAW		
Internal reactor control	RAW	1.0	
de decking units	RAW	1.0	

The final quantity of solid RAW (after treatment, excluding reuse) **does not exceed 50 m^3/year per unit –** Justification of Investments into Nuclear Power Station Construction in the Republic of Belarus. Book 11. Assessment of Impact on the Environment. 1588. Part 8. EIE Report. Part 8.1 NPS Description (Edition 06.07.2010).

- ✓ **Storage of solid radioactive waste**

Solid waste are stored in sales designed for storage of low intermediate and high level solid RAW. For storing of high level waste there is available equipment specified for solid RAW storage, activity category III, designed by ZSV "Atommasheksport". Low and intermediate level waste are stored in protected steel reinforced concrete containers.

At the present solid radioactive waste is stored on site in temporary storages. By the introduction of protected containers it is presumed that such RAW can be stored for 50 years which makes for reduction of treated volume due to natural decay of certain isotopes.

- ✓ **Forecast impact of gaseous RAW**

The only data on forecast radioactive impact caused by ejection of aerosols from AES-2006 reactor can be found in Environmental impact assessment of Baltic NPP[15]. Annual emission level is calculated at 50 tBq for one unit, of which 99.9% are inert gases and are 0.1%

[15] Rosatom. Ñonstruction of the Baltic Nuclear Power Plant Environmental Impact Assessment Summary

aerosols and iodine. Annual emissions of tritium are estimated at 3.9 TBq. The annual tritium emissions are estimated as 3.9 TBq.

4.7.2.3.1 Impact assessment of RAW from the operation of New Nuclear Unit for site selection

All four predetermined sites for construction of new nuclear unit are positioned so that the transport of RAW to existing facilities for radioactive waste treatment at the site do not intersect urban areas and roads of the national road network.

Conclusion: RAW generated by the operation of the NNU and the management thereof do not affect the choice of site.

4.7.2.3.2 Impact assessment of RAW from the operation of New Nuclear Unit for option selection

The technologies discussed as alternatives for the construction of the NNU are designed according to the requirements of EUR, which means that the generated RAW during the operation of the NNU are approximately the same for the three reactor technologies.

Conclusion: The impact of RAW for all three technology alternatives is expected to be limited to local site for all three technology alternatives.

4.7.2.3.3 Impact of RAW during decommissioning for site selection

Conclusion: Regarding site selection, the conclusions made for RAW management during operation are valid also for the management of RAW during decommissioning, i.e. it is not relevant to the choice of site.

4.7.2.3.4 Impact of RAW during decommissioning for option selection

There is no sufficient data on the process of decommissioning of the alternative technologies for the NNU, but because on the site of Kozloduy NPP there is built or in process of construction call infrastructure are needed for RAW management including the infrastructure needed for decommissioning of NNU, the impact of RAW is expected to be limited to local site.

Conclusion: The limited and reversible impact of RAW generated during the decommissioning is expected to be limited to local site for all three technology alternatives.

4.7.2.4 IMPACT ASSESSMENT

4.7.2.4.1 RAW impact assessment in reference to AP-1000:

- Impact probability – expected
- Territorial scope of impact – local – sites for RAW storage
- Type of impact – negative, direct, primary
- Level of impact – very low to medium (on site)
- Impact characteristic: radiation

- Frequency – temporary (to the phase end), permanent for storage and periodical for transportation
- Duration – long-term
- Cumulative impact – Yes
- Impact reversibility – reversible.

4.7.2.4.2 RAW impact assessment in reference to AES-2006 and AES-92

- Impact probability – expected
- Territorial scope of impact – local – sites for RAW storage
- Type of impact – negative, direct, primary
- Level of impact – very low to medium (on site)
- Impact characteristic: radiation
- Frequency – temporary (to the phase end), permanent for storage and periodical for transportation
- Duration – long-term
- Cumulative impact – Yes
- Impact reversibility – reversible.

4.8 HAZARDOUS SUBSTANCES

4.8.1 GENERATED POLLUTANTS FROM STORAGE, RESPECTIVELY USE OF HAZARDOUS SUBSTANCES. EXPECTED IMPACT

The use of "Hazardous Substances" is related to the construction, operation and decommissioning of individual sections of the sites of the investment proposal (IP).

4.8.1.1 HAZARDOUS SUBSTNACES DURING CONSTRUCTION

During the construction of the sites of the investment proposal the following shall be used:

- ✓ diesel fuels, gasoline, hydraulic oils etc. – used for the construction machines and transportation vehicles;
- ✓ paints and varnishes – for industrial design
- ✓ disinfectants for residential waste

In recent years decrees, regulations and other regulations and lists of applications for classification and coding of hazardous substances in accordance with different international conventions are promulgated: working with hazardous substances; storage; transportation; import, export and transboundary movement of hazardous substances.

The assessment of the factor "hazardous substances" is in accordance with the Laws of the Republic of Bulgaria harmonized with the European laws.

Activities provided for in the construction of the site, according to the investment proposal are related to the use of hazardous substances from the group of petroleum products – diesel and mineral oils used respectively for the operation of the construction service

machines and equipment on the site, as well as hazardous paints and varnishes in the implementation of some of the finishing work as follows:

- ✓ Use of fuels for the construction service machines related to the implementation of the respective construction works on the sites: preparation of the sites for the new nuclear unit (NNU); implementation of the internal infrastructure related to communications, electricity, water supply, roads, etc.; performance of individual assembly works, additional activities related to the large volume of construction works, waste water treatment plant etc.
- ✓ Fuels for the vehicles servicing the construction used for delivery and transportation of necessary materials and equipment for the assessed sites;
- ✓ The provided for transport and construction machines and vehicles shall use also lubricants (motor oils) which toxic characteristics make them dangerous to humans and the environment.
- ✓ Finishing (painting in shaping the internal and external appearance of the halls and the like) are associated with the use of paints and varnishes containing organic solvents or other hazardous substances;
- ✓ Laying of asphalt on the various road communications.
- ✓ Chlorinated lime – is likely to be used to disinfect the collected residential waste generated by workers.

Table 4.8-1 lists the chemicals expected to be used during construction of the sites of the IP. CAS No. and EC No, are stated. Their classification classes, categories and hazard statements are under Regulation (EC) No. 1271/2008 on classification, labeling and packaging of substances and mixtures (CLP).

TABLE 4.8-1: CLASSIFICATION OF CHEMICAL SUBSTANCES EXPECTED TO BE USED DURING CONSTRUCTION OF THE SITES OF IP

Name, hazard sign	Place of use	EC No	CAS No	Codes of classes и categories of hazard	Codes of statement of hazard
Diesel fuel – (Xn,F,N); R phrase – R40; R20-65, R38, R51-53	Construction machines and transport vehicles	269-822-7	68334-30-5	Carc.2 Cat. 3	H351
Motor oils (Xn,N, sourses of PAH)		309-874-0	101316-69-2	Carc.1B	H350
Oils and greases		278-012-2	74869-22-0		
Paints and varnishes, (Xn, Xi, F)	Shaping of internal and external appearances of storages and the like	203-539-1, 203-905-0, 201-083-8, 234-324-0 и др. 204-658-1, 203-603-9, 215-535-7, 203-933-3 и др.	107-98-2, 111-76-2 78-10-4 11099-06-2 и др. 123-86-4, 108-65-6, 1330-20-7, 112-07-2 и др.	Flam. Liq.3 Acute Tox.4 Flam. Liq. 3, Acute Tox. 4, Flam. Liq. 3, Acute Tox. 4, Flam.Liq.3 Flam.Liq.3 Flam.Liq.3 Acute Tox.4 Skin Irrit.2	H226 H302,H312,H332 H226, H332 H226 H332 H226 H226 H226 H332, H312 H315

Name, hazard sign	Place of use	EC No	CAS No	Codes of classes и categories of hazard	Codes of statement of hazard
Chlorinated lime (O,C,N)	Disinfection of mixed residential waste	231-908-7	7778-54-3	Skin Corr. 1B	H314
Oxidized asphalt	Laying asphalt on internal roads, sites etc.	265-196-4	64742-93-4		

Short toxic characteristics of hazardous substances according to the standardization documents, scientific literature and field data:

Liquid fuels: Contain polycyclic aromatic hydrocarbons (PAH). Affect the central nervous system, respiratory tract, circulatory system, the condition of the liver and other internal organs, lipid metabolism and skin – oil acne. Narcotic effect on people. Deterioration of hypertensive conditions and shortness of breath Increased sensitivity (irritation) in individuals often accompanied by anemia and other negative phenomena.

The safe way to store is in metal containers in the ground or indoors. The transportation vehicles shall be refilled at service stations.

Oils and Greases: Damage the nervous system, the functional state of the liver, lipid metabolism, cause lipoid pneumonia in an aerosol exposure, oil acne, eczema, dermatitis and melanosis (which are likely to develop into malignant phenomena) folliculitis, hyperpigmentation, solar dermatitis. Have long-term effects – mutagenic, carcinogenic and are toxic for reproduction. These relate mainly to waste petroleum oils. Particularly hazardous are those oils and greases which are produced in the dry distillation of solid fuels. Less hazardous are oils produced synthetically and they possess much better performance properties. The procedure for the storage and use of the oils is the same as for fuels, and their quantities are significantly lower due to their low specific consumption. Therefore, lubricants (oills and greases) will generate even small quantities of hazardous waste as may be oiled textiles (yarn and cloth) used in emergency. Closed metal containers will be provided, which will periodically be seized and transported as directed by the company with the appropriate authorization under the Waste Management Act.

Paints and varnishes: Cause acute and chronic diseases due to irritation or allergic reactions. Damage the nervous and respiratory systems, liver, the endocrine balance and skin. Will be delivered to the site prior to their use in the respective isolated from the environment vessels and their use will be in accordance with the information on labels and instructions for use.

Asphalt: Hazard Class at transportation 9. REACH Registration No. 01-2119498270-36-0013 UN List – UN3257. When laying asphalt it is necessary to follow the instructions for labor safety, hygiene and fire safety (LSHFS).

Accident spills of fuels and lubricants and other contamination of soil and surfaces should be immediately decontaminated with chemicals, dredged and removed from the site as a

hazardous waste in accordance with regulatory requirements. The materials are of high value and spills and leaks that may have a negative impact on the environmental media – air, water, soil, flora, fauna and cause health risks for the population living in the area are almost excluded.

The investment proposal does not provide for activities such as storage and handling hazardous substances in quantities requiring a permit under Article 104 of the Environmental Protection Act (EPA). (Kozloduy NPP has a permit that should be updated by adding the new quantities of hazardous substances).

4.8.1.1.1 Potential impact of hazardous substances on humans and the environment during construction

Use of hazardous substances during the construction phase of the investment proposal is controlled. During construction mainly fuels for the transportation vehicles and construction machines will be used, much smaller quantities of oils and greases, also paints and varnishes. Oil changes and refueling of transport equipment will be carried out well beyond the construction site in the existing motor service stations of KNPP by specifying possibilities for the expansion of some warehouses or update of the operational schedule.

Negative impact at the work place and the environment is not expected subject to compliance with the instructions for labor safety, hygiene and fire safety (LSHFS).

Construction activities related to the construction of the sites of the IP will be in addition with a short term impact of some hazardous substances. This is due to the fact that the heavy excavation and construction machinery are using mainly diesel fuel, petroleum oils and greases, construction dust, cement, generating construction waste containing materials for waterproofing and hydrocarbon resins, waterproofing materials, polymer adhesives, paints and varnishes, special flooring. **Table 4.8-2** lists hazardous substances and products that may pose a risk mainly **for workers health during construction works**.

TABLE 4.8-2: SUBSTANCES WITH ADVERSE HEALTH EFFECTS RELATED TO THE CONSTRUCTION OF THE SITES OF IP

Chemicals or preparations CAS No	Hazard sign	Adverse health effects	Risk exposure
Spent motor oils: PCB's 1336-36-3	Xn Harmful. N-harmful for environment	Cumulative effect danger. Affect the nervous, cardio-vascular, system, liver, kidneys. Mutagens. Hazardous for the environment – in particular aquatic organisms.	Chronic diseases in non-comliance with safety-labor requirements
Diesel fuel 94114-59-7	Xn Harmful	Cumulative effect danger. Allergens. damages the nervous system, skin, haematopoiesis, liver, kidneys. Mutagen. Hazardous for environment – in particular for aquatic organisms	Chronic disease in non-compliance with safety labor requirements.

Chemicals or preparations CAS No	Hazard sign	Adverse health effects	Risk exposure
Cement	Irritant Allergen	Irritant for the skin, eyes and the respiratory tract Allergen. Contains pollutabta)Cr- VI, Cd, Co, Ni) and is controlled by CM Decree No. 156/2004). Inflammatory and allergic impairments of skin and mucous membranes.	Chronic diseases in non-compliance with safety labor requirement.
Paints, varnishes, adhesives Polymers	Xi Irritants Xn Harmful	Damage the nervous system, liver, endocryne system, respiatory organs, skin and mucous membranes. Cause allergic diseases.	Chronic diseases in non-compliance with safety labor requirement.
Asphalt mixtures Reg No.2119498270 -36-0013	Xn Harmful **N – dangerous for environment**	Irritant for the skin, eyes and the respiratory Allergen. Contains pollutants	Chronic diseases in non-compliance with safety labor requirement.

The substances listed in the above Table may cause chronic diseases in case of non-compliance with the safety labor requirements and in non-use of personal protection equipment when this is mandatory and recommended on the label, in accordance with the Regulation on classification, labeling and packaging of hazardous chemicals (2005).

The supply of hazardous substances should be accompanied by a certificate and detailed instructions for storage and handling.

Under strict compliance with the instructions for safety, hygienic labor and fire safety related to handling of hazardous substances (mandatory use of personal protective equipment and other measures) risk to health of workers, local population and the environment is not expected.

4.8.1.1.2 Potential impact of hazardous substances on the environment

The listed estimated hazardous substances are important for the health of the workers involved in the NNU construction. Companies licensed for specific construction activities will be contracted for construction works. Companies with proven experience play a significant role for limiting the risk by the use of well-maintained construction equipment and heavy trucks, ensured refueling with quality fuels and oils and greases change outside the project site, effective instructions, use of personal protective equipment and adequate clean working clothing, providing conditions for personal hygiene.

Assessment of the potential impact of the hazardous substances on humans is:

- health risk for the workers handling hazardous substances is not expected subject to compliance with the labor safety, hygiene and fire safety (LSHFS) instructions, control over technological and labor discipline;
- health risk for the population in the region of the sites is not expected due to the use of relatively limited quantities, the remoteness of the sites and planned measures for their use and consumption;

– for materials classified as hazardous substances measures for storage and control are provided for in compliance with all legislative requirements. The materials are of high value and spills and leaks that may have a negative impact on the environmental media – air, water, soil, flora, fauna and that may cause health risks for the population living in the area are almost excluded.

Impact – **direct, short-term, temporary, with insignificant effect**. In compliance with the operating instructions for handling hazardous substances and timely removal of any small accidental spills, the likelihood of impact will be minimized.

Transboundary impact is not expected.

4.8.1.2 PROPERTIES OF THE HAZARDOUS SUBSTNACES USED DURING OPERATION OF NNU

The activities in the various production departments and sections of NNU in Kozloduy NPP are associated with the use of a number of materials classified as hazardous substances. Some of them were analyzed in the previous sections, as factors of pollution of the respective environmental media. From the large number of available materials, basic representatives of the different groups are presented after expert analysis and assessment by level of-risk and by quantities used in various activities in NNU during operation.

For normal operation, maintenance, and repair of power units and auxiliary sections to them at the nuclear power plant chemicals, fuels and lubricants and other are used.

During operation of the new nuclear unit the use of the following substances is expected:

- ***Liquid fuels*** – are used for the operation of diesel generators, which are reserve sources of electricity for power units; for the motor vehicles and the various workshops and units of Kozloduy NPP. Certain quantities of diesel fuel, gasoline, etc. will be necessary. The quantitative characteristics are indicative and are given in details in the materials and raw materials used. The safe storage of hazardous substances will be ensured, for which Kozloduy NPP has experience in the implementation of good manufacturing practice for handling hazardous substances. The quantities of liquid fuels is expected to increase by about 5000 m^3.
- ***Fuels and lubricants*** – the operation of the new nuclear unit is expected to use various types and quantities of oils and greases – engine and compressor oil, turbine oil, motor oil, various kinds of greases. They will be accompanied by the relevant certificates and other documents such as Material Safety Data Sheets indicating the correct method of storage, use and treatment. The quantities of motor oils and greases are different types and their quantities may be specified following the selection of the equipment in the next stage of the project.

Given the variety and quantities of used oils and greases that have a direct impact on the condition in humans and on the environment they are presented in **Table 4.8-1** summarized as annual consumption by NNU of the main types and their use can be predicted very indicatively. For example, indicative quantities of transformer oils about 2.5-3 t/a, lubricants between 5-30 t/a, machine oils – about 3 t/a. Compressor oils from 1-3 t/a and other types of oils up to 5 t/a, motor oils for diesel generator plants is about 15-40

t. The supplies of fuels and lubricants to be used in NNU will be delivered regularly by the main suppliers , which are currently used in KNPP. According to good manufacturing practice certificates, test certificates and other documents are required in the supply of petroleum products.

→ ***Chemical substances and mixtures*** – for the support of the basic technological process (water-chemical regime of the power units in Kozloduy NPP and for other production and auxiliary activities) different types of chemical reagents will be delivered and used, certified for use in the nuclear industry. Main and more important hazardous substances and mixtures are: ammonia, sulfuric acid, hydrochloric acid, nitric acid, boric acid, sodium hydroxide, hydrazine hydrate, potassium hydroxide, ferric chloride, hydrated lime etc. – **Table 4.8-3**.

TABLE 4.8-3: DESCRIPTION OF THE USED CHEMICAL SUBSTANCES

No.	Name	CAS No	EC No
Chemical reagents for the production of desalinated water, deactivation etc.			
1.	Hydrochloric acid	-	231-595-7
2.	Calcium hydroxide (hydrated lime)	1305-62-0	215-137-3
3.	Sodium hydroxide	1310-73-2	215-185-5
4.	Iron trichloride	7705-08-0	231-729-4
5.	Boric acid	10043-35-3	233-139-2
6.	Nitric acid	7697-37-2	231-714-2
7.	Ammonia	1336-21-6	215-647-6
8.	Sulphuric acid	7664-93-9	231-639-5
9.	Hydrazine hydrate	302-01-2	206-114-9
10.	Potassium hydroxide	1310-58-3	215-181-3
11.	Oxalic acid	144-62-7	205-634-3
12.	Citric acid	77-92-9	201-069-1
13.	Potassium permanganate	7722-64-7	231-760-3
14.	Cleaning solution	-	-
Ion-exchange resins			
15.	Ion-exchange resin LEWATIT	-	-
16.	Ion-exchange resin AMBERLITE	-	-
17.	Ion-exchange resin Wofatit	-	-
Liquid fuels and motor vehicles maintenance			
18.	Euro diesel fuel	68334-30-5	269-822-7
19.	Unleaded gasoline	68334-30-5	269-822-7
20.	Antifreeze[16]	107-21-1	203-473-3
21.	Kerosine	106-97-8	203-448-7
22.	Extraction gasoline	-	-
Oils			
23.	Turbine oils	-	-
24.	Motor oils	-	-

[16] Hazard category, R and S phrases for Ethylene glycol which content in anti-freeze is > 90 %.

No.	Name	CAS No	EC No
25.	Transformer oils	-	-
26.	Hydraulic oils	-	-
27.	Machine oils for general use	-	-
28.	Compressor oils	-	-
29.	Transmission oils	-	-
Greases and lubricants			
30.	Lubricant (K2, graphite, with MoS2 etc.)	74869-21-9	278-011-7
31.	Greases (Litol, Ciatim, graphite with MoS2, high temperature etc.)	74869-21-9	278-011-7
Adhesives and sealing mixtures			
32.	Sealers, adhesives, pastes (loctite, Univer, Proma), silicone, liquid metal etc. [17]	-	-
Paints, primers, varnishes, thinners and cleansers			
33.	Non-aqueous paint (alkyd, oil paints etc.)[18]	-	-
34.	Water-based paints (fasagen, latex)[19]	-	-
35.	Thinners, solvents, rust converters etc.	-	-
36.	Coresilin	-	-
37.	Primers	-	-
38.	Varnishes	-	-
39.	Spirit/Ethyl alcohol	64-17-5	200-578-6
Gases and gas mixtures			
40.	Gaseous nitrogen	7727-37-9	2317839
41.	Liquid nitrogen	7727-37-9	2317839
42.	Oxygen	7782-44-7	231-956-9
43.	Hydrogen	215-605-7	1333-74-0
44.	Propane butane	74-98-6 106-97-8	200-827-9 203-448-7
45.	Argon	7440-37-1	2311470
46.	Gas mixture Kargon (82 % Ar and 18 % CO_2)	7440-37-1 124-38-9	7440-37-1 2046969
47.	Crisal gas mixture (80 % Ar and 20 CO_2)	7440-37-1 124-38-9	2311470 2046969
48.	Freon 22 (Chlorodifluoromethane)	N/A	N/A
49.	Reference gas mixture Ar –CH_4 (9 0%-10 %)	7440-37-1 74-82-8	2311470 200-812-7
50.	Carbon dioxide	124-38-9	2046969

[17] Due to lack of information on the composition of adhesives, sealers and silicones they have been assigned the risk phrase R 20/22 (Harmful by inhalation and ingestion).

[18] Hazard category, R and S - the phrases refer to turpentine, which content in non-aqueous paints, varnishes and solvents is between 15 and 40%.

[19] Hazard category, R and S - the phrases refer to Ethylene glycol which content in water-based paint is < 15%.

Most of these substances have a strong general toxic or toxic effect on different organs in the body with high hazard class. Some of the substances are emitted largely or are used in large quantities as raw materials in main and auxiliary sites of the nuclear power plant.. This is a condition for a considerable health risk, in particular for the personnel, and mainly in case of lack of effective protective measures and in non-compliance with the safety requirements and the technological discipline. In emergency conditions damages are possible resulting from the distribution of secondary-formed toxic and hazardous substances. If the necessary requirements for handling hazardous substances are adhered to the possibility for an emergency, even on a limited scale, can be removed or minimized in terms of scope and negative impact.

4.8.1.2.1 Hazardous substances storage

The investment proposal provides for activities such as storage and working with hazardous substances in quantities requiring a permit under Article 104 of EPA. (Kozloduy NPP has a permit that should be updated by adding the new quantities of hazardous substances). For chemical reagents used in the NNU strict technological control will be applied, for which KNPP has an experience.

Kozloduy NPP has set up a network of warehouses for different types of materials. In terms of environmental protection, a special attention is paid to the warehouse facilities.

It is proposed the industrial and laboratory chemicals for the needs of the main and auxiliary activities in the NNU to be kept in the existing warehouses of Kozloduy NPP, including 35 warehouses – mainly in warehouses No106 and 104 on the site of KNPP and in warehouse No 003 – Handling facility in the city of Vratza and in separate intermediate warehouses in the chemical plants, laboratories in electricity production-1 (EP-1) and electricity production-2 (EP-2). Options will be specified for reconstruction of some of the above, modernization and possible expansion to increase safety on the area of the site, improving the operation and compliance with all regulatory requirements.

The subsequent stages of the design will offer opportunities for separation of the air and the capacity of the existing nitrogen-oxygen stations, to the extent they will satisfy the needs of the NNU. Delivery of chemical substances and mixtures will continue the good practice and they will be accompanied by Material Safety Data Sheets, which is a prerequisite for environmentally safe storage and use.

In recent years decrees, regulations and other regulations and lists of applications for classification and coding of hazardous substances in accordance with different international conventions are promulgated: working with hazardous substances; storage; transportation; import, export and transboundary movement of hazardous substances.

The assessment of the factor "hazardous substances" is in accordance with the Laws of the Republic of Bulgaria harmonized with the European laws.

Chemical Substances to be used during the operation of the sites of the investment proposal are classified per hazard category in terms of their health risk for workers and their risk for the environment.

4.8.1.2.2 Potential impact of hazardous substances on humans and the environment during operation

Use of hazardous substances during operation of the investment proposal will be strictly controlled. Subject to compliance with the instructions for labor safety, hygiene and fire safety (LSHFS)

- health risk for the workers handling hazardous substances is not expected subject to compliance with the labor safety, hygiene and fire safety (LSHFS) instructions, control over technological and labor discipline;
- health risk for the population in the region of the site is not expected due to the use of relatively limited quantities, the remoteness of the sites and planned measured for use and consumption;
- for materials classified as hazardous substances measures for storage and control are provided for in compliance with all legislative requirements. The materials are of high value and spills and leaks that may have a negative impact on the environmental media – air, water, soil, flora, fauna and cause health risks for the population living in the area are almost excluded.

The proven experience of Kozloduy NPP plays a significant role for limiting the risk by the use of well-maintained warehouses, equipment and machinery and motor vehicles, ensured refilling with quality fuels and oils and greases change, effective working instructions, use of personal protective equipment and adequate clean working clothing, providing conditions for personal hygiene.

Additional negative impact of the hazardous substances on the populated areas in the region is not expected. They are located on a sufficient distance from the sites for the implementation of the investment proposal.

Potential negative impact of the factor "hazardous substances" during operation of the sites of the investment proposal (IP) is expected mainly in terms of the workers and only in case of emergencies and incidents with limited territorial scope of the impact – on the sites of the IP, with considerable degree in terms of the NNU, average in terms of the neighboring sites, with frequency and duration of the impact – depending on the period of occurrence, duration and time necessary for elimination of the accident. Delivery of hazardous substances should be accompanied by a certificate and detailed instructions for storage and handling.

Under strict compliance with the instructions for safety labor, hygiene and fire safety related to handling hazardous substances (mandatory use of personal protective equipment and other measures) risk for the health of workers, local population and the environment is not expected.

Potential impact of hazardous substances on the environment: **direct, short-term, temporary, with low-impact** under strict control and management. In case of compliance with the instructions for handling hazardous substances and timely removal of any accidental spills, the likelihood of any impact will be minimized.

Transboundary impact: Not expected.

4.8.1.3 AT DECOMMISISONING

During decommissioning and recultivation of the sites the potential impacts are similar to those during construction.

Transboundary impact is not expected.

4.9 HARMFUL PHYSICAL FACTORS

4.9.1 NOISE

4.9.1.1 DURING CONSTRUCTION

The construction stage includes site preparation of the new nuclear power unit and the construction of the different subsites related to different activities: – excavations, earthmoving works, concrete, formwork, assembly, welding, transportation and others performed using standard construction methods and equipment – source of environmental noise.

The construction activities will be carried out during the day. The noise levels of the traditionally used machines and equipment from measurements by NCPHP – Sofia and literature sources are: excavator – 80÷99 dBA, bulldozer – 97÷105 dBA, mobile crane – 84÷98 dBA, rollers– 87÷89 dBA, front loader (loader) – 83÷90 dBA, concrete laying machines –87÷94 dBA, asphalt spreading machine – 89÷92 dBA, welding devices – 80÷95 dBA, trucks incl. cement truck – 80÷92 dBA.

The construction machinery, excluding transportation vehicles, is located at the future site. The expected noise levels emitted by the operating machines and equipment is 85–90 dBA in the immediate vicinity.

Additional environmental noise source is the construction traffic servicing the preparation of the sites, the supply of construction materials and technological devices, and waste disposal. The equivalent level of the noise emissions depends on the carrying capacity of the trucks, number of trips and their speed. According to data provided by Kozloduy NPP-Department "New facilities", the engineering preparation of the various alternative sites requires various amounts and types of works and respectively various duration: Site 1 – large volume of earthmoving work – about 158 days; Site 2 – a relatively small volume of excavating and earthmoving work and relocation of two power lines – about 87 days; Site 3 – large volume of earthmoving work and relocation of one overhead transmission line, approximately 174 days; Site 4 – large amount of demolition of existing buildings and

removal of debris, for which specific decisions are yet to be made. The preparation activities will be performed in two shifts, 14 hours per day. Expected equivalent levels of noise generated by trucks (dumpers 20 m3) for earth transportation in the preparation of individual sites at a distance of 7.5 m from the axis of motion and estimated average speed of 40 km/h, are as follows: Site 1 – 74 dBA, Site 2 – 69 dBA, Site 3 – 73 dBA. The noise level for Site 4 is estimated to be within the range of the noise of Site 1 and Site 3. At a speed of 20 km/h these noise levels would be by 3 dBA lower.

Currently there is no clarity in terms of the transport servicng the actual construction works of the site and the location of the main supplier of raw materials and material. Presumably part of the oversized and heavy equipment will be supplied by water transport along the Danube. By analogy with the investment proposal under consideration is the expansion of the existing nuclear power plant "Temelin" – Czech Republic with two WWER type reactors with a minimum power of each unit of 1200 MW, for which EIA Report has been prepared. Based on the data of the above report, the expected intensity of the servicing construction transport is: about 42 trips per day for delivery of materials and raw materials and about 5 trips per day for waste disposal. The expected equivalent noise level generated by such traffic is about 64 dBA at a distance of 7.5 m from the axis of movement at a conservative speed estimate of 20 km/h. The vehicles servicing the construction of the new nuclear unit on the site of NNP Kozloduy will run on the national road network – road II-11 and II-15. The investment proposal does not provide for the building of additional road infrastructure. The assumption for similar to the above quoted intensity of the traffic would lead to increase of the noise characteristics of the existing traffic flows on the two main roads during day time as follows:

- ✓ Road II–11 – section Kozloduy – Lom – by about 2.5 dBA (total noise level – 66.5 dBA); section the town of Mizia – Kozloduy– by about 1.0 dBA (total noise level – 72.5 dBA).
- ✓ Road II–15 – section Borovan – Mizia – by about 1.0 dBA (total noise level – 70.5 dBA).

The limit values of noise level for different areas and development zones are regulated by Regulation No 6 on Environmental Noise Indicators, MH, MoEW, 2006. For residential areas, they are: day – 55 dBA, evening – 50 dBA, night – 45 dBA; for residential areas exposed to heavy traffic: day – 60 dBA, evening – 55 dBA, night – 50 dBA, and for industrial and storage areas – 70 dBA for day, evening and night. The periods assessed in the Regulation are: day (7.00 h – 19.00 h), evening (19.00 h – 23.00 h) and night (23.00 h. – 7.00 h.).

Construction works carried out at the site will not be a source of noise for residential areas in the region (sites with standardized noise level) due to the large distances (over 2500 m). Near to the equipment operating on the construction site exceeding of the standard noise level is expected 70 dBA for the production and storage areas.

Existing traffic flows on main roads in the area (II-11 and II-15) are a significant source of noise for residential areas located near to the sites. For residential areas adjacent to the

road routes, the equivalent level of traffic noise during daytime is: in the town of Kozloduy – about 60 dBA, the villages of Harlets and Glozhene – about 68 dBA, in the town of Mizia where traffic flows of both roads pass through a single route – about 70 dBA. It is expected the construction transport for the new nuclear unit to increase these traffic noise levels as follows: for the town of Kozloduy – by 5.5 dBA, the villages of Harlets and Glozhene – by 1.5 dBA, for the town of Mizia – by 1.0 dBA, leading to similar increase in excess of the existing hygiene standards for the day period. Especially noteworthy is the noise impact of trucks supporting the activities for preparation of the sites and passing through the nearby residential areas. For all four proposed alternative sites it is expected an increase of the noise levels of the existing traffic flows in residential areas, as follows: for the town of Kozloduy – from 9.5 to 14.0 dBA, for the villages of Harlets and Glozhene – from 3.5 to 7.0 dBA, for the town of Mizia – from 2.5 to 5.5 dBA, whereby for the residential areas adjacent to the road route, the exceeding of hygiene standards for the daytime period are significant – between 9.5 and 15.5 dBA. The smallest excesses are estimated for preparation of Site 2.

The expected impact from the traffic passing through the site of Kozloduy NPP is about the limit value of 70 dBA for Sites 1, 3 and 4 and below the limit value – for Site 2 at a speed of 20 km/h.

It can be concluded that the noise impact of the traffic supporting preparatory works will be the shortest and with the smallest excesses of hygiene standards for Site 2.

4.9.1.1.1 Comparison of alternatives by location (Sites 1, 2, 3, 4)

The supporting traffic servicing preparatory works for the individual alternative sites have different duration and intensity, which leads to a variable level and duration of noise impact on areas with standardized noise level – the site of Kozloduy NPP and nearby residential areas.

Impact (incl. above the standard) from construction equipment operating on the site and impact (around and under hygienic standard) of servicing traffic will be registered on parts of the site of Kozloduy NPP located near to the alternative sites. It will have shorter duration in the event of selection of Site 2; the other sites are equivalent. The impact will affect the largest part of KNPP site in the event of selection of Site 4, which is located entirely within its boundaries, adjacent to the active production areas of EP-1 and EP-2. The farthest from them is **Site 1**, while Sites 2 and 3 are equivalent.

There will be no noise impact from the construction equipment working on the sites on nearby residential areas because of the sufficiently large distances from the site for all four options of location (2500 m). Noise impact from the traffic supporting construction on the residential areas it crosses will be the shortest and with the smallest excesses of hygiene standards in the event of selection of Site 2. The other three alternative sites (1, 3 and 4) are equivalent.

In conclusion **– in terms of noise impact on areas with standardized noise level during the construction phase, Site 2 is the most favorable.**

4.9.1.2 DURING OPERATION

The investment proposal is an expansion of the existing production of Kozloduy NPP by building a new nuclear unit, which will add new sites to the currently existing ones. New sources of noise in the environment will be the main technological equipment and auxiliary facilities related to the operation of the new nuclear reactor: circulation pumps, steam generators, turbines, auxiliary equipment in the turbine hall, etc. The main equipment will be located indoors in solid buildings. At present, there is no information on the acoustic parameters of the new equipment and its location on each of the alternative sites.

In the absence of data on noise characteristics, according to Regulation No 6 on Environmental Noise Indicators, MH, MoEW, 2006 (Appendix 3, item 4.6.) for the design of new sites, data from similar sites may be used. Similar to the investment proposal under consideration is the expansion of the existing nuclear power plant "Temelin" – Czech Republic with two WWER type reactors with a minimum power of each unit of 1200 MW, for which EIA Report has been prepared. The data from this report shows that the noise levels of main sources from the new equipment are: turbine halls – 85 dB, compressors – 85 dB, transformers – 83 dB, cooling towers – 75 dB, ventilation devices – 84 dB, safety valves of steam generators – 110 dB, shut down devices of substations – 90 dB. The sources of noise are located on the site, on roofs and on front face of buildings and indoors. The report has not specified the total sound output emitted to the environment by the technological equipment of the existing nuclear capacities (two power units). Data is provided for noise measurements in real conditions during normal operation of the power plant, carried out in 29 measurement points within the site. The received noise levels are within the range of 40 dBA – 69 dBA, and the highest values (between 66 dBA and 69 dBA) are measured near the four cooling towers. The levels of noise measured along measurement contours around Electricity production-1 (EP-1) and Electricity production-2 (EP-2) of Kozloduy NPP ((Protocols 618 and 621 of the Regional Laboratory of RIEW-Pleven – Appendix 3.9.2.) are similar to the above limits of 67 dBA due to lack of cooling towers.

For assessment of the expected noise impact on the environment from the new nuclear unit for expansion of Kozloduy NPP at the least favorable scenario can be accepted a level of 116 dBA total sound power emitted in the environment, based on the level of total sound power of existing Electricity production -2 (units 5 and 6) – of about 119 dBA, considering the fact that the new reactor consists of a single power unit. The nearest to Kozloduy NPP urban area is the town of Kozloduy, situated at 2500 m. The estimated expected noise level reaching the town in unobstructed noise propagation over a planar surface is approximately 30 dBA, which is in the range of the low natural background noise. It can be assumed that the total sound power of the new electricity production will be lower than the admissible, as the new equipment will be of a new generation (III, III +), with improved technical and environmental characteristics, including the acoustic characteristics, compared to existing one. In the future simultaneous operation of Electricity production-2 and the new nuclear unit it is theoretically expected a change of the existing background noise at the town of Kozloduy by not more than 1 dBA. For comparison, after

commissioning of the new reactor in NPP "Temelin" – Czech Republic, based on data from the EIA Report, the change in the measured noise levels at the point of impact. at the same distance – 2500 m (outskirts of Litoradlice municipality – measurement point MB01) is about 0.7 dBA (from 28.2 dBA to 28.9 dBA). The measurements are done for APWR 1700 (Mitsubishi) reactors stated by the authors of the assessment as "the most noisy" of all alternative types discussed in the report. To illustrate, in Appendix 4.9.1 to the present EIA report are given the pictures of the noise propagation from NPP "Temelin" (sound maps No 3 – before the expansion and No. 21 – after the expansion, measurement point MB01).

Based on the above data, it can be concluded that after the expansion with the new nuclear unit, the activities of Kozloduy NPP will not be a source of noise for the residential areas in the region.

During operation, source of noise will be also the supporting traffic for delivery of production materials, maintenance equipment, transportation of nuclear fuel, radioactive and non-radioactive waste and workers. At this stage there is no information provided about the expected intensity of the traffic for different purposes. For the similar site in NPP "Temelin" are envisaged maximum 55 trips per day for basic transport – delivery of production materials and maintenance equipment and about 10 trips per day – for transportation of workers. The intensity of the other types of transport is substantially smaller (several tens of trips per year).

For the considered expansion of Kozloduy NPP four times less traffic intensity can be assumed to support the operation (the new nuclear unit has a single power unit), i.e. about 15 trips a day. Expected equivalent level of noise generated by this traffic is about 56 dBA at a distance of 7.5 m from the axis of movement at a speed of 40 km/h. The effect on the existing levels of traffic noise when crossing residential areas located near to the site will be as follows: in the town of Kozloduy – increase by about 1.5 dBA, while for the rest (villages of Harlets and Glozhene, the town of Mizia) practically there is no change (by about 0.3 dBA).

4.9.1.2.1 Comparison of alternatives by location (Sites 1, 2, 3, 4)

A change in the noise levels formed by the existing technological activity of Kozloduy NPP is expected resulting from the operation of the new nuclear unit, which will occur on the overlapping parts of the existing KNPP site and that of the new site: the site of EP-2 and Site 3, the site of EP-1 and Site 2 as well as around the common borders of Site 4 with EP-1 and EP-2. The change in the noise levels in these areas will depend on the location of the noise sources on the site of the new unit. The expected cumulative maximum increase in the noise level is up to 3 dBA. Noise impact from technological activity carried out at the site of the new nuclear unit and from the operation traffic will affect the largest part of the site of Kozloduy NPP in the event of selection of Site 4, which is located entirely within its boundaries, adjacent to the active production areas of EP-1 and EP-2. The other options will affect small end portions of the KNPP site. A significant change is not expected in the selection of Site 1, which is the farthest. Sites 2 and 3 may be regarded as equivalent.

There will be no noise impact from technological activity carried out at the site of the new nuclear unit on nearby residential areas because of the sufficiently large distances from the site for all four options of location (more than 2500 m). The operation traffic will use the same route for all four alternatives; therefore they are equivalent with regard to noise impact on the residential areas it crosses.

In conclusion – in terms of noise impact on the site of Kozloduy NPP the most unfavorable is Site 4, the most favorable is Site 1, and Sites 2 and 3 are equivalent. In terms of noise impact on residential areas in the region, the four alternatives are equivalent.

4.9.1.2.2 Comparison of alternatives by technology

The investment proposal provides for a nuclear unit with pressurized water reactor. In the EIA Report for the similar IP – the expansion of the nuclear power plant "Temelin" – Czech Republic – are considered four alternative models of reactors of the same type of technology, with some differences namely in the noise emissions of the equipment. The model study shows that after the expansion of the plant, the change in the noise level at a point located 2 500 m away from the site (equivalent to the distance between the town of Kozloduy and KNPP), is negligible – 0.7 dBA.

Based on this data it can be assumed that for the implementation of the new nuclear unit of Kozloduy NPP the alternative options for the model of the reactor are equivalent in terms of noise impact on nearby residential areas.

4.9.1.3 DURING DECOMMISISONING

The stage of decommissioning is connected with the construction of new and reconstruction of existing buildings, disassembly of equipment, activities for waste processing and transportation. A source of noise will be the equipment used for the various types of works. Besides the standard construction machinery and vehicles (excavator, bulldozer, front loader, mobile crane, trucks) specific machines and equipment will be used to reduce the size of the dismantled equipment. The expected noise emissions in the environment and the impact on areas with standardized noise level in the region will be lower than those during construction, since the period of decommissioning is very long (years),very far in the future, and it is assumed that the equipment used will be of a new generation with improved noise characteristics.

4.9.1.4 EXPECTED IMPACT ON AREAS WITH STANDARDIZED NOISE LEVEL AS PER THE PARAMETERS OF THE MATRIX FOR EACH OF THE ALTERNATIVE SITES

4.9.1.4.1 Construction stage

Site 1

- → Probability of Impact occurrence – likely
- → Territorial scope of impact – KNPP and NNU sites, and locally (the territories of the nearby residential areas)

- → Type of impact – negative, direct, primary
- → Level of impact – very low (on KNPP site), moderate to high (on residential areas from the servicing traffic)
- → Characteristics of impact:
- → Frequency – temporary (until completion of construction), periodical (during daytime)
- → Duration – medium-term
- → Cumulative effect – yes
- → Reversibility – reversible

Site 2

- → Probability of Impact occurrence – likely
- → Territorial scope of impact – KNPP and NNU sites, and locally (the territories of the nearby residential areas)
- → Type of impact – negative, direct, primary
- → Level of impact – low (on KNPP site), low to moderate (on the residential areas from the servicing traffic)
- → Characteristics of impact:
- → Frequency – temporary (until completion of construction), periodically (during daytime)
- → Duration – short-term
- → Cumulative effect – yes
- → Reversibility – reversible

Site 3

- → Probability of Impact occurrence – likely
- → Territorial scope of impact – KNPP and NNU sites, and locally (the territories of the nearby residential areas)
- → Type of impact – negative, direct, primary
- → Level of impact – low (on KNPP site), moderate to high (on residential areas from the servicing traffic)
- → Characteristics of impact:
- → Frequency – temporary (until completion of construction), periodically (during daytime)
- → Duration – medium-term
- → Cumulative effect – yes
- → Reversibility – reversible

Site 4

- → Probability of Impact occurrence – likely
- → Territorial scope of impact – KNPP and NNU sites, and locally (the territories of the nearby residential areas)
- → Type of impact – negative, direct, primary
- → Level of impact – high (on KNPP site), moderate to high (on residential areas from the servicing traffic)
- → Characteristics of impact:
- → Frequency – temporary (until completion of construction), periodically

(during daytime)
→ Duration – medium-term
→ Cumulative effect – yes
→ Reversibility – reversible
→ Receptor sensitivity – regional

In conclusion, in terms of noise impact during the stage of construction, Site 2 is the most favorable.

4.9.1.4.2 Operation stage

Site 1

→ Probability of Impact occurrence – likely
→ Territorial scope of impact – KNPP and NNU sites, and locally (the territories of the nearby residential areas)
→ Type of impact – negative, direct, primary
→ Level of impact – very low (on KNPP site), very low (on residential areas from the operation traffic)
→ Characteristics of impact:
→ Frequency – permanent
→ Duration – long-term
→ Cumulative effect – yes
→ Reversibility – reversible

Site 2

→ Probability of Impact occurrence – likely
→ Territorial scope of impact – KNPP and NNU sites, and locally (the territories of the nearby residential areas)
→ Type of impact – negative, direct, primary
→ Level of impact – low (on KNPP site), very low (on the residential areas from the operation traffic)
→ Characteristics of impact:
→ Frequency – permanent
→ Duration – long-term
→ Cumulative effect – yes
→ Reversibility – reversible

Site 3

→ Probability of Impact occurrence – likely
→ Territorial scope of impact – KNPP and NNU sites, and locally (the territories of the nearby residential areas)
→ Type of impact – negative, direct, primary
→ Level of impact – low (on KNPP site), very low (on the residential areas from the operation traffic)
→ Characteristics of impact:
→ Frequency – permanent
→ Duration – long-term
→ Reversibility – reversible

Site 4

- → Probability of Impact occurrence – likely
- → Territorial scope of impact – KNPP and NNU sites, and locally (the territories of the nearby residential areas)
- → Type of impact – negative, direct, primary
- → Level of impact – moderate (on KNPP site), very low (on the residential areas from the operation traffic)
- → Characteristics of impact:
- → Frequency – permanent
- → Duration – long-term
- → Cumulative effect – yes
- → Reversibility – reversible

In conclusion, in terms of noise impact during operation, Site 1 is the most favorable.

4.9.1.4.3 Decommissioning stage

Sites 1, 2, 3 and 4

- → Probability of Impact occurrence – likely
- → Territorial scope of impact – KNPP and NNU sites, and locally (the territories of the nearby residential areas)
- → Type of impact – negative, direct, primary
- → Level of impact – moderate to high (on KNPP site), moderate (on residential areas from the servicing traffic)
- → Characteristics of impact:
- → Frequency – temporary (until completion of the stage), periodic (only during daytime)
- → Duration – long-term
- → Cumulative effect – yes
- → Reversibility – reversible

In terms of noise impact during the decommissioning stage, the four alternative sites are equivalent.

Transboundary noise impact is not expected, given the large distance between the KNPP site and the nearest populated areas on the territory of the Republic of Romania (more than 10 km).

4.9.2 VIBRATIONS

4.9.2.1 DURING CONSTRUCTION

The construction machines used for construction of the site are not a source of vibrations to the environment. Vibratory rollers, which will be used during construction are construction equipment with wide practical application for alignment and sealing of earth surface, embankments, asphalt application. Their vibrations are of low amplitude and frequency between 30 and 70 Hz, depending on the power and weight. The vibrations of these machines are distributed at shallow depth and fade over short distances. Data from

literature and practical experience of using these rollers show that their vibrations do not affect the seismic characteristics of the terrain. Vibrations are a factor of the work environment when certain types of machines, facilities and vehicles are used. The heavy trucks servicing construction can be a source of vibrations disseminating in the earth base only if the traffic routes are not appropriate to the category of the traffic and this must be taken into account when preparing the project transportation plan.

4.9.2.2 DURING OPERATON

The project does not provide for the future technological equipment to be a source of vibrations to the environment. The vibrations are characteristic of large-scale machine parts, at high rotation speeds. In the electricity generation these are mainly the turbines located in the turbine halls. For the machinery and equipment, limiting the distribution of vibrations outside the source is achieved by compliance with special technical requirements to the installation: anti-vibration treatment of their foundations by means of rubber pads, insulation joints of vibration damping materials, removal of the rigid connection between the vibrating sites and the structural elements of the premises, etc. Vibrations in industrial sites are solely factor of the working environment.

The transport vehicles, servicing the activities of the new nuclear unit, are not expected to become source of vibrations in the environment. They shall travel along the class II national road network, designed to comply with the respective road traffic category, which provides for attenuation of the vibrations from heavy vehicles within a short distances from the road.

Due to the mentioned considerations technological and transport vibrations are not considered as a factor affecting the environment.

4.9.2.3 SURING DECOMMISSIONING

In terms of the vibrations factor, this phase is similar to the construction phase. **Table 4.13-1** shows the evaluated potential impact on each component of the environment and human health.

4.9.3 NON-IONIZING RADIATION

According to the literature concerning Outdoor Switchgears (OS) with voltage 110, 220 and 400 kV, and also from our research across the country it becomes clear that unfavorable impacts from electric and magnetic fields are only expected on the personnel working at OS and in the Indoor Switchgears (IS).

4.9.3.1 WORKING ENVIROMENT

Values above the norms can be detected on the walkways in and around Outdoor Switchgears (OS), nearby transformers, the circuit breakers and inputs/outputs of

consumers.[20] Values above the norms can be expected mainly in OS with voltage 220 and 400 kV, but only in the magnetic field component. The intensity of the electric field and the density of the magnetic flow (magnetic induction) in the work environment are not expected to exceed, in relative units, the values presented in **Table 4.9-1** and regulated by the national and European legislation:

TABLE 4.9-1: MAXIMUM LIMIT LEVELS OF THE ELECTRIC FIELD (EF) AND THE MAGNETIC FIELD (MF) IN RELATIVE UNITS FOR OS COMPARED TO THE MAXIMUM ADMISSIBLE LEVELS UNDER REGULATION NO. 7/SG 88 OF 1999 AND COMPARED TO THE REFERENCE LIMIT LEVELS RECOMMENDED BY ICNIRP

OS	National standards		ICNIRP	
	EF	MF*	EF	MF
110 kV	0.22	1.053	0.56	1.053
220 kV	0.28	0.137	0.71	0.137
400 kV	0.57	0.018	1.42	0.018

** Data for the magnetic field are compared with the limit levels for individuals with pacemakers in national legislation*

The expected average levels of the **electric and magnetic fields at work places at the open parts of OS** (busbars, circuit breakers, transformers), determined based on our measurements and estimates for similar equipment in the country are as follows:

TABLE 4.9-2: AVERAGE MAXIMUM LEVELS OF THE ELECTRIC FIELD (EF) AND THE MAGNETIC FIELD (MF) AT WORK PLACES AT THE OPEN PARTS OF OS

No	Voltage	EF, E, kV/m	MF*, B, μT
1.	10	1.21	**105.3**
2.	110	5.59	13.68
3.	220	7.12	11.86
4.	400	**14.25**	1.75

** The average maximum levels of the magnetic field are measured nearby transformers*

The expected average levels of ***the electric and magnetic fields in the Control and Relay Rooms of OS 400 kV*** determined based on our measurements and estimates for similar equipment in the country are as follows:

[20] M. Israel et al. – Theme 2.2. Assessment of impact of electromagnetic emissions on personnel working at electrical substations in Varna, Dobrich and Shumen District , NCHMEH, Sofia, 1998.

TABLE 4.9-3: AVERAGE MAXIMUM LEVELS OF THE ELECTRIC FIELD (EF) AND THE MAGNETIC FIELD (MF) IN THE CONTROL AND RELAY ROOMS OF OS 400 KV

No	Place of measurement	EF, E, kV/m	MF, B, μT
1.	Control Room	0.15 – 0.25	0.47
2.	Relay Room	0.15 – 0.25	11.57

Irrespective of the presented excess values (levels) of the electric field (values in bold) for OS 400kV in comparison to the limit values of ICNIRP, the technological requirements for work in OS does not permit continuous stay of the workers in places with values above the norms. This requires estimates to be made on the basis of the *weighted average values* of the field in accordance with the technological requirement for maintenance of the equipment.[21, 22]

Moreover, the facilities are constructed according to the voltage with dimensions that do not pose a risk to workers from the effects of excessive magnetic field values. Only when working in Indoor Switchgears (IS) excess values of the magnetic induction may be expected to exceed the maximum admissible values for persons with pacemakers as per Regulation 7 as well as as per the reference limit values of ICNIRP – 100 μT (1G) due to proximity of power cables with high consumption to the work places of the personnel.

Referring to data from literature in terms of the impact of the electromagnetic fields on the workers,T.Lindh, S.G.Tornqvist and L.K.Anderson[23] Higher values of the magnetic field (0.115 μT) were found with workers in the substations, those servicing power lines and in the nuclear power plants at OS 400 kV Higher values of the electric field were measured in the substations with voltage above 30 kV as has been shown by our study as well.

Similar results were received by D.Looms, H.Kromhout, L.A.Peipins, R.C.Kleckner, R.Iriye and D.A.Savitz[24] as well in their epidemiological study of 135,000 persons employed in the electric industry.

Based on previous studies for the duration of stay by occupation of individuals in the zone of Outdoor Switchgear (OS) and Indoor Switchgear (IS) estimates could be made as to the impact of the electric and magnetic fields by applying the "work shift scenario" Timing

[21] M. Israel et al. – Theme 2.2. Assessment of the impact of electromagnetic emissions on personnel working at the electric substations in Varna, Dobrich and Shumen District , NCHMEH, Sofia, 1998

[22] M. Israel et al. - Report under Contract No. 28/1996 r. - Assessment of exposure and risk from the impact of electromagnetic fields on the personnel servicing OS. 110 kV, IS 20 kV, 6 kV, 1.65 kV in Maritsa Iztok Mines EAD, NCHMEH, Sofia, 1997

[23] Lindh,T., S.G.Tornqvist, L.K.Anderson - Exposure to Elektric and Magnetic Fields Among Employee in the Elektric Utility Industry, Appl.Occup.and Env.Hygiene, 1997;12:293-301.

[24] Looms,D.P.,H.Kromhout,L.A.Peipins,R.C.Kleckner,R.Iriye,D.A.Savitz - Sampling Design and Field Methods of Large, Randomized, Multisite Survey of Occupational Magnetic Field Exposure; Appl. Occup. and Env. Hygiene,1994;1:49-53

maps by occupation of individuals servicing Outdoor Switchgears and Indoor Switchgears, show the following.[25]

Occupation ***„operator"***:

- ✓ Control Room - 8.25 h
- ✓ OS - 2.00 h
- ✓ IS - 1.75 h

→ Occupation ***„relay worker"***:

- ✓ Control Room - 3.0 h
- ✓ Relay Room - 2.25 h
- ✓ OS - 2.75 h

→ Occupation ***„engineering and technical personnel"***:

- ✓ Control Room – 2.40 h
- ✓ Relay Room - 1.00 h
- ✓ OS - 1.40 h
- ✓ IS - 1.00 h
- ✓ offices – 2.20 h

Occupation ***„electrical mechanic"***:

- ✓ Control Room – 1.20 h
- ✓ Elelctric Workshop- 3.40 h
- ✓ OS - 0.30 h
- ✓ IS - 0.30 h
- ✓ on installation - 2.80 h

The assessment of the exposure by ***average weighted values of the electromagnetic field*** that could be expected for the different occupational groups servicing OS and IS is made based on preliminary studies of similar equipment and installations in the country and shows (**Table 4.9-4**):

[25] M. Israel et al. – Report under Contract No. 28/1996 r. – Assessment of exposure and risk from the impact of electromagnetic fields on the personnel servicing OS. 110 kV, IS 20 kV, 6 kV, 1.65 kV in Maritsa Iztok Mines EAD, NCHMEH, Sofia, 1997

TABLE 4.9-4: TIME AVERAGE WEIGHTHED VALUES OF THE ELECTRIC FIELD (EF) AND THE MAGNETIC FIELD (MF) ON THE WORK PLACES PER OCCUPATION

No.	Ocupation	E_{TWA}, kV/m	B_{TWA}, μT
1.	**Operators**	**2.34**	**4.554**
A.	Working day		
B.	Temporary work		
B1.	- OS repairs	**0**	**1.112**
B2.	- Maintenance	**0**	**2.006**
2.	**Electrical mechanics**	**0**	**0.059**
3.	**Relay workers**	**0**	**8.676**
4.	**Engineering and technical staff**	**1.75**	**1.793**

Existing data of point measurements show ***excess of limit values of electric fields*** at certain workplaces in the OS 400 kV and with less probability in OS 220 kV – on the walkways in and under busbars nearby busbar breakers, at inputs/outputs of consumers. ***Excess on point measurement of the magnetic field*** can be expected only at certain places in IS (along corridors in front of the equipment). These excess values refer to persons with pacemakers (as per Regulation No. 7) and to all employed (as per ICNIRP).

Preliminary exposure assessment shows that such excess values are not expected if complying with the requirements for work day scenario of the respective occupational groups (respective work regime), evaluated as per the time average weighted values of the electric and magnetic fields during one working shift.

4.9.3.2 RESIDENTIAL AREAS

The estimation of the potential exposure impact on the population from electric and magnetic fields of industrial frequencies is made on the basis of studies published in scientific magazines.

An exemplary study of people living near high-voltage lines with voltage 735 kV is conducted by P.Levallois, D.Gauvin, J.St.Laurent, S.Gingras and J.E.Deadman[26] and establishes a 3 to 4-fold higher values of the magnetic field, and about two-fold higher electric field in comparison with a control group of people living-far away from the power lines.

The common in most such studies is the conclusion of the need to continue research in this area, and to establish the fact that in neither of the cases there is no excess of the basic limits recommended by ICNIRP[27, 28].

[26] Levallois P., D.Gauvin, J.St.Laurent, S.Gingras and J.E.Deadman - Elektric and Magnetic Field Exposure for People Living near 735 kV Power Line; Env. Health Perspectines,1995;103.

[27] Bracken,T.D.,R.S.Senior,R.F.Rankin,W.H.Bailey and R.Kavet-Magnetic Field Exposures in the Electric Utility Industry Relevant to Occupational Guideline Levels, Appl.Occup.Environ. Hyg.,1997;Vol.12;11:756-768.

[28] Handbook of Health and Safety Practice, Jeremy Stranks, Pitman Publishing, Third Edition 1994, p.143-158.

In many studies in the last 10 years speculations have been made as to the "carcinogenicity" of the magnetic fields of industrial frequencies[29]. As however, in most of the announcements the relative risk factor for the occurrence of neoplasms is about 1.2 to 2.0 (very low!), the research in this area continues. Still no causal relationship between exposure to a magnetic field of industrial frequency and cancer has been established, and there are no known mechanisms of such an effect.

International Agency for Research on Cancer (IARC) investigated for the accuracy of studies on the likelihood of occurrence of cancer under the influence of electric and magnetic fields of industrial frequency[30]. It is concluded that in the researched announcements there are many imperfections, mainly methodological. The authors concluded that if the fields with extremely-low frequency (ELF) have any effect on the development of neoplasms, they are associated with the disease itself, rather than its appearance. However, this agency has included low-frequency magnetic field in the list of human carcinogens in Class 2B – possible carcinogen.

Research has been conducted in Bulgaria of Outdoor Switchgears with voltage 110, 220, 400 and 750 kV and measurements have been made both in terms of the intensity of the electric and magnetic field and targeted risk assessment research[31].

Some of the measurements made in urban areas and near to the power lines route show the following:[32]

→ ***A)*** *Power lines 110 kV:*

✓ in residential areas located near to power lines (at a distance of up to 30 m), outside the buildings:

- Electric field intensity: E up to 1.51 kV/m
- Magnetic flow density: B = 0.02 – 8.8μT

in residential areas located near to power lines (at a distance of up to 30 m), inside buildings:

- Electric field intensity: E = 122 -155 V/m
- Magnetic flow density: B = 0.018 – 1.87 μT

→ ***B)*** *Power lines 400 kV:*

[29] Harington,J.M.,D.I.McBride,T.Sorahan,G.M.Paddle,M.van Tonregen-Occupational Exposure to Magnetic Fields in Relation to Mortality from Brain Cancer among Electricity Generation and Transmission Workers, Occup.and Envir.Med.1997;54:7-13.

[30] Ad Hoc Working Group-Extremely Low Frequency Electric and Magnetic Field and Risk of Human Cancer, Bioelectromagnetics, 1990;11:91-99.

[31] M. Israel et al. – Theme 2.2. Assessment of the impact of electromagnetic radiation on personnel working at electrical substations in Varna, Dobrich and Shumen District , NCHMEH, Sofia, 1998.

[32] Ivanova, M., M. Israel – Problems of transboundary "pollution" from high voltage power lines, J. Env. Prot. Ecology, Vol.6, No.4, p.807-813, 2005.

- ✓ out of residential areas (measurements from 5 to 30 m from the power line projection):
  - Electric field intensity: E = 1.23 до 10 kV/m
  - Magnetic flow density: B = 0.087 – 2.13 μT

The measured intensities of the electric fields depend on the voltage carried by power line. These intensities are highest below the conductors (buses) of the relevant phases of the power line and rapidly decrease as the distance increases.

The intensity of the magnetic fields depends on the power consumption during the measurements, therefore the values only reflect the power consumption at the time of measurement.

Around electric power lines there can also be values exceeding 5 kV/m, which has been accepted by international organizations (including ICNIRP) as a limit reference value for residential areas. Provided that the required servitude zones around high-voltage power lines are maintained, above-norm electric field intensities cannot be expected.

In terms of the magnetic fields, magnetic induction at levels of relevance to public health in residential areas cannot be expected even if the electrical systems are operated at full load.

It can be summarized that the exposure of personnel to EMF of industrial frequency will be continuous, but at low levels provided that the national and EU standards are compiled with and the designs are made in accordance with the regulatory requirements in our country and with the recommendations of the European Commission.

The population is not expected to be exposed to EMF of industrial frequency originating from the KNPP.

4.9.3.3 POTENTIAL IMPACT ASSESSMENT

4.9.3.3.1 During construction

Impacts from non-ionizing radiation are limited subject to compliance with the regulatory requirements and the envisaged measures, and are reversible after the construction phase. They relate to short-term radiation during welding works (low-frequency EMF and UV radiation), and to electric and magnetic fields of industrial frequency 50 Hz coming from the power supply units of the construction equipment.

The construction works carried out at the site of the new nuclear power unit will not be a source of non-ionizing radiation to the territories of populated settlements in the area since these impacts will be localized to the personnel working at the site.

The expected non-ionizing radiation (NIR) impact on the various sites during construction can be defined as:

- → Probability of Impact occurrence – likely
- → Territorial scope of impact – work places at the KNPP sites;
- → Type of impact – negative, direct, primary

- Level of impact – low (excess of limit values is not expected);
- Impact characteristics – temporary (only during performance of the respective activities during the day), short-term (until completion of construction works), no cumulative impact, reversible.

4.9.3.3.2 During operation

The impacts caused by the exposure of the personnel to electromagnetic fields of industrial and radio frequency are expected to be long-term, but of low to medium importance (above-norm intensities of electric and magnetic fields of industrial frequency are expected at certain workplaces in OS and IS, although the initial exposure assessments demonstrate conformity with the limit values) subject to compliance with the requirements of the national and European legislation.

Impacts on the population from industrial frequency EMF generated by the sources after the implementation of the investment project are not expected, provided that the national requirements for servitude areas around high-voltage power lines are complied with.

The expected NIR impact on the various sites during operation can be defined as:

Probability of Impact occurrence – likely

- Territorial scope of impact – work places at the KNPP sites (OS, IS);
- Type of impact – negative, direct, primary
- Level of impact – low to moderate (above-norm intensities of electric and magnetic fields of industrial frequency are expected at certain workplaces, although the initial exposure assessments demonstrate conformity with the limit values) subject to compliance with the requirements of the national and European legislation.
- Characteristics of impact – during the periodic use of walkways around the equipment in OS and during control activities in IS, frequency – permanent (with different exposure during the work shift of the engineering and technical staff servicing the equipment),
- Long-term (for the entire work experience of the engineering and technical staff), reversible.
- Possible cumulative impact during the work experience and possible impact of the existing OS and high-voltage power lines.

4.9.3.3.3 During decommissioning

The impacts from harmful physical factors will be similar to the ones during the construction phase, but will be of very low importance.

The impacts of non-ionizing radiation during the decommissioning phase relate to the construction of new and reconstruction of existing buildings, dismantling of equipment and waste processing and disposal. These activities will not involve sources of non-ionizing radiation (NIR) except certain construction equipment having high electricity consumption.

At that stage there will not be sources of non-ionizing radiation to the territories of populated settlements in the area, either.

The expected NIR impact on the territories during the decommissioning phase can be defined as: probability of occurrence – unlikely; territorial scope – there are no NIR sources either in the work environment or in the populated settlements; type – not discussed; level – very low; characteristics – temporary; non cumulative impact; reversibility of impact – not relevant because there is no such effect.

4.9.3.4 POTENTIAL IMPACT ASSESSMENT

The potential impact assessment is provided in the potential impact matrix – **Table 4.13-1**.

As far as the impact of non-ionizing radiation is concerned, it is not important which of the 4 sites will be selected for implementation of the project. As mentioned above the selection of so called **Site 3** northwest of Units 5 and 6 of NPP Kozloduy, near the bypass road of the existing plant, will envisage certain specific measures to be taken in respect to OS 400 kV. From the perspective of the engineering implementation and connection to the Power Grid this scenario would require a great number of activities and complicated reconstructions of the the 400 kV overhead power line (OPL) route.

This does not change the level of impact of the non-ionizing radiation on the other 3 alternatives and is not a basis for non-selection of this site.

4.9.4 HEAT IMPACT ON DANUBE RIVER

4.9.4.1 TEMPERATURE REGIME OF DANUBE RIVER

The temperature regime of Danube River in the Bulgarian section is of particular importance in assessing the impact of warmer water from the exhaust circulating plant operation.

Distribution of water temperature across the width of the river is dependent on water levels, the season and the hydraulic characteristics of the river section. Maximum measured temperature differences across the width of the river reach 0.2 – 0.4^{0}C and the biggest are in the early morning hours. During the warm season the cross-section of the river is isothermal.

Depthwise, the temperature of the water especially in the central part of the riverbed is equalized. Relatively rarely differences in the range of 0.2 – 0.4°C occur in the area of the thalweg (fairway). Due to the intense turbulent mixing and the inertia of the thermal processes in the open flows, at relatively rapid changes in air temperature, changes in water temperature at depth remain within a 0.2˚C – 0.4˚C.

The maximum water temperature in January is 6°C and the absolute maximum measured in August is 27.5 °C.

The maximum monthly amplitude of the temperature of the water is 14.9 °C and occurs in April. Some insignificant increase of the water temperature from 0.1°C to 0.3°C is

observed for the periods 1941-1980 and 1981-1985 compared to the previous two periods.

In terms of the maximum monthly temperatures a more significant increase is observed in the periods 1941-1980 and 1981-1985 by about 1.7°C in March and by about 1°C in October compared to 1941-1970 and 1971-1975.

Figure 4.9-1 shows the average daily temperatures for ports Lom and Oryahovo for the period 2002 – 2012.[33]

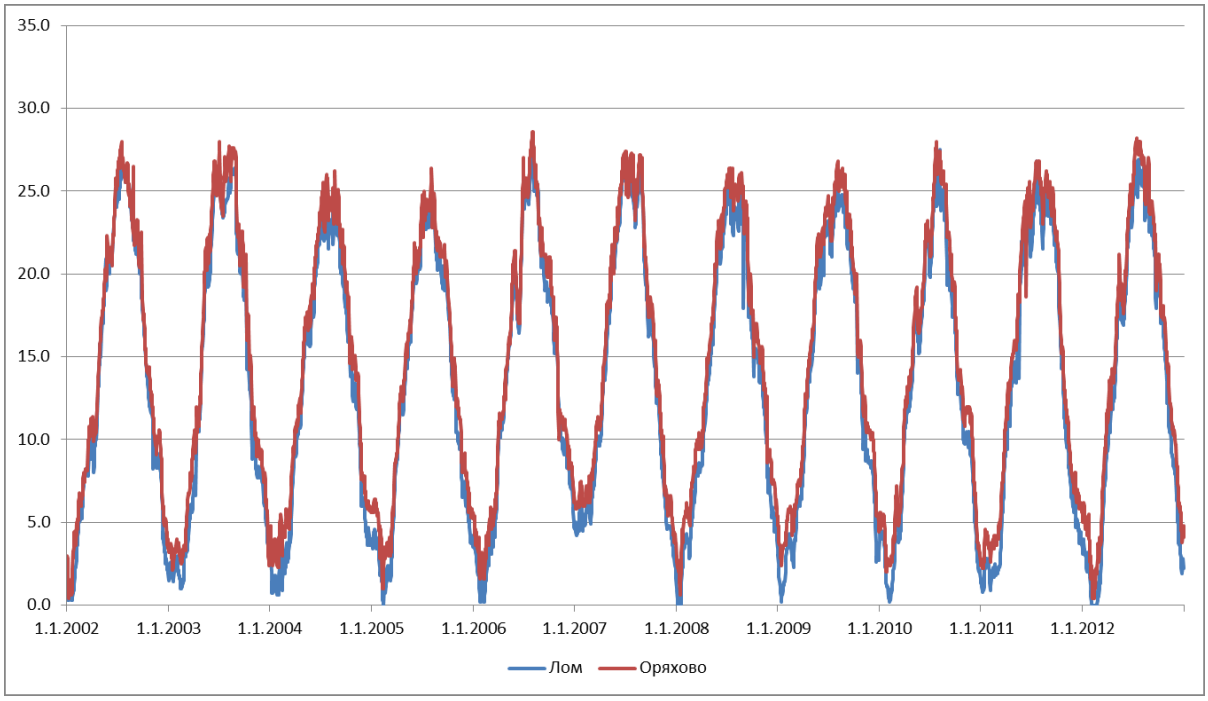


FIGURE 4.9-1: AVERAGE DAILY WATER TEMPERATURE (IN ^{0}C) OF STATIONS LOM AND ORYAHOVO FOR THE PERIOD 2002-2012

4.9.4.2 THERMAL POLLUTION

The change of the temperature regime of the river as a result of the discharge of the water heated by Kozloduy NPP is a specific form of pollution. The permissible limit for the temperature rise of the open flow is 3°C for the warmest and 5°C for the coldest month of the year.

Studies of the water temperature regime in the Kozloduy NPP section are carried out in terms of the construction of units 5 and 6 in 1991. They include field studies, such as capturing a temperature profile of the water in the Danube in the section of the discharge of the "hot" (outlet) channel to the town of Oryahovo. Because the field measurements can not cover all possible combinations of changes in the factors that determine the thermal

[33] Letter No 438 dated 17.03.2013 by Acceptance Protocol 34 dated 17.03.2013 - data provided by the Executive Agency for Exploration and Maintenance of the Danube River (EA EMDR, www.appd-bg.org) to the Client.

impact of Kozloduy NPP on Danube River, semi-empirical relationships are derived form the results of the measurements to calculate the size of thermally influenced area of the Danube River. These include the volume of water in the Danube before the BPS, the volume of water taken for the KNPP cooling system, the temperature difference between the taken from and returned to the river waters and geometrical characteristics of the section of the Danube River – average width and average depth.

The studies show that:

- The water temperature in the hot channel before discharging in the river follows the natural rise of the temperature of Danube River before the Bank Pump Station (BPS) during various time zones of the day, with temperature difference 7.5˚C – 8.5˚C at normal operational conditions;
- Thermal stratification of the flow in the area of the thermal plume is obtained only only up to about 700 m after the discharge of the hot channel (HC). The maximum stratification along the vertical (about 4˚C) is observed at about 200 m after the discharge and at about 80-100 m in the fairway (thalweg) profile of the river;
- The stain of "thermal pollution" of Danube River (with ΔT = 3˚C) then occurs at about 1700 m after the discharge of the HC with a maximum width of about 300 m. For example, 80% relative dissipation of the temperature of the water in the Danube after discharge of HC with capacity 75 m3 / s) is obtained at about 2 km down the stream.

Studies are done in operation of 3760 MW and the corresponding amount of warmed-up water of up to 180 m3/s of the hot channel. Calculations have been made for two isotherms +3 and +5˚C. The results showed that during operation of four reactors with a total volume of heated water 104 m^3/s with temperature of 10˚C above the temperature of the water in the Danube the thermally influenced area with probability of exceeding 5% and temperature +3˚C above the natural in different months of the year with length 2.3 to 10.6 km i.e. varies within the section from $^{km}684.3$ to $^{km}676.1$, and is formed near the Bulgarian coast, and has a maximum width from 100 m to 185 m..

When the plant is operated at 3760 MW (2002) and the corresponding amount of warmed-up water is up to 180 m^3/s, the length of the 3°C thermal impact zone will vary in different months from 7.0 to 31 km at maximum width 175 m to 320 m. The size of the thermal impact zone is the largest typically in October. It has been found that the thermal plume moves relatively quickly to the right-hand bank and at 7-7.5 km after the discharge point the difference between the temperature of the water and the thermal plume reaches 1.8°C (dissipation of about 80%). With temperature difference of 0.2°C the maximum width of the thermal plume from the bank to the fairway reaches 195 m and the length is up to 21-22 km. It can be concluded that after the commissioning of Kozloduy NPP some thermal burden is observed at Oryahovo ($^{km}678$) compared to Lom ($^{km}743.3$), which does not exceed the regulatory threshold of 3 ^{0}C.

Figure 4.9-1 displays the difference of the average daily temperature measured at Oryahovo and Lom for the period 2002 – 2012.[34]

It is seen that a sustained upward trend of these differences for the period can not be distinguished. The average temperature increase is within the range of 1.5 – 2.0 ^{0}C which in certain cases exceeds 3.0 ^{0}C. In certain cases the temperature difference is reverse, which can be explained by the intense turbulent exchange that led to the rupture of the torch of warmed-up waters to the Bulgarian coast.

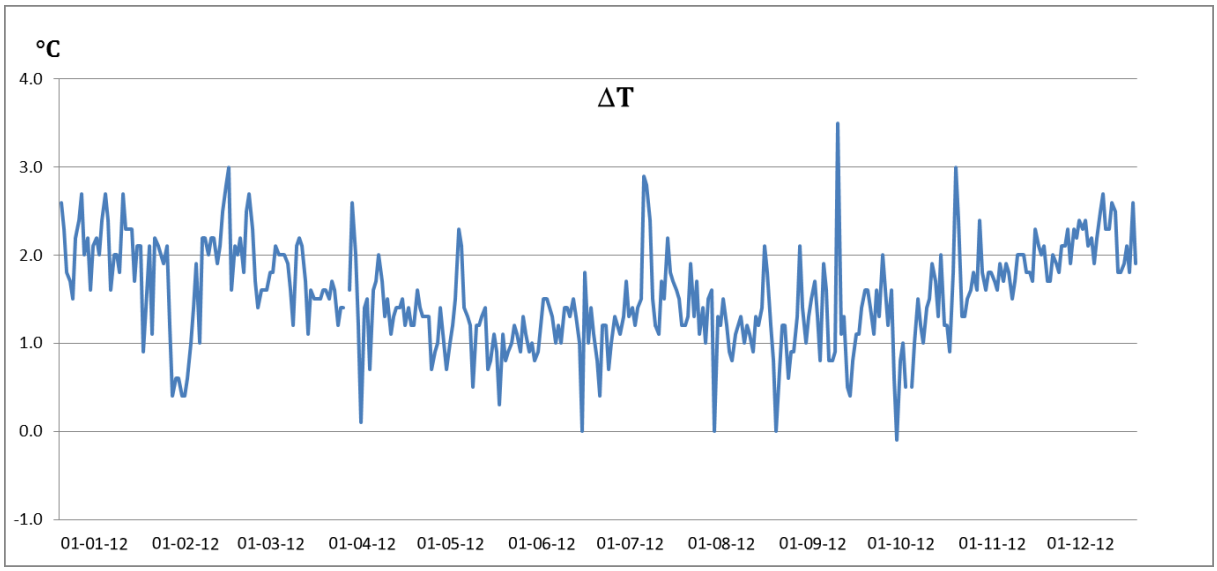


FIGURE 4.9-2: DIFFERENCE IN THE AVERAGE DAILY TEMPERATURE OF THE WATER (IN ^{0}C) OF STATIONS ORYAHOVO AND LOM FOR 2012

Figure 4.9-2 displays the difference of the average daily temperature measured at Oryahovo and Lom for the period 01.01.2012-31.12.2012. It is seen that during operation of KNPP with 2000 MW the difference in the temperature rarely exceeds 2°C.

Based on these data precise quantitative estimates can not be made, but they are attached to illustrate current trends. For almost 30 years before commissioning of KNPP there was no difference between the average monthly temperatures at the two stations of Lom and Oriahovo. In 1983, when the 4 units were in operation, the average difference in that year was 1.84°C, and it was a shallow-water year. The difference in 2006 was as little as 0.84°C, but the volume of water in that year reached very high levels. During the period 2008-2010, when two units were operational, the average annual temperature difference between the two stations was 1.38°C. The differences in the winter months are higher than those in the summer months and reach 2.3°C, the differences are also higher in years characterized by shallow waters.

[34] Letter No 438 dated 17.03.2013 by Acceptance Protocol 34 dated 17.03.2013 – data provided by the Executive Agency for Exploration and Maintenance of the Danube River (EA EMDR, www.appd-bg.org).

4.9.4.3 DURING CONSTRUCTION

During the construction of the new nuclear unit, irrespective of the selected site, the temperature profile of the Danube will not be affected in any way.

4.9.4.4 DURING OPERATION

The change of the temperature regime of the river resulting from the discharge of the water heated by Kozloduy NPP is a specific form of pollution. According to the norms applicable in Bulgaria, the assessment of the thermal pollution of open flows should be carried out for the minimum average monthly water quantity (in a year with 95% provision) and natural temperature of the open flow – average for the warmest or the coldest month of the year. The norm does not take into account the probability of combinations with water quantity with 95% provision and average water temperature for the last 10 years, and whether this temperature is representative of the natural temperature regime of the open flow.

The analysis of the results from previous studies demonstrates that at full capacity of the then operational six units, the expected discharge from Kozloduy NPP to Danube River via the existing discharge canal was about 180 m^3/s warmed-up water with temperature 10˚C higher than the natural temperature of the water in the river.

The water temperature in the hot channel before discharging in the river follows the natural rise of the temperature of the Danube water before the Bank Pump Station (BPS) during various time zones of the day, with temperature difference 7.5˚C – 8.5˚C at normal operational conditions.

During operation of units 5 and 6 and NNU with total capacity of 3200 MW and corresponding amount of warmed-up waters of up to 160 m3/s, the length of the 3°C thermal impact zone will vary in the different months from 5.0 to 20 km at maximum width 250 m. The largest thermal impact zone is expected in October. It has been found that the thermal plume moves relatively quickly towards the river bank and at 7-7.5 km after the discharge point the difference between the temperature of the river water and the thermal plume reaches 1.8°C (dissipation of about 80%). With temperature difference of 0.2°C the maximum width of the plume from the bank to the fairway reaches 195 m and the length is about 20 km.

The above-cited results enable a conclusion that at water inflow rates of up to Q_T=160 m3/s the impact of the heat exchange between the warmed-up waters from Kozloduy NPP to Danube River in the section between $^{km}687$ (discharge point of the hot channel) to $^{km}678$ (Port of Oryahovo) and the environment is insignificant and could be neglected. Even the connection of the new nuclear unit will not cause the warm plume to reach the maximum parameters cited above and measured in natural conditions when the nuclear power plant was operated at Q_T=180 m^3/s. After the commissioning of Kozloduy NPP some extent of thermal burden is observed at Oryahovo ($^{km}678$) compared to Lom ($^{km}743.3$), which does not exceed the regulatory threshold of 3°C.

Significant progress has been made in the course of the last ten years in the modeling of conservative and non-conservative pollutants in river flows. It is recommended that a similar study is undertaken at the design stage in order to address finally this specific pollution burden.

4.9.4.5 DURING DECOMMISSIONING

After the new nuclear unit is decommissioned and the discharge of spent cooling water is discontinued, the thermal profile of the river stretch between BPS and port Oryahovo is expected to recover promptly.

4.9.5 IMPACT OF ICE FORMATIONS

Ice dams occur mainly around groups of islands as there are favorable conditions for deceleration of the average flow speeds in these sections. Typical ice dam sections where this phenomenon is frequent are those at $^{km}246$, $^{km}140$ and $^{km}81$. All three sections are outside the Bulgarian part of Danube River.

Nontheless, ice dams have formed in the section from $^{km}375$ to $^{km}845$. The points where ice dams may occur are given in **Table 4.9-5**:

TABLE 4.9-5: TYPICAL POINTS WITH ICE DAMS

Vidin	($^{km}802$)	Archar	($^{km}764$)	**Kozloduy**	**($^{km}702$-$^{km}704$)**
Oryahova	($^{km}660$-$^{km}678$)	Island	($^{km}660$)	Nikopol	($^{km}594$-$^{km}597$)
Ruse	($^{km}490$)	Aleko	($^{km}476$)	Brashlyan isl.	($^{km}454$)
Tutrakan	($^{km}428$)				

Table 4.9-6 provides data for winter periods in which there was a possibility of the formation of ice dams and the following can be determined

TABLE 4.9-6: ICE DAM FORMATIONS

Winter	Oryahovo	Svishtov
1899/1900	20.12.-04.02.	
1904/1905	25.01.-05.02.	
1908/1909	24.01-12.02.	
1913/1914	29.01.-24.02.	
1921/1922	04.02.-25.02	
1923/1924	26.01.-29.01.	
1927/1928	03.01.-20.01.	
1928/1929	30.01.-20.03.	
1931/1932	20.02.-16.03.	
1936/1937	-	31.01.-08.02.
1939/1940	16.01.-06.03.	16.01.-05.03.

Winter	Oryahovo	Svishtov
1941/1942	26.01.-13.03.	22.01.-11.03.
1942/1943	13.01.-11.02.	12.01.-16.02.
1946/1947	10.01.-02.03.	08.01.-01.03.
1953/1954	12.01.-08.03.	06.01.-13.03.
1962/1963	01.02-06.02.	27.01.-16.02.
1963/1964*	07.01.-27.02.	22.01.-15.02.

**- after the winter of 1963/64 ice dams are not observed*

In 1942 as a result of an ice dam in the zone of km664- km678 the Port of Oryahovo is flooded (water level 929 cm). The lower part of Nikopol was flooded in the same year (^{km}597.5) as a result of an ice dam in the area of ^{km}594.

In 1947 an ice dam is recorded in the area of Oryahovo and it is the largest ice dam on the Bulgarian section of the Danube River. The ice dam is formed at the group of islands Oreh, Ezik and Popadia. The ice dam length was 18 km and width 1-2 km. It stayed for 18 days. It developed at relatively small water volumes.

After 1971 complete freezing is not recorded with the exception of one overnight in 1985. Similar are the ranges of the Danube River stations located near Silistra. There is a tendency to reduce the number and duration of ice formations. Possible reasons for this decline are anthropogenic activity, or more specifically the construction of Hydropower Systems "Zhelezni Vrata 1"(Iron Gate 1) and "Zhelezni Vrata 2"(Iron Gate 2) and a general increase in air temperature and water.

There is information for ice dams in 1983 but the latter could not be dated precisely and linked with data for the factors that have caused that ice dam. During the study recorded data were not found as to the methods used before 1965 for "clearing" the data of the regime monitoring of the impact of ice formations.

The last recorded ice dam was in the Bulgarian section of Danube River from 28.02.2012 at the town of SIlistra with a legth of about 3.0 km which lead to water level increase of above 1.0 m. The ice dam was for several days only and on 02.03.2012 river navigation was restored.

The Bulgarian section of Danube River has seen only 5 ice dams in more than 70 years at flow rates between 4870 m^3/s up to 11 910 m^3/s. The fact that the last one was in 1963 indicates that the construction of the "Zhelezni Vrata" (Iron Gates) Hydropower System has significantly reduced the probability of freezing in the Bulgarian section of the Danube River. Events such as catastrophic wave due to accident at Iron Gates I and II and ice dams are ones of low probability and should not occur concurrently, moreover ice damming is not possible in the existence of catastrophic high water flows above 20 000 m^3/s. Freezing can occur in low to medium waters (elevation +25 m), typically in winter. Assuming that even such an unlikely event occurs, its damming effect will be up to 2.5 m and from 25.00 m

the average level will reach 27.00 m. Therefore, rise of water levels and flooding of Kozloduy NPP due to the damming effect of ice drifts is an event of very low probability.

Earlier research demonstrates that the damming effect in the BPS area in shallow waters can reach 3.60 m and 1.50 m in high waters.

The probability of damming due to ice dam at Oryahovo is 1 time in 10 years while the water standstills reached after damming correspond to standstills of repeatability 0.5%, i.e. 1 time in 200 years. Thus far, the potential for formation of ice dams at higher water levels has not been investigated and the probability of such phenomena has not been assessed.

4.9.5.1 DURING CONSTRUCTION

Having regard to the above-stated facts, it can be expected with a high extent of probability that during the construction of the new nuclear unit there would not be an actual danger of the construction site being flooded due to spillover from the fencing dikes. Even if extreme ice dams occur with sizes over and above anything registered to date, there is a risk, although a very limited one, for sites 1 and 3 (eventual spillover from fencing dikes during the construction process before completion of the construction works), while the expectations for sites 2 and 4 are that they would be fully protected from ice dams in the stretch at Kozloduy NPP.

Having regard to the foregoing considerations, we are of the opinion that, from the perspective of the security of the new site, the advantage is on the side of the proposed sites 2 and 4 where the ground level there is the highest and they are at a maximum distance from the dikes at Danube River. They have natural flooding protection even in the case of ice dams causing catastrophic high waters in the Danube.

4.9.5.2 DURING OPERATION

The commissioning of the new nuclear unit would not cause a significant change of the thermal and ice profile of the river stretch between the BPS and Oryahovo. As all the four proposed sites are at absolute elevation 35.00 the facility is unlikely to be flooded due to formation of ice dams in that stretch. If the water level of Danube River exceeds the elevation of the fencing dikes, the floods would affect the lowlands near the river, which would protect the NPP site from flooding. The only problem that might occur is increase of ground water levels during the ice dam period. From this perspective sites 2 and 4 should be preferred to sites 1 and 3.

4.9.5.3 AFTER DECOMMISSIONING

The conditions after decommissioning of the new nuclear unit will be similar to those during the operations stage, which means that sites 2 and 4 should again be preferred to sites 1 and 3.

4.10 HEALTH AND HYGIENIC ASPECTS OF THE ENVIRONMENT AND RISK TO HUMAN HEALTH

4.10.1 IMPACT IN THE WORK INVIROMENT

The radiation impact of Kozloduy NPP is being assessed since the commissioning of the plant in 1974 in the framework of long-term programmes coordinated with the national supervisory authorities – the Nuclear Regulation Agency (NRA), the Ministry of Environment and Water (MoEW) and the Ministry of Health (MH). The programmes define the control targets, the frequency of testing and measurements, the controlled parameters and the methods of analysis. The components of the environment are controlled by laboratory tests and automated equipment. A dedicated mobile laboratory is used for field measurements. The present scope of controls is consistent with the practices of EU Member-States that operate power plants.

Radiation impact of the nuclear power plant on the environment and the population is being studied in the 30 km surveillance zone and in a radius of 100 km around Kozloduy NPP. Within the 100 km zone a total of 36 control posts have been set up for measuring the content of natural and technogenic radionuclides. Air radioactivity, atmospheric depositions, soil, vegetation and the background gamma radiation are monitored periodically. Outside control posts, samples of water, milk, meat, fish etc. are being analyzed. Permanent monitoring of the waters of Danube River and the drinking water supply sources is performed by several control posts located along the river.

In the precautionary protective action planning zone (PPAPZ) around KNPP, 10 monitoring stations of the Automated Information System for External Radiation Monitoring (AISERM) are deployed for continuous automated monitoring of the dose rate and the contents of I-31I in ground-level air. In addition to the above system three automated weather stations and five water quality monitoring stations controlling the activity of unbalanced and waste waters are operating. The AISERM system of Kozloduy NPP is integrated with the national system of the MoEW and information exchange in both directions is provided. The results of the departmental radiation monitoring are verified annually by the programs for radio-ecological monitoring implemented by MoEW[35] Radiation Protection (NCRRP) (MH)[36].

Radioactive substances can be released in the environment during the operation of nuclear power plants. The routes for introduction of technogenic radionuclides in the environment are the releases of gases and aerosols in ground-level atmospheric air (gaseous and aerosol depositions) and radioactive releases (liquid waste).

The above-background irradiation to the population during normal operation of KNPP is typically caused by gaseous and aerosol releases of radio nuclides in the ground-level air.

[35] Departmental radiation monitoring, MoEW

[36] Programmes for radiological surveillance, NCRRP

According to estimates of the UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)[37], , the concentrations of radioactive substances in the ground-level air account for about 96% of the total radiation dose to the population.

The evaluation of the above-background irradiation of the population depends on a number of factors, the most important of which are:

- Activity of the radioactive substances released in the atmosphere;
- Climatic and weather conditions in the plant's potential impact zone;
- Characteristics of the soil – prevailing types and categories of soil in the impact area;
- Demographic indicators;
- Consumption of locally produced main types of foods.

The summary of the results from the measurement of the background gamma radiation at the control posts and in the residential areas in the monitored zone around NPP Kozloduy for 2007 -2012 demonstrate that the rates of the gamma-radiation equivalent dose is within the limits of the **natural background radiation – from 0.05 to 0.15 µSv/h.**

The total beta-activity measured in open water bodies is within normal values: from < 0.018 to 0.084 Bq/l, which is 3.6% to 16.8 % of the norm of 0.5 Bq/l [38]. The maximum measured value for the water of the Danube is 0.084 Bq/l, measure at Port Oryahovo.

The results for the total beta-activity in drinking water in 2012 are within the limit of 0.031÷0.075 Bq/l, average 0.048 Bq/l at allowed norms of 1 Bq/l.[39] Tritium activity in all analyzed samples for 2012 varies within maximum detected activity (MDA) from < 3.9÷< 6.4 Bq/l, average 4.8 Bq/l), which is much lower than allowed drinking water norms of 100 Bq/l (under Regulation No. 9/16.03.2001). These results are similar to and comparable with those of the previous years.

The penetration of radioactive isotopes through the biological chain KNPP – water – soil and biota – air – plants – animals – humans has a substantial contribution to the internal radiation exposure of the population with long-life radionuclides. The largest contributor to the individual effective equivalent dose for the population in the area of NPP Kozloduy is the consumption of plant foods, fish and milk of local origin. In order to establish the transmission of radionuclides in the food chain during the period 2009 – 2011, the Environmental Radiological Control Department of NPP Kozloduy analysed milk samples from farms in the town of Kozloduy, the village of Harlets and the town of Oryahovo. The measured values are near to those obtained during and before the operation of Kozloduy NPP and demonstrate the absence of impact of NPP Kozloduy on the ichthyofauna and the main foods consumed by the population.

[37] UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

[38] Regulation No H-4/14.09.2012 concerning categorizing surface waters.

[39] Regulation No. 9/16.03.2001 on the quality of drinking water.

Additional dose exposure of the population within the 30-km zone to technogenic radionuclides released in the atmosphere by NPP Kozloduy at normal operational mode are below the values of the method for analysis. The maximum value of the individual effective annual dose due to gaseous releases from the plant in the period 2010-2012 has been in the range of $8.02x10^{-7}$ up to $2.72x10^{-6}$ Sv. This is less than the background irradiation and is below 27 % of the 1 mSv norm as per the Regulation on Basic Norms of Radiation Protection (BNRP), 2012. The normalized collective effective annual dose to the population living in the 30-km zone due to gaseous and aerosol emissions varies from $8.44x10^{-3}$ up to $1.87x10^{-2}$ manSv/GW.a. In terms of noble radioactive gases (NRG) and I-31I, the dose values are lower than the average for the countries with nuclear power plants. The doses received by the population from liquid and semi-liquid releases by KNPP are negligible and the maximum estimated one amounts to $6.37x10^{-7}$ Sv.

Seen from these considerations, the above-background irradiation, although negligibly low in respect to the radiation risk and health status of the population in the 30-km zone, is mainly due to the presence of gases and aerosols in the ground-level air deposited by KNPP. The remaining sources of above-background irradiation to the population, namely external irradiation from radionuclides settled on the ground surface and internal irradiation from inhaled radionuclides and radaionuclides incorporated in the food, have negligible contribution to the aggregate radiation exposure.

The radiation situation in the 100-km zone does not differ from the other areas of the country.

4.10.1.1 POSSIBLE IMPACT DURING CONSTRUCTION OF NNU

The main risk factors for the health of the workers involved in the construction activities for the implementation of the proposed Investment Project (IP) are dust, toxic hazards, noise, general and local vibrations, unfavorable micro-climate and physical strain, radiation, generated in the environment as a result of the arc welding and industrial radiography for testing the weld defects, which cannot be detected by visual control

Atmospheric air measurement results of the values measured by the Regional Inspection of the Environment and Waters (RIEW) – Vratsa in the three municipalities nearby Kozloduy NPP: carbon monoxide, ozone, sulfur dioxide, nitric oxide, nitrogen dioxide, ammonia, hydrogen sulfide, methane and non-methane hydrocarbons meet the limit values according to the current legislation There is no requirement to develop program for reduction of the level of pollutants, as pursuant to Article 30 and Article 31 of Regulation No. 7 Ambient Air Quality Assessment and Management, the measured concentrations of harmful substances are lower not only than the admissible norm, but also than the higher and lower evaluation thresholds.

Among the chemical risk factors, presented as material composition, the most important are the exhaust gases: polycyclic aromatic hydrocarbons (PAH), carbon and nitric oxides, sulfur dioxide, tars.

Harmful physical factors

During construction of the new nuclear unit heavy machines will be used (bulldozers, excavators), drilling equipment etc., even if being relatively limited in number. This fact suggests that increased emissions of certain hazardous substances and fine particulate matter on the construction site itself will be observed.

The welding causes ionizing radiation, which creates prerequisites for deterioration of the workers' health and requires the use of protective equipment around the welding area. The type of the protection depends on the time period of exposure and the distance to the source. These activities shall be carried out in compliance with the welding specifications, preparaed at the design stage, and with all valid rules and standards in the country.

The non-destructive radiation control shall be carried out only under a special mode of work with such tools by highly specialized workers, to whom it is required to provide individual dosing tools and medical surveillance..

Dust and fine particulate matter

The main potential health hazard for the workers on the construction site is dust.

Work on the site will be carried out in the open. During adverse weather conditions (dry and windless weather), the dust is the main potential health hazard to workers. These dust emissions are fugitive and will depend largely on the characteristics of earth particles (size, moisture content), and many other conditions – wind, air temperature. During transportation of construction waste and earth, dust emissions may occur for a short period of time on unpaved road sections.

Acute health effects

Health effects provoked by dust is mucosal irritation (eyes, nose, throat) and shortness of breath, but the exposure to "clean" (free of toxic substances) dust particulates is very rare. More common is the situation in which dust exposure is combined with exposure to other toxic chemical substances. In these cases the acute effects of the toxic chemical substances may prevail on those of dust. The role of fine particulate matter in the transportation of other chemical toxic compounds to lung cells and their retention there is one of the possible explanations for the progressive damage of lung tissue that occur after acute exposure

Chronic health effects

Fine particulate matter damage lung function either temporarily (reversibly} or permanently(irreversibly). They help in the development of chronic bronchitis and are a prerequisite for the development of acute bacterial or viral respiratory infections, particularly in susceptible individuals. Exposure to dust creates a complicated course of bronchial asthma, late stages of chronic bronchitis, pulmonary emphysema and existing heart diseases, as well as the occurrence of morphological changes in the lung tissue.

Unfavorable micro-climate

Work on the site preparation and the construction of the reactor will be carried out in the open, which in the best case scenario is classified as unfavorable micro-climate category "Outdoor work". During the summer months there are conditions fro overheating in the cabins of heavy machines.[40]

Excessive noise levels

The adverse health effect of the noise is mainly on the central nervous system and is expressed predominantly in sleep disorders and the development of neurosis-like states. The impact will be on limited number fo workers.

The heavy construction machinery -bulldozers, excavators, heavy trucks generate high intensity noise which in the cabins exceeds the admissible norms of 85 dB/A, and have an adverse health impact on the analysis of sound by the auditory nervous system.

For the implementation of the investment proposal roadworthy machines and vehicles should be used, as to minimize the adverse noise effects both for workers working on the NNU, and at the installation of the unit itself as well as for the nearby residential areas. The noise and vibration levels in the cabin of the latest types of loaders are mostly within the permissible limits.[41]

Excess levels of overall vibrations

Data from literature sources and expert surveys show that heavy machinery will generate excessive overall vibration levels. They are more pronounced with older machines. Drivers of heavy trucks, excavators, bulldozers will be exposed to overall vibrations. Overall vibrations damage mainly locomotor system, vascular system, and by the effect of resonance, they also have an adverse effect on a number of internal organs.

Local vibrations

Drivers of servicing machines will be exposed on local vibrations. Adverse health effect is expressed in damages to the sensory and upper extremity microvascular systems. This effect is more pronounced when operating in conditions of overcooling microclimate.

Physiological and ergonomic factors

Weightlifting damage to the joints, bones and cardiovascular problems. Physical fatigue and tension to the possible development of neurosis and stress.[42]

Incidents and accidents

Work accidents with injuries, fires and explosions, possible road accidents.

Harmful toxic and chemical factors

[40] BDS 14776-87 Production microclimate

[41] BDS ISO 1999:2004

[42] Regulation No. 15 regulating the conditions, terms, and requirements for development and introduction of workplace labour and rest physiological regimes.

Pollution by toxic substances, preparations and materials with unfavorable health impact during construction will be mainly due to the emitted into the air exhaust gases from internal combustion engines (ICE) of the machines performing work on the site and transport activities in the area of the road route. The main pollutants to the environment are CO, NOx, SO_2, hydrocarbons, petrol vapor. These emissions are fugitive and will depend on the number and type of equipment used, their mode of operation, the functional load of the traffic of the site and the area of Kozloduy NPP:

Carbon monoxide – entering the human body it binds into a carboxyhemoglobin complex decreasing the ability of hemoglobin to transport oxygen. It causes hypoxia and hypoxemia. Damages the nervous, cardio-vascular systems and haemotopoiesis. Toxic for reproduction. Risk exposure to exhaust gas emissions – anemia, headache, malaise.

Carbon dioxide – displaces oxygen from air. Risk exposures to exhaust gas emissions – leads to headaches.

Nitrogen and sulfur oxides -in contact with the body they are transformed into acids with irritative and corrosive effect. Damage lung alveoli causing lipid peroxidation. In high concentrations lead to edema of the lung, alveolitis. Irritate respiratory tract and eyes. Risk exposures to exhaust gas emissions – leads to chronic bronchitis, bronchopneumonia.

Diesel fuel – mixture of light hydrocarbons, it is composed of paraffins, cycloparaffins aromatic hydrocarbons – colorless, with specific smell, evaporating under normal conditions. With regard to the toxicity of gasoline vapor, at concentrations of 40 mg/m3 they are life-threatening if inhaled for 5-10 min. Danger of cumulative effect. Allergen – damages the nervous system, haemotopoiesis, liver, kidneys, skin. Hazardous for the environment. Lower exposure concentrations of one or more hours cause irritation of the mucous membranes of the upper respiratory tract, conjunctiva of the eyes, headache, dizziness, stomach pain Risk exposure -chronic effects in non-compliance with safety regulations.

Sulfur dioxide – toxic if inhaled, damages the respiratory system, nervous system, heart. In high concentrations, results in chemical burns. Irritates respiratory tract, eyes and skin. It has a strong unpleasant smell. Dangerous to the environment. Risk exposures to exhaust gas emissions – leads to chronic bronchitis.

Hydrogen sulfide – heavy, colorless gas with a characteristic odor of rotten eggs. At high concentrations reduces the odor due to paralysis of the olfactory nerve. Concentration in the air higher than 1 mg / l is terminal. For milder acute poisoning irritation of the mucous membrane of the eye is observed. In acute poisoning with average influence damages of the central nervous system occur: headache, dizziness, general weakness, catarrhal phenomena of the respiratory tract (bronchi). In severe cases of poisoning comatose condition occur. Risk exposure – in violation of the technological process with its use as a solvent for certain products.

Ammonia – colorless gas with a specific sharp odor. It is found in the air of industrial plants in various processes. Irritates upper respiratory tract. When working with ammonia due to

the effect of low doses repeatedly occur dysfunctions of various organs and systems, comparatively rapidly emerge irritation of the respiratory tract, salivation, lacrimation, conjunctivitis, coughing, spasm of the bronchial musculature and other. Risk exposure – broadly used for preparation of various products in the composition of which nitrogen is included.

Carbons – widely used in various industries is hydrogen chloride (CC_{14}). Characterized by a high degree of evaporation and a chloroform reminiscent odor. Upon contact with a flame or hot objects it is decomposed with the formation of phosgene. Inhalation of high concentrations leads to acute poisoning accompanied by cyanosis, fever, nervousness, loss of consciousness, respiratory paralysis, toxic jaundice, and more. Risk exposure – requires work at good pressurization and effective functioning ventilation.

The adverse impacts during the construction phase are temporary and direct ones, and affect mainly the personnel directly involved in the construction and installation works at the KNPP site.

Prevention or mitigation of health risks depends on compliance with occupational health and safety requirements. The Kozloduy NPP personnel

working at places proximal to the investment project site will incur temporary exposure to the above-listed non-radiation factors.

A Health and Safety Plan is being developed in relation to the implementation of the proposed project and will form part of the technical specification of the project. The Plan will be developed in accordance with Regulation No. 2 on the minimum requirements for health and safety work conditions during construction and installation works harmonized with Directive 92/57/EC[43].

NPP Kozloduy has well established infrastructure, good and secure power supply, firefighting service, supply of drinking water, sewerage system, draining systems for prevention of flooding during natural disasters, internal roads surfaced in asphalt or concrete. The plant has washrooms, toilets and bathrooms, canteen with warm food and fast food locations. The on-site health center has the opportunity to provide qualified medical aid. All this provides for the normal presence and safe working of the personnel that will be engaged in the construction and installation works described in the Investment Project (IP) "Construction of a new nuclear unit at the site of NPP Kozloduy".

During the construction phase no impacts from radiation factors related with the IP are expected due to the lack of significant, constant and non-regulated radioactive sources, as well as the special mode of work during non-destructing testing and compliance with the safety measures and all valid rules and standards in the country.

[43] Protection Against the Harmful Impact of Chemical Substances and Preparations Act, 2000, last amendment SG issue 63 dated August 13, 2010.

4.10.1.1.1 Health risk assessment, measures for health protection and risk management

Preventive measures related to health protection of workers involved in the construction and installation works on the site.

The Investment Proposal envisages a set of measures for mitigation, reduction or elimination of the risk to the environment and the health of the personnel during the construction and operation of the new nuclear unit. The proposed measures are compliant to the health, labor and environmental legislation. The measures proposed in the project to prevent, reduce or offset the impact, adhere to the radiation protection requirements.

The following labor safety requirements can be listed:

- ✓ Anti-noise ear muffs for the excavator and bulldozer drivers.
- ✓ Use of anti-vibration gloves and mats.
- ✓ Measures to be taken to keep the hands dry and warm in cold weather.
- ✓ During hot summer days to put ventilators in the excavator and bulldozer cabins.
- ✓ Workers to be provided with appropriate clothing for the season.
- ✓ To conduct regular preventive examinations aimed at detecting work-related diseases.

Table 4.10-1 classifies risk factors with a negative impact on the health of workers involved in the implementation of the investment proposal for a new nuclear unit and related measures for reducing occupational risk.

TABLE 4.10-1: RISK FACTORS WITH NEGATIVE IMPACT ON THE HEALTH OF WORKERS

Risk factor type	Conditions for negative impact	Measures limiting health risk at work place
Soil dust Dust from activitie sperformed with rock and soil with rock and soil.	Dry and windless weather.	Use of personal protective equipment.
Exhaust gas emissions.	Diesel fuel for machines on the site.	Refilling with high quality fuels.Emission controls, technical roadworthy vehicles.
Environment pollution by motor oils and greases.	Technically non-compliant vehicles, improper oil change.	Oil change as per the requirements.
Excess noise levels about 86-90 dB(A), Vibrations. Electric welding activities.	Work with heavy machinery and dumpers. Work with CSI.	Work with well maintained machines and dumpers. Anti-noise ear muffs.
	Work with welding and high voltage devices emission of toxic substances.	Personal protective equipment and special instructions.
Over heating or over cooling micro climate.	Work in the open	Suitable working clothes are provided, boots, hats.
Heavy physical work. Forced work posture.	Weightlifting. Manual Activity..	Adequate rest provided.
Psycho-sensory load. High responsibility.	Difficult to develop stages of the site.	To work under guidance of qualified experts.

Risk factor type	Conditions for negative impact	Measures limiting health risk at work place
Possible accidents at work.	Falls, skin-deep injuries and traumas, burns.	Staff instructions are held. Use of personal protective equipment.
To adhere to the requirements for safety labor conditions in terms of below limit reduction of dust and physical hazards in the workplace.	Non-compliance with work and rest	Measures to reduce the health risk conditions in the workplace. Prevention of occupational diseases.
To adhere strictly to the safety and health plan.	Poor organization of labor process.	Measures to lower the level of occupational diseases. Lower risk of occupational injuries.
To use specialized devices and specialists trained to work with them for the non-destructive testing	Use of ionizing radiation devices without the presence of specilists during the construction works	To organise planned testing with non-destructive tools used only by specialists trained to work with them

In connection with the potential health risks it is necessary that all the requirements of preventive health care, are kept with, namely:

- ✓ Excessive dust levels are a risk factor for the development of general pulmonary diseases relating to the irritating effect of dust, such as rhinitis, chronic bronchitis and their complications, and the development of occupational dust pathology. In this regard taking all technical and medical preventive measures is essential to preserve the health of workers.
- ✓ Compliance with the technical specifications for the general vibration of bulldozers and trucks;
- ✓ Observing the physiological modes of work and rest (Regulation No 15/1999 of the Ministry of Health);
- ✓ Shift work cycle involves a health promotion and physiological modes of work and rest for workers on the site, including the work with CSI (Regulation No 16/1999 of the Ministry of Health).

It is necessary to take all necessary measures to secure the safety labor of workers by instructions for operation of the necessary machines and equipment.

4.10.1.2 POSSIBLE IMPACT DURING OPEERATION AND DECOMISSIONING OF THE NEW NUCLEAR UNIT AT THE KOZLODUY NPP SITE

4.10.1.2.1 In non-radiation environment

This section discusses the probable impact of radiation and non-radiation factors during the operation and decommissioning of the new nuclear unit. Consideration is given to non-radiation and radiation impacts on the personnel, the population and the environment. The analysis deals only with the probable radiation impacts related with the operation and decommissioning of the reactor, together with the cumulative environmental impact from the operation of KNPP and the new nuclear unit.

During operations

The main risk factors of non-radiation nature for the personnel engaged in the operation of the new nuclear unit are hazardous substances in the work environment, unfavorable physical factors of the work environment, physical and psycho-sensory strain of the personnel directly involved in welding activities.

Summary results of the analysis of possible non-radiation impact during operation on the health of the staff servicing NNU are negative, direct, combined and cumulative associated with the risk of unfavorable physical, chemical, psycho-sensory, physiological and ergonomic factors in the workplace.

The role of primary medical examinations and periodic plans during the operation of the facility are based on the prevention of health risks.

During decommissioning

It is estimated that the non-radiation impact **during the decommissioning** of the new nuclear unit on the health of the personnel and other staff working at NPP Kozloduy is a combination of the impact comparable during construction and operation, but of lower level due to the experience of the employees and the technical personnel and the nature of the activities.

4.10.1.2.2 Radiation impact

The radioactive exposure of humans in Bulgaria is regulated by the Regulation on Basic Norms of Radiation Protection (ONRZ -2012).

The Regulation determines the radioactive protection requirements and the measures that must be taken for performing activities related with the usage of atomic energy and sources of ionizing radiation in accordance with the requirements of the Safe Use of Nuclear Energy Act[44]. Furthermore, the Regulation also controls the radioactive exposure of the population to natural sources of radiation.

In addition to the radiation exposure determined in the Regulation there is one other major requirement: ensure that all radiation exposures will be justified and maintained at ALARA levels under the dose limits set out in the Regulation, taking into account the social and economic conditions.

The technical specification for design and construction of the new nuclear unit determines the requirements to the proposed facility.

In compliance with Regulation on Basic Norms of Radiation Protection (ONRZ-2012) the CEO of NPP Kozloduy determines annually the applicable administrative control levels of the doses at the site of KNPP[45].

[44] Safe Use of the Nuclear Energy Act, 2002.

[45] Regulation on Basic Norms of Radiation Protection (ONRZ -2012).

The new nuclear unit project guarantees that the radiation exposure of the personnel is in accordance with the ALARA principle and is limited to ONRZ-2012. It is expected that the experience gained in ensuring compliance with the procedures of NPP Kozloduy will be applied during normal and emergency operations and conditions, and will limit the likelihood of radiation exposure in future.

It is expected that the dose exposure of the personnel during operation to be in conformity with the legal requirements.

Nature of exposure:

The exposure of workers to non-radioactive substances is expected to be mostly direct, by the atmosphere, periodic in terms of duration and intensity, and affecting mainly the employees.

Direct exposure exists when environmental pollutants reach the body, penetrate into it and metabolized into its biological environments.

Following an assessment of the exposure route, it should be mentioned that the construction and installation works and the operation of the new nuclear unit are expected to produce mainly fugitive atmospheric emissions from:

- Exhaust gases from Internal combustion engines of the machines operated within the site and transportation vehicles outside the site;
- Dust;
- Noise pollution from means of transport.

Part of the dangerous emissions are long-term ones, but of limited territorial scope and depend on the measures that will be taken for their mitigation.

The radiation resulting from the operation of the new nuclear unit is calculated as insignificant compared to other external sources – around 0.01% of the total exposure level.

4.10.1.2.3 Health risk assessment, measures for health protection and risk management

Preventive measures related to health protection of workers

The main legal documents that address issues related to working with indoor and outdoor sources of ionizing radiation related to the activities in KNPP (Regulation on Radiation Protection During Activities with Sources of Ionizing Radiation (SIR), 2004 of CM and other departmental documents) determined the following requirements to safety work environment:

- ✓ zone planning of the premises;
- ✓ stationary biological protection of neutron and gamma radiation;
- ✓ portable radiation protection shields during repair and other works;
- ✓ decontamination of premises and equipment;
- ✓ designation of the premises per dose rate radiation;

- ✓ special technological ventilation systems;
- ✓ temporary and permanent storage facilities for radioactive waste;
- ✓ sanitary checkpoints and permanent and temporary sanitary locks;
- ✓ storage facilities for dismantled radioactive contaminated equipment;
- ✓ physical barriers;
- ✓ radiation and dosimetric control;
- ✓ conduct and personal hygiene in the CA;

Main measures for ensuring radiation impact safety :

Organizational measures:

- ✓ zoning of the premises as per the degree of radiation risk;
- ✓ defining a control area (CA) and a surveillance zone (SZ);
- ✓ arranging a sanitary checkpoint regime by a sanitary checkpoint including:
  - changing rooms;
  - post for distribution of radiation dosimeters;
  - decontamination room;
  - a monitor for the control of surface contamination of the body;
  - a monitor for the control of contaminated devices and other objects;
- ✓ developing procedures for admission and work in the production facilities;
- ✓ implementing programs for radiation protection of personnel during operation and maintenance;
- ✓ dosimetry duty.

Technical systems and equipments:

- ✓ biological protection and protection shields;
- ✓ protective barriers;
- ✓ collection and water treatment facilities from the technological cycle;
- ✓ collection, treatment and storage of solid and liquid RAW;
- ✓ automated systems for permanent radiation monitoring and control in the production facilities and adjacent areas;
- ✓ systems for dosimetric control.

During scheduled and unscheduled repairs decontamination of premises and equipment is carried out. Marking of locations and equipment with a relatively high dose rate gamma radiation (over 0.20 mGy / h) is introduced and placing disciplinary barriers at a dose rate of above 1 mGy / h.

Dosimetric control is mandatory in the restricted area (RA). Individual monitoring shall be conducted with two individual dosimeters and exposure data for each member of staff are archived and kept for 30 years. Individual control levels are introduced by order for individuals with higher cumulative doses.

Activities exposed to higher radiation risk include: refueling of the active zone, and nuclear fuel transportation, activities at a dose rate above 10 mSv / h and such where the expected collective dose is above the 10-2man Sv per duty; activity in non-fixed radioactive

respiratory contamination over 8000 part / (cm2min), activities associated with the machining of parts of the primary circuit. For these activities additional safety measures apply. These include additional instructions, providing additional reliable dosimetric control, use of special personal protective equipment, preliminary decontamination, monitoring of compliance with rules for radiation protection.

Provisions and use of personal protective equipment

The personal protective equipment of workers at KNPP includes:

- basic special clothing (coveralls, suits);
- protective equipment (respirators, radiation protection masks and suits etc.)
- special boots;
- hand protection (rubber, plastic and cotton gloves).

Assessment of the circumstances and reasons for the occurrence of occupational risks for accidents in the workplace is an important component of the comprehensive assessment of occupational risks and their impact on the health of workers in the Kozloduy NPP.

Safety and Health at Work Act (SG 124/1997) requires the presence of an occupational health service and such is available at KNPP. Its objectives are mainly preventive and targeting occupational medical doctors. The occupational health service has proven its competence and successful prevention of risks in the years of operation of the Kozloduy NPP.

Periodic monitoring of the psycho physiological state of senior personnel in the management of the power units, and training requirements are also very important factors to ensure trouble-free and safe operation.

Management of Kozloduy NPP carries out targeted policy of compliance with the legal acts and regulations on safety and health at work; the requirements of the European Union Conventions and Recommendations of the ILO in order to:

- protect the life and working ability of the workers in Kozloduy NPP;
- preserve the health of workers and the populations in the implementation of activities related to the use of nuclear energy;
- protect the environment from harmful effects.

With the long-term program of Kozloduy NPP for HSW a systematic approach is applied to solve problems related to safety and to align labor conditions in Kozloduy NPP in accordance with the requirements of the Health and Safety at Work Act. It includes the implementation of programs and actions for:

- building an automated system for management of the health and safety at work;
- providing medical equipment and technical devices for closing the cycle of healthcare with respect to workers and the jobs;
- periodic assessment of the risk of the work processes and jobs, and planning measures to risk prevention;
- implementation of compensatory measures related to work under hazardous working conditions etc.

4.10.1.3 DECOMMISSIONING

During decommissioning of the new nuclear unit construction and radioactive waste is expected to generate, whose quantities can not be determined reliably at this stage.

The decommissioning, after 60 years, of the new nuclear unit, discussed in the present EIA report will be done as per a preliminary developed plan.

Treatment of the different types of waste will be done as follows:

- Construction waste – following the radioactive check and after proof of non-contamination they will be stored in the landfill for non-radioactive municipal and industrial wastes;
- Radioactive waste – with SE RAW.

Workers involved in the dismantling of parts of the NPP, that are defined as construction workers, should be preliminary instructed with regard to labor safety. Personal protective equipment for decommissioning of the NPP are strictly defined for activities involving radioactive and respectively non-radioactive waste and labor conditions.

No cumulative impact is expected during normal operation and the decommissioning of NPP.

Radiation protection procedures are the basis for the prevention of health risks in the decommissioning of nuclear facilities and parts thereof.

Planned preventive medical examinations of workers are recommended during decommissioning.

4.10.2 IMPACT ON POPULATION

4.10.2.1.1 In non-radiation aspect

During construction

Impact on the residential areas around NPP "Kozloduy during construction is not expected due to the sufficiently large distance from the sites.

During operations

The developed programmes and measures for prevention of health risks to the population in the 30-kilometers and 100-kilometers zone around NPP Kozloduy, and their efficiency, are proven by various national and international inspections.

The risks for pollution of the living environment, the farming lands which are used mainly for growing fodder crops, groundwater, drinking water from the water wells on the terrace of Danube River and the water of the Danube, and the riverbank, are all decreasing.

The necessary preventive and protective measures in and around the KNPP have been developed. The main facilities are remote-controlled to ensure fast response if needed.

The European health indicators for the environmental impacts on the population are: quality of the ambient air, noise level, living environment including at home, traffic related

accidents, quality of the drinking water, accidents with chemical substances, radiation. The collected information regarding the current status of NPP Kozloduy and the non-radiation risk related to the investment proposal enable the conclusion that the operation of the NNU in the course of 60 years will not have a negative impact on the population in the 100-kilometers zone around the plant in Bulgaria and Romania.

Significant social impacts are not foreseen.

During decommissioning

Impact on the residential areas around NPP "Kozloduy during implementation of IP is not expected due to the sufficiently large distance from the NNU.

The negative impact related to the operation of the heavy construction machinery and transportation of significant quanities of construction waste will spread only within the limits of the determined zone for preventive protection measures (ZPPM) around the existing nuclear facilities at the Kozloduy NPP site.

4.10.2.1.2 Radiation impact

During operations

Radioactivity causes emission of ionizing radiation of charged particles and electromagnetic radiation (gamma and X-rays) The impact of radioactivity (natural and artificial) via ionizing radiation on living organisms is assessed on the basis of the irradiation received.

The energy absorbed as a consequence of ionizing radiation divided by unit of mass of the substance in which the absorption occurs is the main parameter of radiation dosimetry. It is termed “dose” or “absorbed dose”. This parameter and its derivatives are widely used in the area of radiation protection, radiobiology, nuclear medicine, nuclear technology, etc. The entire set of dosimetric values is directly related with the energy transmitted by ionizing radiation to the substance. The absorbed energy causes physical, chemical and biological processes leading to radiation induced processes. In this sense dosimetric values are a measure of the expected consequences from the exposure of living organisms.

Types of exposure

Sources of exposure are the natural radiation contained in the atmosphere and the artificial radiation released in the atmosphere, lithosphere and hydrosphere as a result of human activity – **Figure 4.10-1,** Sources of artificial (technogenic) radioactivity can be the industry (including power generation), medicine, scientific activities, the defense industry, etc. The exposure is the product of ionizing radiation and the penetration of radioactivity in living organisms and accordingly in the human body.

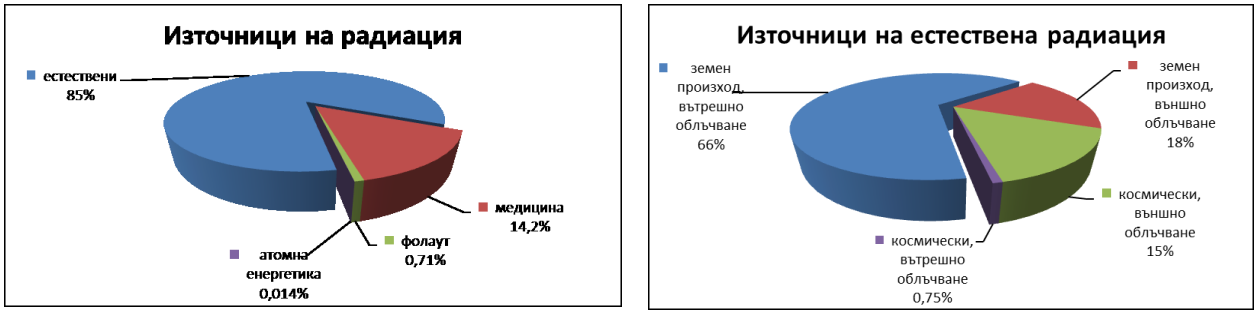


FIGURE 4.10-1: SOURCES OF RADIATION EXPOSURE

All natural media contains radioactivity. For example, one MT of earth contains approximately 5 g potassium -40 (R-40), 2.5 g of uranium -238 (U-238), 10 g of thorium-232 (Th-232). The human body also emits radiation.

TABLE 4.10-2: NATURAL RADIOACTIVITY OF SOME COMMON NATURAL SUBSTANCES

Object	Radioactivity
Rain	0.5 Bq/l
Sea water	12 Bq/l (mainly potassium-40)
Foodstuffs	Bq/kg
-potatoes	150 (potassium-40)
-milk	50-80 (potassium-40)
– fruit	40-90 (potassium-40)
– wheat	140 (potassium-40)
Human body (80-90 kg) contains about:	4500 Bq (potassium-40) 370 Bq (carbon-14)

The main effect radiation has on matter is its ability to ionize atoms to become ions. In penetration and collision with atoms of cells, ionizing radiation transmits its energy putting themin an excited/unstable/ state – ionizing them. In any collision with atoms, pair of ions are produced – a free-electron and a positively charged ion of the atom. Ionizing the atom within the molecule leads to falling apart of the molecule itself. Cell reproduction process is largely damaged when large molecules like DNA fall apart. The biological impact at the cellular level may rise to the so-called early and late effects, incl. leading to the degeneration of cells (cancer).

Alpha, beta and gamma radiation emitted by radioactive materials / sources / can affect the human body in 3 possible ways, external exposure, internal exposure and radioactive contamination of the skin.

The parameter “equivalent dose” has been introduced for more detailed characterization of the biological impact to take account of the various types of ionizing radiation. The equivalent dose is a main parameter in the area of radiation protection as it reflects the

amount of energy received by the organism and the distribution of this energy in the tissues of the organism.

Equivalent dose H[46] is the absorbed dose averaged over the organ or tissue multiplied by the appropriate radiation weighting factor. Measurement unit is Sievert [Sv] – 1 Sv=1 J.kg^{-1}.

Effective dose E[47] is the sum of the products of the equivalent dose in organs and / or tissues with the appropriate tissue weighting factor. Measurement unit is Sievert [Sv] – 1 Sv=1 J.kg^{-1}. By uniform irradiation of the whole body effective dose is numerically equal to the equivalent dose.

Collective effective dose is the total effective dose for a defined group of the population. The measurement unit is man-sievert [man.Sv].

Assessments of individual or collective doses to the population are a main factor in the determination of the radio ecological impacts from the operation of any NPP. The term **normalized collective dose** has been introduced to achieve comparability of these parameters on international scale for all NPPs throughout the world. For this purpose the dose is divided by the amount of electric power generated during a certain period of time, typically one year. The measurement unit is **man-sievert per gigawatt year [manSv/GW.a]**. The obtained values reflect the impact of the generated power on the dose exposure of the population. The data are summarized by type of nuclear reactors in the world and published in the periodical reports of the Scientific Committee for the Study of the Effects of Atomic Radiation to the United Nations (UNSCEAR-United Nations). This is the basis for comparative analysis of best practices worldwide.

In certain cases it is not possible to directly measure and determine the doses obtained from a specific radioactive source. For example, during normal operation the releases of radioactive substances from a NPP are insignificant, hence it is not possible to determine directly the individual and collective doses of exposure of the population. In these cases, mathematical models are used to evaluate the migration and quantitative contents of radionuclides in the environment, and hence for calculation of the dose exposure of the population in the area. This is an established practice, which uses internationally recognized methodologies and verified modeling software. Thus, NPP Kozloduy uses the CREAM methodology, which is accepted in the European Union. The estimated individual and collective effective doses are compared to the regulatory norms and statutory collective doses are benchmarked to the worldwide practice – UNSCEAR. This methodology is also applied to prognosticate the results for this IP at the stated parameters of the new nuclear reactor.

The results demonstrate negligibly low levels of exposure of the population. For example, the additional dose exposure of the population in the area of NPP Kozloduy is less than 0.1% of

[46] Regulation on Basic Radiation Protection Standards adopted by Decree No 229 of 25.09.2012, the Prom. SG, issue 76 of October 5, 2012.

[47] Regulation on Basic Radiation Protection Standards adopted by Decree No 229 of 25.09.2012, the Prom. SG, issue 76 of October 5, 2012.

exposure from the natural radiation background (country and world average – 2.33 mSv) and the annual limit of the effective dose 1 mSv, according to the Basic Norms of Radiation Protection (ONRZ-2012).

According to Art. 15, para. 1 of ONRZ-2012, the limit of the annual effective dose to any member of the public is 1 mSv, and in par. 2 the limits on annual equivalent doses, complying with the effective dose limits in para. 1 are:

- 15 mSv for the eye lens;
- 50 mSv for skin (this limit applies to average doses received by an area of 1 cm2, regardless of the area of exposed surface).

During decommissioning

The various activities related with the decommissioning of KNPP are not expected to produce a negative impact on the population outsidethe determined ZPPM of the existing by now nuclear facilities at the Kozloduy NPP site. The planned activities should exclude generation of radiation factors on soils and food ecochains.

The decommissioning of the NPP is not expected to produce impacts of non-radiation or radiation nature on tangible assets or to lead to exhaustion of non-renewable sources.

The health risk to the population in the nearest residential area (town of Kozloduy) is negligible.

4.10.3 HEALTH STATUS OF THE POPULATION

Impact of the Kozloduy NPP releases on the health status of the population in the 30 km zone was studied at Kozloduy Oriahovo, Misia, Hayredin and Borovan In the morbidity analysis a priority group of diseases are considered eligible for a possible causal relationship to radiation impact.

To demonstrate a potential link of a disease with radiation impact extensive specialized complex examinations are required.

The interpretation of results from various studies indicates that radioactivity emitted by KNPP noble gases and aerosols is below admissible levels. This means that emissions from the plant may not be the only reason for the increase of newly formed neoplasms, congenital anomalies, thyroid diseases, respiratory diseases, etc. Obviously it should be kept in mind the whole set of environmental factors, including total pollution after the accident at the Chernobyl NPP. Undoubtedly, in this set of factors Kozloduy NPP has a special place as emitter of radioactive noble gases, long-lived aerosols and I-131 in the atmosphere and as a source of very large amounts of discharge of unbalanced water released into Danube River.

Assessment of the potential impact of radionuclides is performed with analysis of risk-based methods which are constantly being developed by the U.S. Environmental Protection Agency (USEPA) and the European Union aimed at establishing the nature and likelihood of

possible adverse effects which can affect humans and the environment as a result of exposure to chemicals or other hazardous substances.

The methodological approach to conventional risk assessment consists of four consecutive steps:

4.10.3.1 HAZARD IDENTIFICATION

Qualitative introduction is performed to the evaluation of the site, the hazardous substances and circumstances of their possible adverse impact on the population. The main result of this stage is a list of the major health impact pollutants and justification of the method used for their selection. The list is completed with a description of the basic physical, chemical and toxicological properties of selected hazardous substances and their movements, as well as possible changes in the environment, routes of exposure, impact on the human organism and possible health effects.

4.10.3.2 DOSE – RESPONSE ASSESSMENT

This step identifies the relationship between the exposure level and the magnitude of risk. Risk of hazardous substance is often expressed as a risk throughout lifetime in a single exposure.

In terms of types of health impact chemical and physical hazardous substances fall into two main categories:

- Hazardous substances with dust impact where it is assumed that the minimum dust level to a certain threshold have no adverse effect. Above threshold levels the severity of the impact increases with the size of the exposure. Most of the toxic substances are listed under this group:
- Hazardous substances without a threshold level where a certain adverse effect is assumed even in lower doses. Thus, the risk increases with the exposure of its zero level, the dependence of the dose and its impact within lower doses range is generally considered to be linear. This group includes most of the carcinogenic substances and ionizing radiation as well.

Some substances can have both impacts, threshold and non-threshold (toxic and carcinogenic).

4.10.3.3 EXPOSURE ASESSMENT

Alleged assessment of levels (doses) is performed with which different groups of people (subpopulation) are exposed to chemicals or other harmful environmental factors. The degree of exposure depends not only on the concentration of substances in the components of the environment, but also in residential areas and at work places. Upon breathing (inhaling) the impact depends on, for example, how much time members of each subpopulation (including risk members) spend outdoors and in buildings, how intensively they breathe (at work or during sport activities), for oral intake (ingestion) it depends of how much water they drink per day from a local source, in what quantities contaminated

food is consumed, etc. Processing of documents in terms of exposure is an extremely complex matter, the most difficult of the entire process of risk assessment.

4.10.3.4 RISK CHARACTERIZATION

In this fourth step the impact on the health of the population is estimated, respectively – on a part of it, based on the integration of knowledge on the hazard identification of various substances and the exposure data. For substances with a threshold effect the ER index (Exposure Ratio) is calculated, i.e. the exposure ratio and the corresponding exposure limit or recommended reference level. For substances with non-threshold effect the risk is calculated to the number of inhabitants. The most stringent requirement referred to here is the target risk level of 10^{-6}, i.e. lifelong exposure represents 1 case of disease (respectively – 1 death per 1 million people exposed).

In conclusion, it should be noted that in this part of the methodology the risk definition applied is valid where a given pollutant in the corresponding component of the environment (air, water, etc.) has not a certain limit defined, or where the limit is exceeded. Limit values are determined in such a way that the margins ensure health security, and if the calculations are made as above they only confirm this fact as a rule. If there is no specific reasons, subject to compliance with the limits, risk calculation under the assessment method described is generally not performed.

The biological impact of radiation on matter is based on its ability to ionize atoms to become ions. In penetration and collision with atoms of cells, ionizing radiation transmits its energy putting them in an excited/unstable/ state – **ionizing**. Cell reproduction process is largely damaged when large molecules like DNA /desoxy ribonucleic acid/all apart /are damaged/. The biological impact at the cellular level may rise to the so-called early and late effects, incl. leading to the degeneration of cells (cancer).

Alpha, beta and gamma radiation emitted by radioactive materials / sources / can affect the human body in 3 possible ways, **external exposure, internal exposure and radioactive contamination of the skin.**

The biological effects of ionizing radiation consists of four stages: physical, physico-chemical, chemical and biological

- **Physical** – the energy of the radiation is transmitted to substances in biological objects causing excitation and ionization of their molecules. The primary products received are very unstable. Spontaneously or when colliding with other molecule structures they form chemically active center: free radicals, ions etc.
- **Physico-chemical** – it consists of a single reaction or consecutive chain reactions that are not seen in other areas of physics and chemistry.
- **Chemical** – the chemically active radicals and ion formed during the first stage interact with other biomolecules, cleave chemical bonds of organic compounds and unusual for the organism novel compounds are formed.
- **Biological** – Chemical modifications of the molecules are converted to cellular changes that can lead to a number of disorders of organs, systems, body as a whole,

i.e. the result is an observable biological effects.

To understand the nature of the effects of ionizing radiation it is necessary to study its mechanism at cellular and molecular level.

Biological effects are:

→ **acute and chronic:**

– acute – they are observed in a short period of time after exposure – within a period of hours to weeks;

– chronic – observed over a long period of time, years after the exposure;

→ **deterministic and stochastic:**

– Deterministic (non-stochastic) effects are dangerous for the body effects of the ionizing radiation which have a minimum dose causing the effect and above which the severity of the effect increases as the dose increases i.e. the dose-effect relation has a threshold character. These include local radiation injuries, chronic and acute radiation sickness. Most attention is paid to radiation sickness and acute radiation burns, as they pose the most immediate threat to the lives of victims.

– Stochastic (probabilistic) effects are adverse health effects from the effects of ionizing radiation, for which it is considered that there is no threshold dose and the probability of their occurrence is directly proportionate to the dose and the severity is independent of dose. They are divided into somatic, genetic and some effects of radiation before birth. Somatic are malignant neoplasms (cancer). Genetic are disorders that are inherited. Internally uterine damage and inherited disorders are distinguished. The lesions or other pathological changes of the cells of the fetus are not transferred to the next generation. Violations in germ cells can be transmitted and occur in later generations in the form of modifications or disabilities. There is a breach in the development of fetuses exposed to radiation during the period from 8th to 15th week. Genetic disorders in other periods of pregnancy do not occur.

The following different types of effects on cells after irradiation are observed:

- **no changes** – radiation does not affect the cell;
- **destruction of the cell** – radiation causes cell death;
- **recovery** – cell restores DNA molecule;

It is important to know that ionizing radiation is fatal when for a short period of time a large dose is received, and this is only possible during a nuclear war or nuclear accident.

Ionizing radiation in small doses has stimulating effect and is used in medicine as life-saving i.e. it can cause the death of the body, but it can also save lives.

4.10.4 PHYSIOLOGY OF RADIATION DAMAGES

Pathogenic peculiarities of the different kinds of radiation (X-α-, β-and γ-rays and neutrons) depend a lot on their penetrating abilities.

Hard X-rays, gamma rays and neutrons have a great penetrating power. Soft X-rays, α-and β-rays have insignificant penetrating properties.

Ionizing radiation can cause damage or mainly skin damage or to give rise to radiation sickness. This is explained by the fact that less tissue penetration α-and β-rays and soft X-rays acting on the body as an external emitters strike mostly exposed parts of the body.

The external irradiation with gamma-rays, neutrons and hard X-rays, having a large penetrating ability cause general radiation sickness.

It can be caused also by various radioactive substances that have penetrated organism by food, the air, and through damaged skin surfaces. These substances are sources of internal irradiation of the organism with α-, β- and γ-rays.

The effect of the incorporated radiation is determined by the dose of the substance that has penetrated the body, its radiation nature, its half-life and the time necessary to leave the body. At equal terms more hazardous are radioactive substances that are deposited in the body, such as bones (strontium, plutonium, radium).

In considering the different types of ionizing radiation it is necessary to consider first of all the effect of neutrons. Their effect on the body is very complex.

As a result of the effect of the neutrons in the body are formed: protons, gamma rays-stable isotopes of the heavy hydrogen (deuterium) and unstable radioactive isotopes. The latter are called induced radioactivity.

Radioactive substances that are formed in the body during exposure to neutrons does not represent a particular danger to surrounding people and staff because of the extremely insignificant magnitude of the range of beta particles, the short life of the substances that cause the gamma radiation (Na), and the small percentage of induced activity (1%) of the total ionization of the body.

The perception of the characteristics of the biological activity of the various radiations results from the manner of distribution of their energy when penetrating the body. It had proved that in the same amount of absorbed energy (e.g., an X-ray physical equivalent), the biological effect of various types of radiation is different, and is given by the following parameters, which represent the ratio of the relative biological activity.

4.10.5 REGULARITY OF ACUTE RADIATION SICKNESS. CAUSES OF DEATH BY IONIZING RADIATION

Different types of ionizing radiation have somewhat similar pathogenic effect, which consist in their ability by reacting with a substance to cause ionization of its atoms and molecules. This peculiar feature of the external and internal irradiation explains one type of the diseases. It is also possible to have individual symptoms typical for radiation from various sources, but they rarely are essential.

Furthermore, the characteristics of the biological effect of penetrating radiation depend on 1.) dose of the radiation, 2.) reactivity of the body 3.) duration of irradiation and 4.) the size of the irradiated surface and its localization.

Radiation sickness may be caused: a.) by a continuous exposure to very low doses of ionizing radiation in the course of many months or years, b.) by local irradiation of the organism with high doses like thousands and tens of thousands of X-rays; during radiation therapy – two to three weeks after termination of the radiation therapy, typically all of the symptoms of the disease disappear, c.) by total intensive irradiation of the whole organism.

In the development of acute radiation sickness the following periods can be defined: the primary reaction that occurs immediately after irradiation; latent period, which develops over 4-7 days and is characterized only by changes in peripheral blood; expressed clinic phenomena and recovery period. The length of these periods depends mainly on the dosage of irradiation: the larger the dose received, the processes develop more rapidly.

Death occurs primarily between the expressed clinical phenomena – the emergence of adynamia, full withdrawal of food, fever and bleeding (haemorrhage). As a rule, the number of leukocytes decreases less than 200 cells per mm^3 of blood, but cases are known of survival with lower ranges of leukopenia (50 cells per mm3). In assessing the outcome of the disease hematology may have tentative importance.

Experts believe that it is unacceptable to consider cases in which the leukocyte count falls below 800 cells mm^3 as hopeless.

The recovery period of dysfunctions begins at the 20^{th} – 30^{th} day after exposure to ionizing radiation.

Full recovery is very rare. Very often late chronic effects appear in survivors. Outwardly it appears in early graying and aging.

After surviving an acute radiation sickness the changes of the nervous system, the peripheral blood circulation and the bone marrow are preserved for a long period of time.

Adverse effects of ionizing radiation on humans are divided into two groups:

1. Deterministic effects with tissue damage (e.g., inflammation of the skin, discoloration of the lens, acute radiation sickness). They appear when exposed to higher dose rates. They have a threshold and at doses exceeding the threshold, the severity of the damage and decrease of regenerative ability is increased in proportion to the uptake dose. Below the threshold the effects are not observed. Frequently, but not always, they have severe manifestations, occurring shortly after exposure.
2. Stochastic effects associated with the formation of malignant tumors and hereditary disabilities. They can occur not only at high but also at low doses. In terms of the dose effect relation, the increase of the dose increases the probability for disease and not its severity. Unlike carcinogenic effects harmful impact on human heredity has not been proven. Stochastic effects are delayed in time, occurring after a certain period of time, often many years later.

Scientific basis from which risks of human exposure to ionizing radiation are derived are on the one hand human studies (mainly persons who survived the explosions of the

nuclear bombs in Hiroshima and Nagasaki and their descendants, as well as other special epidemiological studies) and on the other – experimental studies on animals, especially mice. From the studies in Hiroshima and Nagasaki for example, the risk factor coefficient for cancer death among the population has been derived **$5.10^{-2}.Sv^{-1}$, i.e. at a dose of 1 Sv – 5 death cases are found per 100 people, at a dose of 1 mSv – 5 cases per 100 000 people**.

4.10.6 CONCLUSION

The proposed Investment Project envisages a set of measures for mitigation, reduction or elimination of the risk to the environment and the health of the personnel and the population during the construction and operation of the new nuclear unit. The proposed measures will conform to the requirements of the health, labor and environment legislation on prevention, reduction or neutralization of the impact of the new nuclear unit, and will be compliant with the radiation protection requirements.

The expected impact during the construction phase is negative (within the construction site), direct, primary, temporary, short-term (only during daytime until the end of construction works), without cumulative effect and reversible.

During the operations phase, the non-radiation emissions from the new nuclear facilities are not expected to produce significant negative impact, provided that the necessary technological requirements are complied with and environmental monitoring is carried out on regular basis.

The potential impact zone is limited to the secure site of NPP Kozloduy. This zone is inaccessible to the general public. Transboundary impact is not expected.

The radiological impact during operations on human health is very unlikely, indirect, secondary, temporary, short-term, of very low significance, without cumulative effect and reversible. Each probable negative impact of the NNU on the environment and the public health, including and taking into account the synergistic effect of the radiation background, is within the permissible limits according to the regulatory documents. The new nuclear unit is not expected to produce significant impact on the health of the population or cause negative deviations in the parameters that describe the prevalence of diseases or demographics.

The **contribution of the new nuclear unit to the radiation background in the vicinity of the town of Kozloduy is low in terms of the external radiation exposure. The cumulative impact on the environment will be negligible. Transboundary impact is not expected.**

The expected impact during the decommissioning phase will be similar to the impact during the construction phase, namely negative (within the construction site), direct, primary, temporary, short-term (only during daytime until the end of the decommissioning activities), without cumulative effect and reversible. Transboundary impact is not expected.

4.11 RADIATION RISK TO THE POPULATION IN THE EVENT OF RADIOACTIVE RELEASES

4.11.1 CHARACTERISTICS OF THE ENVIRONMENTAL RISK DURING NORMAL OPERATIONS AND EXPECTED OPERATIONAL EVENTS

The evaluation of the risk to the population caused by radioactive releases during normal operation and expected operational events in the NNU includes:

- ✓ Evaluation of individual and collective doses to the population;
- ✓ Evaluation of the radiobiological effects and of the radiation risk.

The following routes of impact were considered in order to evaluate the internal and external exposure of the population in the NNU area from gaseous and aerosol releases:

- ✓ External exposure to radioactive cloud;
- ✓ External exposure to depositions on the ground surface;
- ✓ Internal exposure by inhalation;
- ✓ Internal exposure due to consumption of radioactively contaminated foodstuffs.

The following routes of impact were considered in order to evaluate the internal and external exposure of the population in the NNU area from liquid releases:

- ✓ Presence in/on the waters of the Danube River – external exposure during swimming or boating;
- ✓ Contact with bank sediments at the Danube River – external exposure to depositions on the bottom and during presence at beaches;
- ✓ Ingestion of products (fish) from the Danube River waters – internal exposure as a consequence of fish consumption;
- ✓ Presence on territories irrigated with water from the Danube River – external exposure;
- ✓ Ingestion of vegetable products (fruits, vegetables, etc.) irrigated with water from the Danube River – internal exposure;
- ✓ Ingestion of meat and milk from livestock watered with drinking water from the Danube River – internal exposure;
- ✓ Ingestion of meat and milk from livestock fed with fodder irrigated with water from the Danube River – internal exposure;
- ✓ Consumption of drinking water – internal exposure.

The scope of the radiation risk assessments is the following one:

(1) Risk for radiation induced cancer for the entire population and the persons in working age;
(2) Risk of hereditary diseases for the entire population and the persons in working age;
(3) Risks for and damage to certain tissues for the population as a whole;
(4) Risks of hereditary diseases for the first generation and for two generations;
(5) Risks of hereditary diseases for the reproductive part of the population evaluated for two generations with the first generation irradiated before the second one;

(6) Risks of hereditary diseases for the reproductive part of the population, evaluated for the first generation after the exposure.

4.11.1.1 DOSES FROM GASEOUS AND AEROSOL RELEASES

4.11.1.1.1 Input data

Input data is the data for radioactive releases in the atmosphere from the NNU, meteorological and hydrological data, statistic demographic data, data on consumption and habits.

- ✓ Demographic data and data on consumption and habits:
  - Bulgarian territory: Annual report, Results from the radiation monitoring of Kozloduy NPP environment in 2012, No. 13.RM.DOC.175,
  - Romanian territory: Letter from the Romanian Ministry of Environment and Forests, No. 3672/RP/18.10.2012.

As per the data provided by the National Statistical Institute the census shows that as of 01.02.2011 the population in the 30 km zone around Kozloduy NPP on the territory of the Republic of Bulgaria is 65994 people. As a comparison under the latest statistical data used from 2007 the population was 10% higher – 72416 people. The distribution by gender is – male (48.6%), female (51.4%). The level of urbanization in the researched area is 37.7%, which is quite lower than the average for the country – 70.7%.

The distribution by age groups in the region is as follows: 0-14 years (14.2%), 15-60 years (54.3%) and above 60 years (31.5%). For the purposes of the doses assessment a more detailed age distribution was used.

To calculate the collective doses an equal population density of 43 people per 1 km^2 in all directions was taken into account. The population of the critical group along the Danube River (the town of Oryahovo, the village of Leskovets, the village of Ostrov and the village of Gorni Vadin) is assessed to 7469 people (2011).

By taking into account the demographic factors for the Romanian part (another 75 150 people) the collective efficient dose for the entire zone can be nearly doubled. These are completely comparable data to the established practice for PWR reactors around the world.

Statistical data for main food products production and consumption in the region was used. Data is mainly about plant foods, leaf vegetables, meat and milk.

- ✓ Microclimate data for the period 2001-2012 from:
  - Annual report on “Results from the radiation monitoring of the environment of Kozloduy NPP” in 2012, No. 13.RM.DOC.175
- ✓ Emissions in the air from:
  - Annual report on “Results from the radiation monitoring of the environment of Kozloduy NPP” in 2012, No. 13.RM.DOC.175

- Data on the emissions in the air from the NNU (Letter by Kozloduy NPP – New Build" EAD, exit No. 396/08.05.2013)

TABLE 4.11-1: RADIONUCLIDES IN GASEOUS AND AEROSOL RELEASES DURING REGULAR OPERATION AND EXPECTED OPERATION EVENTS, BQ/A

Nuclide	Westinghouse AP 1000	AES BBEP-1000/B466
H – 3	1.3E+13	3.9E+3
C – 14	2.7E+11	3.0E+2
Ar-41	1.3E+12	
Kr-83m		1.0E+3
Kr-85m	1.3E+12	3.6E+3
Kr-85	1.5E+14	3.6E+2
Kr-87	5.6E+11	1.9E+3
Kr-88	1.7E+12	7.0E+3
Xe-131m	6.7E+13	3.1E+2
Xe-133m	3.2E+12	1.4E+3
Xe-133	1.7E+14	4.7E+4
Xe-135m	2.6E+11	
Xe-135	1.2E+13	2.5E+4
Xe-138	2.2E+11	3.5E+2
I – 131	4.4E+09	3.4E+8
I – 132		7.5E+8
I – 133	1.5E+10	9.0E+8
I – 134		1.9E+8
I – 135		6.1E+8
Cr – 51	2.3E+07	6.3E+3
Mn – 54	1.6E+07	8.7E+3
Co – 57	3.0E+06	
Fe – 59	2.9E+06	
Co – 58	8.5E+08	
Co – 60	3.2E+08	1.0E+5
Sr – 89	1.1E+08	9.8E+5
Sr – 90	4.4E+07	2.1E+3
Zr – 95	3.7E+07	
Nb – 95	9.3E+07	
Ru – 103	3.0E+06	
Ru – 106	2.9E+07	
Sb – 125	2.3E+07	
Cs – 134	8.5E+07	4.7E-2
Cs – 136	3.2E+06	
Cs – 137	1.3E+8	5.9E-2
Ce – 141	1.6E+06	

- Requirements described in EUR – European Utility Requirements for LWR Nuclear Power Plants.

The limits of radioactive emissions in the atmosphere according to EUR for the regimes of regular operation and expected operation events are:

- For radioactive noble gases – 50 TBq;
- For long-lived aerosols and halogenic elements – 1 GBq.
  (*The above reference values are determined on the basis of 1500 MW_e*).

For completeness and conservativeness of the evaluation to determine the normalized annual collective doses the following power values of the NNU were taken into account: AP 1000 – 1200 MWe, AES BBEP-1000/B466 – 1000 MWe, in accordance with the set in EUR – 1500 MWe and availability of 90%.

4.11.1.1.2 Models and software used for assessment

The determination of the quantitative content of technogenic radionuclides in natural objects shows that the results are most often lower or comparable to the lower detectable limit of the modern measuring methods and devices. This fact necessitates the usage of modelling-mathematic methods to assess the migration and quantitative content of radionuclides in the environment. As input data is used actual data from the radioactive control at source – radioactive releases into the atmosphere and hydrosphere, real meteorological and hydrological data, statistic demographic data, data on the consumption of food produced in the region, and data on the electricity generated by the NPP for the assessment period.

Microclimate analysis is performed by the program EcoClimate. The modelling program is successfully verified and validated.

By using the determined authentic climate parameters in forecasting aspect can be solved the task for determining the combined radiation exposure of the facility for the entire period of operation (by following several scenarios), which is an important integral-normative feature.

The availability of reliable and sufficiently long-term twelve-year hour data received from the automated meteorological surveillance system in the region of location of the respective object: wind speed and direction; quantity and intensity of precipitation; pressure; temperature; stability classes give reason to make a detailed quantitative micro-climatic analysis of the region, related to the ecological status of the facility and they are also necessary for solving various practical tasks in this respect.

This data represents the basis of consideration: meteorological file of hourly values of meteo-parameters for the calendar year contains two groups of records:

- calendar identification – year, month, day, hour;
- meteorological group – wind direction (deg), wind speed (m/s), air temperature (K), stability class by Pasquill, rainfall (mm), intensity (mm/h).

The input data is assessed differently in accordance with the period length they refer to. For the input data, which refer to a period of time of several hours, days or week, statistical levelling will be applied.

For the input data, which refer to longer periods of time (years) verification by an expert will be performed.

At the output are received the necessary representative for the micro-climatic regime of the region characteristics for the entire considered period.

As the main and most important result from the application of the current methodology and program is the drafting of a report for the microclimate of the region that includes:

1. frequency distributions:
   - wind roses: for the entire period and by seasons;
   - roses of atmospheric stability: for the entire period and by seasons;
   - combined: for the entire period
2. temperature change: for the entire period;
3. precipitation quantity change: for the entire period;
4. atmospheric pressure change: for the entire period;
5. information about the atmospheric stability classes: by hours and months;
6. information about the wind classes: by hours and months;
7. Roses:
   - wind roses: distribution by the four parts of the day;
   - roses of atmosphere stability: distribution by the four parts of the day.

Besides, the program allows detailed presentation of all meteo-components and gives information about their change by different criteria, as well as by combination of different criteria. For example: data on the wind direction change by hours for a period of seven years; temperature values change in the different parts of the day by seasons; precipitation quantity by seasons, etc.

To assess the radiation exposure of the population in the 30 km zone from gaseous and aerosol releases the modelling program LEDA-CM "SHIELD Normal was used, as adapted to the geographical and meteorological characteristics of the area of Kozloduy NPP. The methodology takes into account both external and internal impact of radioactive releases and the estimated annual individual effective dose, annual individual dose equivalent and the dose to critical group, as well as the collective dose to the population by age groups. The program is based on the adopted by the EU (European Union) methodology CREAM (Consequences of Releases to the Environment Assessment Methodology) Radiation Protection 72 – Methodology for assessing the radiological consequences of routine releases of radionuclides to the environment.

This modelling program is based on the following types of mathematical models: 1) releases, 2) transfer into the environment, 3) routs of impact (terrestrial model) and 4) dosimetric models.

The radioactive materials released in the atmosphere endanger the population in different ways. Air-borne radionuclides can lead to radiation under two principle routes: external – by the photons and electrons emitted as a result of the radioactive decay and internal – through their inhalation. The radionuclides in the air stream will gradually decrease due to the processes of deposition upon the surface ground layer and of radioactive decay. Dry and wet deposition of radionuclides leads to their transfer in the terrestrial environment,

where they can continue their impact on the population. The deposited nuclides can again be inhaled as a result of the resuspension, caused by wind or human activity. The radioactive decay of the deposited radionuclides leads to external radiation by photons and electrons. The deposition on plants and soil results in transfer of radionuclides in the human food chain, and the consumption of this food – internal radiation. Another possible internal radiation can result from unintentional ingestion of contaminated soil. Therefore a follow-up assessment of the individual and collective doses should include not only nuclides dissemination by the wind but also their distribution in the terrestrial environment (**Figure 4.11-1**).

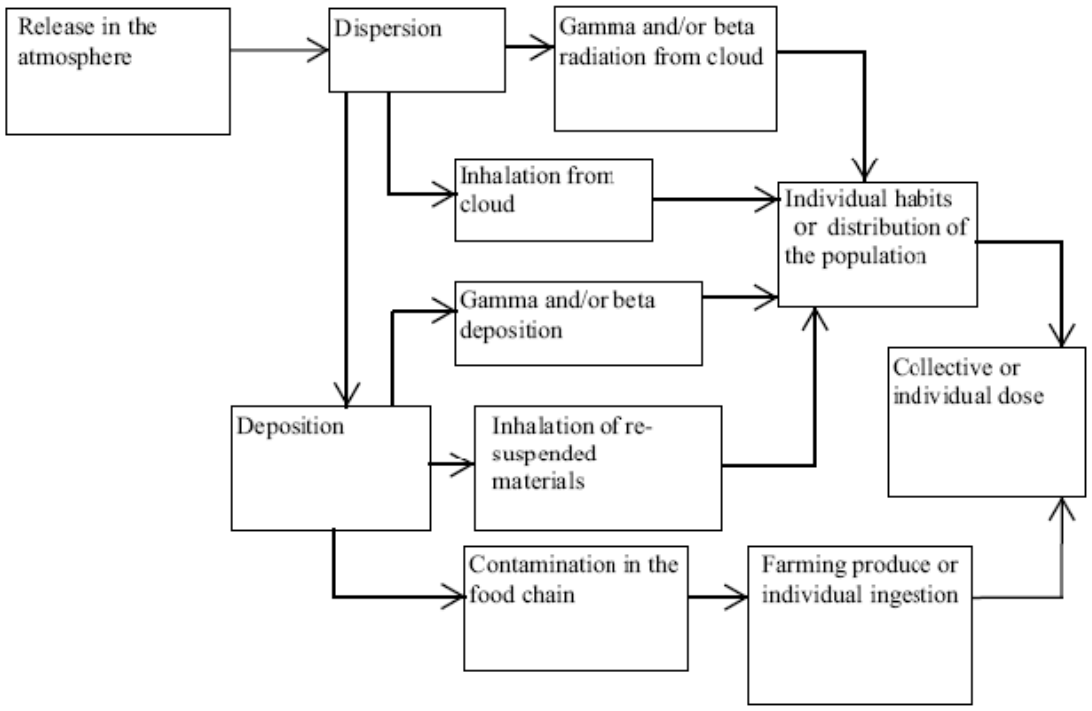


FIGURE 4.11-1: MAIN ROUTES OF RECEIVING INDIVIDUAL OR COLLECTIVE DOSES FROM GASEOUS AND AEROSOL RELEASES IN THE ATMOSPHERE

The radionuclides concentration in the respective environment and the dose from the internal radiation are used under the same models as the collective doses but considering other specific factors such as impact of buildings, rising of the stream and relief of the land surface. Statistical data on the individual such as consumption and habitation are mandatory for the assessment of the ingestion and of the internal radiation dose.

In this methodology the concentration of radionuclides into the air, the deposition and external radiation from gaseous and aerosol radioactive releases are calculated as a function of distance per unit of certain nuclides release under specific atmospheric conditions. The radionuclides concentration in the atmosphere and the internal radiation dose can be combined with population distribution in space by taking into account the location for calculating the collective dose of inhalation and external radiation from the

cloud. Analogically, the transfer in the terrain environment is calculated per unit of certain nuclides deposition, defined are the time-dependant dose of external radiation from the land surface, the resuspended concentration in the air and the time-integrated concentration in the various food products.

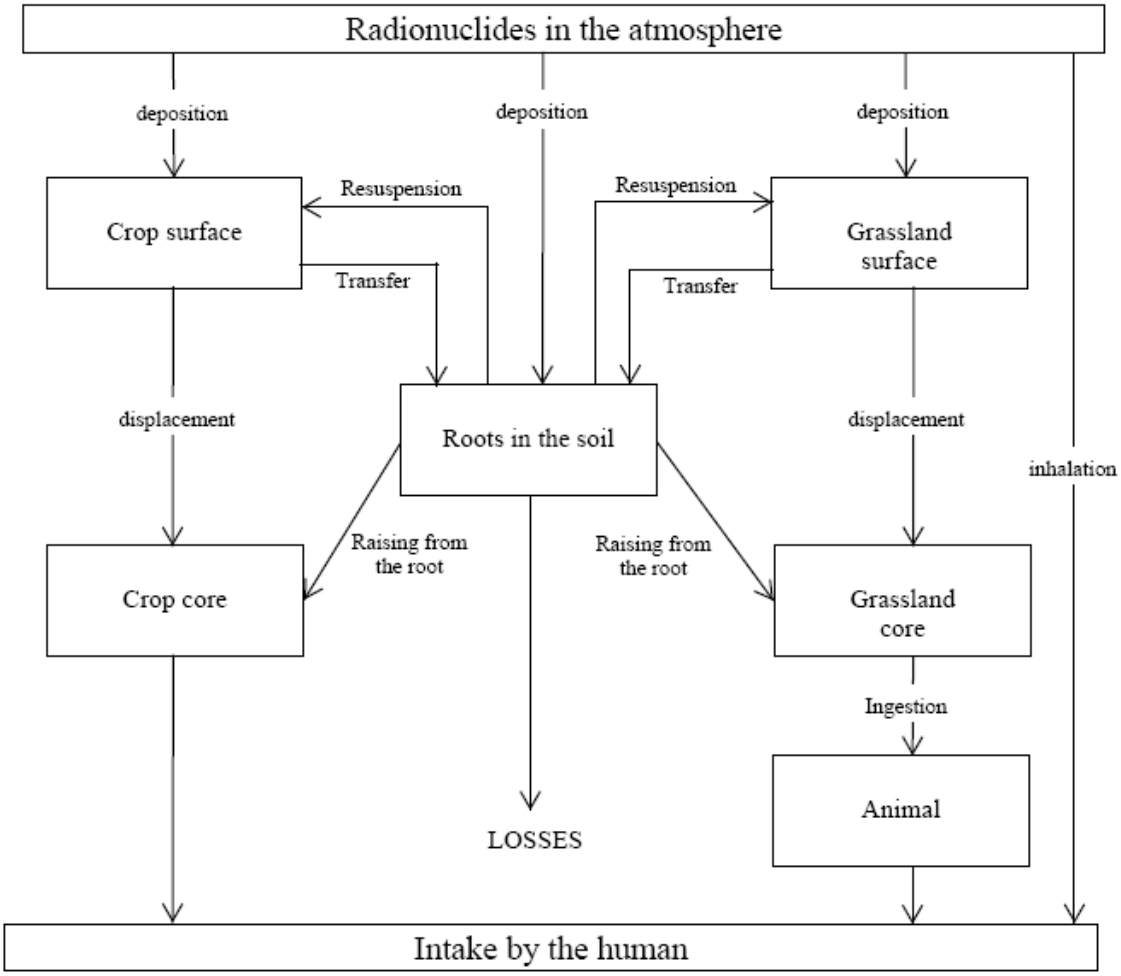


FIGURE 4.11-2: MAIN PROCESSES IN THE TRANSFER OF RADIONUCLIDES INTO THE FOOD PRODUCTS

The transfer of radionuclides into the food products is a complex of many processes and depends on the characteristics of the nuclides and the environment. **Figure 4.11-2** illustrates the most significant processes.

The combined matrix of these values with the specific location of the population and the agricultural production allows the calculation of the collective doses.

In the calculation of the individual doses in the region of the location of Kozloduy NPP should be determined more specific to the area factors. Information is needed about the location of the individuals and of the points, where food products consumed by people are produced.

The modelling programs used for assessment of the individual and collective efficient doses of population from radioactive releases in the environment are verified and validated.

4.11.1.1.3 Results

The evaluations made with mathematical modelling techniques demonstrate that the additional dose burden to the population in the 30-kilometers zone from the operation of the NNU is negligibly low. The evaluations of the individual and collective doses of the population with the microclimate data are given in **Table 4.11-2÷Table 4.11-4**. The estimated annual effective doses per capita have been compared with: the permissible norm for the population country wide 1 mSv/a (BNRP-2012); the limit for exemption from control 10 μSv/a (BNRP -2012); the limit for exposure to NPP at all operational conditions 0.05 mSv/a (NRA instruction letter no No. 47-00-171/12.02.2013) and the background exposure typical of this area of 2.33 mSv/a. The normalized collective doses are benchmarked to averaged data for PWR reactors worldwide (UNSCEAR Report-2000, 2008).

The maximum individual effective annual dose in the 30 km zone from gaseous and aerosol releases, accordance to EUR, is estimated at 6.13×10^{-7} Sv/a with microclimate data – **Table 4.11-2**. The maximum values are calculated in south-southeast direction at 2.5 km distance for age group 7-12 years.

The maximum individual effective annual dose in the 30 km zone for the design basis gaseous and aerosol releases of AP-1000 in the atmosphere are estimated at 5.99×10^{-7} Sv/a with microclimate data – **Table 4.11-3**. The maximum values are calculated in south-southeast direction at 2.5 km distance for age group 1-2 years.

The maximum individual effective annual dose in the 30 km zone for the design basis gaseous and aerosol releases of ASE VVER-1000 in the atmosphere are estimated at 1.79×10^{-8} Sv/a with microclimate data – **Table 4.11-4**. The maximum values are calculated in south-southeast direction at 2.5 km distance for age group 1-2 years.

TABLE 4.11-2: DISTRIBUTION OF THE INDIVIDUAL EFFECTIVE DOSE FOR ADULTS FOR ALL ROUTES OF EXPOSURE AND INTRODUCTION OF RADIOACTIVE EMISSIONS IN THE ATMOSPHERE IN ACCORDANCE WITH EUR, SV

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
600	1.04E-07	8.17E-08	4.24E-08	4.09E-08	5.37E-08	6.68E-08	1.21E-07	7.21E-08	1.17E-07	1.28E-07	1.18E-07	6.88E-08	9.09E-08	7.78E-08	7.51E-08	9.73E-08
700	1.34E-07	1.05E-07	5.41E-08	5.25E-08	6.76E-08	8.42E-08	1.67E-07	1.04E-07	1.56E-07	1.68E-07	1.52E-07	8.91E-08	1.17E-07	9.66E-08	9.73E-08	1.24E-07
800	1.66E-07	1.31E-07	6.67E-08	6.55E-08	8.20E-08	1.02E-07	2.14E-07	1.41E-07	1.95E-07	2.10E-07	1.87E-07	1.12E-07	1.44E-07	1.15E-07	1.20E-07	1.51E-07
900	1.97E-07	1.58E-07	8.03E-08	7.99E-08	9.75E-08	1.20E-07	2.62E-07	1.79E-07	2.34E-07	2.53E-07	2.21E-07	1.36E-07	1.70E-07	1.34E-07	1.41E-07	1.79E-07
1000	2.27E-07	1.85E-07	9.44E-08	9.55E-08	1.14E-07	1.39E-07	3.07E-07	2.18E-07	2.71E-07	2.93E-07	2.54E-07	1.60E-07	1.95E-07	1.52E-07	1.61E-07	2.07E-07
1100	2.56E-07	2.11E-07	1.09E-07	1.12E-07	1.32E-07	1.58E-07	3.49E-07	2.55E-07	3.05E-07	3.32E-07	2.85E-07	1.84E-07	2.17E-07	1.69E-07	1.80E-07	2.34E-07
1200	2.81E-07	2.35E-07	1.23E-07	1.30E-07	1.51E-07	1.78E-07	3.86E-07	2.88E-07	3.36E-07	3.67E-07	3.13E-07	2.06E-07	2.37E-07	1.85E-07	1.96E-07	2.59E-07
1300	3.04E-07	2.57E-07	1.37E-07	1.49E-07	1.70E-07	1.98E-07	4.19E-07	3.18E-07	3.63E-07	3.98E-07	3.39E-07	2.26E-07	2.55E-07	1.99E-07	2.10E-07	2.82E-07
1400	3.24E-07	2.77E-07	1.50E-07	1.68E-07	1.90E-07	2.18E-07	4.48E-07	3.45E-07	3.86E-07	4.25E-07	3.61E-07	2.45E-07	2.72E-07	2.13E-07	2.22E-07	3.02E-07
1500	3.41E-07	2.95E-07	1.62E-07	1.87E-07	2.09E-07	2.37E-07	4.72E-07	3.68E-07	4.05E-07	4.48E-07	3.80E-07	2.61E-07	2.86E-07	2.25E-07	2.32E-07	3.20E-07
1600	3.56E-07	3.11E-07	1.74E-07	2.06E-07	2.28E-07	2.55E-07	4.92E-07	3.87E-07	4.22E-07	4.67E-07	3.96E-07	2.76E-07	2.99E-07	2.35E-07	2.40E-07	3.36E-07
1700	3.68E-07	3.25E-07	1.85E-07	2.23E-07	2.45E-07	2.72E-07	5.09E-07	4.03E-07	4.35E-07	4.83E-07	4.10E-07	2.89E-07	3.10E-07	2.45E-07	2.47E-07	3.49E-07
1800	3.79E-07	3.38E-07	1.94E-07	2.39E-07	2.61E-07	2.87E-07	5.22E-07	4.16E-07	4.45E-07	4.95E-07	4.21E-07	2.99E-07	3.20E-07	2.53E-07	2.52E-07	3.61E-07
1900	3.88E-07	3.49E-07	2.03E-07	2.54E-07	2.75E-07	3.00E-07	5.33E-07	4.26E-07	4.53E-07	5.05E-07	4.30E-07	3.08E-07	3.28E-07	2.60E-07	2.57E-07	3.70E-07
2000	3.96E-07	3.59E-07	2.11E-07	2.68E-07	2.89E-07	3.12E-07	5.41E-07	4.34E-07	4.59E-07	5.13E-07	4.37E-07	3.16E-07	3.34E-07	2.66E-07	2.60E-07	3.79E-07
2100	4.03E-07	3.68E-07	2.19E-07	2.81E-07	3.00E-07	3.23E-07	5.47E-07	4.40E-07	4.63E-07	5.18E-07	4.42E-07	3.22E-07	3.40E-07	2.71E-07	2.63E-07	3.86E-07
2200	4.10E-07	3.77E-07	2.26E-07	2.92E-07	3.11E-07	3.32E-07	5.51E-07	4.45E-07	4.66E-07	5.22E-07	4.46E-07	3.27E-07	3.45E-07	2.75E-07	2.66E-07	3.92E-07
2300	4.16E-07	3.86E-07	2.33E-07	3.02E-07	3.20E-07	3.40E-07	5.53E-07	4.48E-07	4.67E-07	5.24E-07	4.49E-07	3.32E-07	3.48E-07	2.80E-07	2.68E-07	3.98E-07
2400	4.23E-07	3.94E-07	2.39E-07	3.11E-07	3.28E-07	3.46E-07	5.55E-07	4.50E-07	4.68E-07	5.25E-07	4.51E-07	3.35E-07	3.52E-07	2.83E-07	2.70E-07	4.04E-07
2500	4.29E-07	4.02E-07	2.46E-07	3.20E-07	3.35E-07	3.52E-07	5.55E-07	4.51E-07	4.68E-07	5.25E-07	4.52E-07	3.38E-07	3.54E-07	2.87E-07	2.72E-07	4.09E-07
2600	4.35E-07	4.11E-07	2.52E-07	3.27E-07	3.41E-07	3.57E-07	5.55E-07	4.51E-07	4.67E-07	5.24E-07	4.53E-07	3.40E-07	3.57E-07	2.90E-07	2.73E-07	4.13E-07
2700	4.41E-07	4.19E-07	2.57E-07	3.34E-07	3.46E-07	3.61E-07	5.54E-07	4.51E-07	4.65E-07	5.23E-07	4.53E-07	3.42E-07	3.59E-07	2.92E-07	2.75E-07	4.18E-07
2800	4.47E-07	4.27E-07	2.63E-07	3.40E-07	3.51E-07	3.64E-07	5.52E-07	4.50E-07	4.63E-07	5.21E-07	4.53E-07	3.43E-07	3.60E-07	2.95E-07	2.76E-07	4.22E-07
2900	4.53E-07	4.35E-07	2.68E-07	3.46E-07	3.54E-07	3.67E-07	5.50E-07	4.49E-07	4.61E-07	5.18E-07	4.52E-07	3.44E-07	3.61E-07	2.97E-07	2.78E-07	4.26E-07
3000	4.59E-07	4.42E-07	2.73E-07	3.51E-07	3.58E-07	3.69E-07	5.47E-07	4.48E-07	4.58E-07	5.15E-07	4.51E-07	3.44E-07	3.62E-07	3.00E-07	2.79E-07	4.30E-07
3100	4.65E-07	4.50E-07	2.78E-07	3.55E-07	3.61E-07	3.70E-07	5.45E-07	4.46E-07	4.55E-07	5.12E-07	4.49E-07	3.45E-07	3.63E-07	3.02E-07	2.81E-07	4.33E-07

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
3200	4.71E-07	4.57E-07	2.83E-07	3.59E-07	3.63E-07	3.71E-07	5.42E-07	4.44E-07	4.52E-07	5.09E-07	4.48E-07	3.45E-07	3.63E-07	3.04E-07	2.82E-07	4.37E-07
3300	4.76E-07	4.64E-07	2.87E-07	3.62E-07	3.65E-07	3.72E-07	5.38E-07	4.41E-07	4.49E-07	5.05E-07	4.46E-07	3.45E-07	3.64E-07	3.05E-07	2.83E-07	4.40E-07
3400	4.82E-07	4.71E-07	2.91E-07	3.65E-07	3.66E-07	3.72E-07	5.35E-07	4.39E-07	4.46E-07	5.02E-07	4.44E-07	3.44E-07	3.64E-07	3.07E-07	2.84E-07	4.43E-07
3500	4.87E-07	4.78E-07	2.95E-07	3.68E-07	3.67E-07	3.72E-07	5.31E-07	4.36E-07	4.42E-07	4.98E-07	4.42E-07	3.44E-07	3.64E-07	3.08E-07	2.85E-07	4.46E-07
3600	4.92E-07	4.84E-07	2.99E-07	3.70E-07	3.68E-07	3.72E-07	5.27E-07	4.33E-07	4.39E-07	4.94E-07	4.40E-07	3.43E-07	3.63E-07	3.09E-07	2.86E-07	4.48E-07
3700	4.96E-07	4.90E-07	3.02E-07	3.72E-07	3.68E-07	3.71E-07	5.24E-07	4.30E-07	4.35E-07	4.90E-07	4.37E-07	3.42E-07	3.63E-07	3.10E-07	2.86E-07	4.51E-07
3800	5.00E-07	4.95E-07	3.05E-07	3.73E-07	3.68E-07	3.70E-07	5.20E-07	4.27E-07	4.31E-07	4.86E-07	4.35E-07	3.41E-07	3.62E-07	3.11E-07	2.87E-07	4.52E-07
3900	5.04E-07	5.00E-07	3.08E-07	3.74E-07	3.68E-07	3.69E-07	5.15E-07	4.24E-07	4.28E-07	4.81E-07	4.32E-07	3.40E-07	3.61E-07	3.12E-07	2.87E-07	4.54E-07
4000	5.07E-07	5.04E-07	3.11E-07	3.75E-07	3.67E-07	3.68E-07	5.11E-07	4.21E-07	4.24E-07	4.77E-07	4.29E-07	3.39E-07	3.60E-07	3.12E-07	2.87E-07	4.56E-07
4100	5.10E-07	5.08E-07	3.13E-07	3.76E-07	3.67E-07	3.66E-07	5.07E-07	4.18E-07	4.20E-07	4.73E-07	4.26E-07	3.37E-07	3.59E-07	3.12E-07	2.88E-07	4.57E-07
4200	5.13E-07	5.12E-07	3.15E-07	3.76E-07	3.66E-07	3.65E-07	5.03E-07	4.14E-07	4.16E-07	4.68E-07	4.23E-07	3.36E-07	3.58E-07	3.12E-07	2.88E-07	4.58E-07
4300	5.15E-07	5.15E-07	3.17E-07	3.76E-07	3.65E-07	3.63E-07	4.98E-07	4.11E-07	4.12E-07	4.64E-07	4.20E-07	3.34E-07	3.57E-07	3.12E-07	2.88E-07	4.58E-07
4400	5.17E-07	5.18E-07	3.18E-07	3.76E-07	3.63E-07	3.61E-07	4.94E-07	4.07E-07	4.08E-07	4.59E-07	4.17E-07	3.32E-07	3.55E-07	3.12E-07	2.87E-07	4.59E-07
4500	5.19E-07	5.21E-07	3.19E-07	3.75E-07	3.62E-07	3.59E-07	4.89E-07	4.04E-07	4.04E-07	4.55E-07	4.14E-07	3.30E-07	3.53E-07	3.12E-07	2.87E-07	4.59E-07
4600	5.20E-07	5.23E-07	3.20E-07	3.75E-07	3.60E-07	3.56E-07	4.85E-07	4.00E-07	4.00E-07	4.50E-07	4.11E-07	3.28E-07	3.52E-07	3.11E-07	2.86E-07	4.59E-07
4700	5.22E-07	5.24E-07	3.21E-07	3.74E-07	3.58E-07	3.54E-07	4.80E-07	3.97E-07	3.96E-07	4.45E-07	4.07E-07	3.26E-07	3.50E-07	3.10E-07	2.86E-07	4.58E-07
4800	5.22E-07	5.26E-07	3.22E-07	3.73E-07	3.56E-07	3.52E-07	4.75E-07	3.93E-07	3.92E-07	4.41E-07	4.04E-07	3.24E-07	3.48E-07	3.10E-07	2.85E-07	4.58E-07
4900	5.23E-07	5.27E-07	3.22E-07	3.71E-07	3.54E-07	3.49E-07	4.71E-07	3.89E-07	3.88E-07	4.36E-07	4.01E-07	3.22E-07	3.46E-07	3.09E-07	2.84E-07	4.57E-07
5000	5.23E-07	5.28E-07	3.22E-07	3.70E-07	3.52E-07	3.46E-07	4.66E-07	3.86E-07	3.84E-07	4.32E-07	3.97E-07	3.20E-07	3.44E-07	3.08E-07	2.83E-07	4.56E-07
5100	5.23E-07	5.28E-07	3.22E-07	3.68E-07	3.50E-07	3.44E-07	4.62E-07	3.82E-07	3.80E-07	4.27E-07	3.94E-07	3.17E-07	3.42E-07	3.06E-07	2.82E-07	4.55E-07
5200	5.22E-07	5.28E-07	3.22E-07	3.67E-07	3.48E-07	3.41E-07	4.57E-07	3.78E-07	3.76E-07	4.23E-07	3.90E-07	3.15E-07	3.39E-07	3.05E-07	2.81E-07	4.54E-07
5300	5.22E-07	5.28E-07	3.22E-07	3.65E-07	3.45E-07	3.38E-07	4.52E-07	3.75E-07	3.72E-07	4.18E-07	3.87E-07	3.12E-07	3.37E-07	3.04E-07	2.80E-07	4.52E-07
5400	5.21E-07	5.28E-07	3.21E-07	3.63E-07	3.43E-07	3.36E-07	4.48E-07	3.71E-07	3.68E-07	4.14E-07	3.83E-07	3.10E-07	3.35E-07	3.02E-07	2.79E-07	4.50E-07
5500	5.20E-07	5.27E-07	3.21E-07	3.61E-07	3.40E-07	3.33E-07	4.43E-07	3.67E-07	3.64E-07	4.09E-07	3.80E-07	3.08E-07	3.32E-07	3.01E-07	2.78E-07	4.49E-07
5600	5.18E-07	5.26E-07	3.20E-07	3.59E-07	3.38E-07	3.30E-07	4.39E-07	3.64E-07	3.60E-07	4.05E-07	3.76E-07	3.05E-07	3.30E-07	2.99E-07	2.76E-07	4.47E-07
5700	5.17E-07	5.25E-07	3.19E-07	3.57E-07	3.35E-07	3.27E-07	4.34E-07	3.60E-07	3.56E-07	4.00E-07	3.73E-07	3.03E-07	3.27E-07	2.98E-07	2.75E-07	4.45E-07
5800	5.15E-07	5.24E-07	3.18E-07	3.55E-07	3.33E-07	3.24E-07	4.30E-07	3.56E-07	3.52E-07	3.96E-07	3.69E-07	3.00E-07	3.25E-07	2.96E-07	2.73E-07	4.43E-07
5900	5.14E-07	5.22E-07	3.17E-07	3.52E-07	3.30E-07	3.21E-07	4.25E-07	3.53E-07	3.49E-07	3.92E-07	3.66E-07	2.97E-07	3.22E-07	2.94E-07	2.72E-07	4.40E-07
6000	5.12E-07	5.21E-07	3.16E-07	3.50E-07	3.27E-07	3.18E-07	4.21E-07	3.49E-07	3.45E-07	3.87E-07	3.62E-07	2.95E-07	3.20E-07	2.92E-07	2.70E-07	4.38E-07

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
6100	5.10E-07	5.19E-07	3.15E-07	3.48E-07	3.24E-07	3.15E-07	4.16E-07	3.45E-07	3.41E-07	3.83E-07	3.59E-07	2.92E-07	3.17E-07	2.91E-07	2.68E-07	4.36E-07
6200	5.08E-07	5.17E-07	3.13E-07	3.45E-07	3.22E-07	3.12E-07	4.12E-07	3.42E-07	3.37E-07	3.79E-07	3.55E-07	2.90E-07	3.15E-07	2.89E-07	2.67E-07	4.33E-07
6300	5.05E-07	5.15E-07	3.12E-07	3.43E-07	3.19E-07	3.09E-07	4.08E-07	3.38E-07	3.34E-07	3.75E-07	3.52E-07	2.87E-07	3.12E-07	2.87E-07	2.65E-07	4.31E-07
6400	5.03E-07	5.13E-07	3.10E-07	3.40E-07	3.16E-07	3.06E-07	4.03E-07	3.35E-07	3.30E-07	3.71E-07	3.48E-07	2.85E-07	3.09E-07	2.85E-07	2.63E-07	4.28E-07
6500	5.00E-07	5.11E-07	3.09E-07	3.38E-07	3.13E-07	3.03E-07	3.99E-07	3.31E-07	3.27E-07	3.67E-07	3.45E-07	2.82E-07	3.07E-07	2.83E-07	2.62E-07	4.26E-07
6600	4.98E-07	5.08E-07	3.07E-07	3.35E-07	3.11E-07	3.01E-07	3.95E-07	3.28E-07	3.23E-07	3.63E-07	3.41E-07	2.80E-07	3.04E-07	2.81E-07	2.60E-07	4.23E-07
6700	4.95E-07	5.06E-07	3.06E-07	3.33E-07	3.08E-07	2.98E-07	3.91E-07	3.25E-07	3.19E-07	3.59E-07	3.38E-07	2.77E-07	3.01E-07	2.79E-07	2.58E-07	4.20E-07
6800	4.93E-07	5.03E-07	3.04E-07	3.30E-07	3.05E-07	2.95E-07	3.87E-07	3.21E-07	3.16E-07	3.55E-07	3.35E-07	2.75E-07	2.99E-07	2.77E-07	2.56E-07	4.17E-07
6900	4.90E-07	5.00E-07	3.02E-07	3.27E-07	3.02E-07	2.92E-07	3.82E-07	3.18E-07	3.13E-07	3.51E-07	3.31E-07	2.72E-07	2.96E-07	2.75E-07	2.54E-07	4.15E-07
7000	4.87E-07	4.98E-07	3.00E-07	3.25E-07	3.00E-07	2.89E-07	3.78E-07	3.15E-07	3.09E-07	3.47E-07	3.28E-07	2.70E-07	2.94E-07	2.73E-07	2.53E-07	4.12E-07
7100	4.84E-07	4.95E-07	2.99E-07	3.22E-07	2.97E-07	2.86E-07	3.74E-07	3.11E-07	3.06E-07	3.43E-07	3.25E-07	2.67E-07	2.91E-07	2.71E-07	2.51E-07	4.09E-07
7200	4.81E-07	4.92E-07	2.97E-07	3.20E-07	2.94E-07	2.84E-07	3.71E-07	3.08E-07	3.03E-07	3.40E-07	3.22E-07	2.65E-07	2.89E-07	2.69E-07	2.49E-07	4.06E-07
7300	4.78E-07	4.89E-07	2.95E-07	3.17E-07	2.92E-07	2.81E-07	3.67E-07	3.05E-07	2.99E-07	3.36E-07	3.18E-07	2.62E-07	2.86E-07	2.67E-07	2.47E-07	4.03E-07
7400	4.75E-07	4.86E-07	2.93E-07	3.14E-07	2.89E-07	2.78E-07	3.63E-07	3.02E-07	2.96E-07	3.32E-07	3.15E-07	2.60E-07	2.84E-07	2.65E-07	2.45E-07	4.00E-07
7500	4.72E-07	4.83E-07	2.91E-07	3.12E-07	2.86E-07	2.75E-07	3.59E-07	2.99E-07	2.93E-07	3.29E-07	3.12E-07	2.57E-07	2.81E-07	2.63E-07	2.43E-07	3.97E-07
7600	4.69E-07	4.80E-07	2.89E-07	3.09E-07	2.84E-07	2.73E-07	3.55E-07	2.96E-07	2.90E-07	3.25E-07	3.09E-07	2.55E-07	2.79E-07	2.61E-07	2.41E-07	3.94E-07
7700	4.66E-07	4.77E-07	2.87E-07	3.07E-07	2.81E-07	2.70E-07	3.52E-07	2.93E-07	2.87E-07	3.22E-07	3.06E-07	2.53E-07	2.76E-07	2.58E-07	2.40E-07	3.92E-07
7800	4.63E-07	4.74E-07	2.85E-07	3.04E-07	2.78E-07	2.67E-07	3.48E-07	2.90E-07	2.84E-07	3.19E-07	3.03E-07	2.50E-07	2.74E-07	2.56E-07	2.38E-07	3.89E-07
7900	4.60E-07	4.71E-07	2.83E-07	3.02E-07	2.76E-07	2.65E-07	3.44E-07	2.87E-07	2.81E-07	3.15E-07	3.00E-07	2.48E-07	2.71E-07	2.54E-07	2.36E-07	3.86E-07
8000	4.57E-07	4.68E-07	2.81E-07	2.99E-07	2.73E-07	2.62E-07	3.41E-07	2.84E-07	2.78E-07	3.12E-07	2.97E-07	2.46E-07	2.69E-07	2.52E-07	2.34E-07	3.83E-07
8100	4.54E-07	4.65E-07	2.79E-07	2.97E-07	2.71E-07	2.60E-07	3.37E-07	2.81E-07	2.75E-07	3.09E-07	2.94E-07	2.43E-07	2.66E-07	2.50E-07	2.32E-07	3.80E-07
8200	4.50E-07	4.62E-07	2.77E-07	2.94E-07	2.68E-07	2.57E-07	3.34E-07	2.78E-07	2.72E-07	3.05E-07	2.91E-07	2.41E-07	2.64E-07	2.48E-07	2.30E-07	3.77E-07
8300	4.47E-07	4.59E-07	2.76E-07	2.92E-07	2.66E-07	2.55E-07	3.31E-07	2.75E-07	2.70E-07	3.02E-07	2.89E-07	2.39E-07	2.62E-07	2.46E-07	2.29E-07	3.74E-07
8400	4.44E-07	4.56E-07	2.74E-07	2.89E-07	2.63E-07	2.52E-07	3.27E-07	2.72E-07	2.67E-07	2.99E-07	2.86E-07	2.37E-07	2.59E-07	2.44E-07	2.27E-07	3.71E-07
8500	4.41E-07	4.53E-07	2.72E-07	2.87E-07	2.61E-07	2.50E-07	3.24E-07	2.70E-07	2.64E-07	2.96E-07	2.83E-07	2.34E-07	2.57E-07	2.42E-07	2.25E-07	3.69E-07
8600	4.38E-07	4.50E-07	2.70E-07	2.84E-07	2.59E-07	2.47E-07	3.21E-07	2.67E-07	2.61E-07	2.93E-07	2.80E-07	2.32E-07	2.55E-07	2.40E-07	2.23E-07	3.66E-07
8700	4.35E-07	4.47E-07	2.68E-07	2.82E-07	2.56E-07	2.45E-07	3.18E-07	2.64E-07	2.59E-07	2.90E-07	2.78E-07	2.30E-07	2.52E-07	2.39E-07	2.21E-07	3.63E-07
8800	4.32E-07	4.44E-07	2.66E-07	2.79E-07	2.54E-07	2.43E-07	3.14E-07	2.62E-07	2.56E-07	2.87E-07	2.75E-07	2.28E-07	2.50E-07	2.37E-07	2.20E-07	3.60E-07
8900	4.29E-07	4.40E-07	2.64E-07	2.77E-07	2.52E-07	2.40E-07	3.11E-07	2.59E-07	2.54E-07	2.84E-07	2.72E-07	2.26E-07	2.48E-07	2.35E-07	2.18E-07	3.57E-07

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
9000	4.26E-07	4.37E-07	2.62E-07	2.75E-07	2.49E-07	2.38E-07	3.08E-07	2.57E-07	2.51E-07	2.81E-07	2.70E-07	2.24E-07	2.46E-07	2.33E-07	2.16E-07	3.55E-07
9100	4.23E-07	4.34E-07	2.60E-07	2.72E-07	2.47E-07	2.36E-07	3.05E-07	2.54E-07	2.49E-07	2.79E-07	2.67E-07	2.22E-07	2.44E-07	2.31E-07	2.15E-07	3.52E-07
9200	4.19E-07	4.31E-07	2.58E-07	2.70E-07	2.45E-07	2.34E-07	3.02E-07	2.52E-07	2.46E-07	2.76E-07	2.65E-07	2.20E-07	2.42E-07	2.29E-07	2.13E-07	3.49E-07
9300	4.16E-07	4.28E-07	2.56E-07	2.68E-07	2.43E-07	2.31E-07	2.99E-07	2.49E-07	2.44E-07	2.73E-07	2.62E-07	2.18E-07	2.40E-07	2.27E-07	2.11E-07	3.46E-07
9400	4.13E-07	4.25E-07	2.54E-07	2.66E-07	2.41E-07	2.29E-07	2.97E-07	2.47E-07	2.41E-07	2.70E-07	2.60E-07	2.16E-07	2.37E-07	2.25E-07	2.10E-07	3.44E-07
9500	4.10E-07	4.22E-07	2.52E-07	2.63E-07	2.38E-07	2.27E-07	2.94E-07	2.45E-07	2.39E-07	2.68E-07	2.57E-07	2.14E-07	2.35E-07	2.24E-07	2.08E-07	3.41E-07
9600	4.08E-07	4.19E-07	2.51E-07	2.61E-07	2.36E-07	2.25E-07	2.91E-07	2.42E-07	2.37E-07	2.65E-07	2.55E-07	2.12E-07	2.33E-07	2.22E-07	2.06E-07	3.39E-07
9700	4.05E-07	4.16E-07	2.49E-07	2.59E-07	2.34E-07	2.23E-07	2.88E-07	2.40E-07	2.34E-07	2.63E-07	2.53E-07	2.10E-07	2.31E-07	2.20E-07	2.05E-07	3.36E-07
9800	4.02E-07	4.13E-07	2.47E-07	2.57E-07	2.32E-07	2.21E-07	2.85E-07	2.38E-07	2.32E-07	2.60E-07	2.50E-07	2.09E-07	2.29E-07	2.18E-07	2.03E-07	3.33E-07
9900	3.99E-07	4.10E-07	2.45E-07	2.55E-07	2.30E-07	2.19E-07	2.83E-07	2.36E-07	2.30E-07	2.58E-07	2.48E-07	2.07E-07	2.27E-07	2.17E-07	2.01E-07	3.31E-07
10000	3.96E-07	4.07E-07	2.43E-07	2.53E-07	2.28E-07	2.17E-07	2.80E-07	2.33E-07	2.28E-07	2.55E-07	2.46E-07	2.05E-07	2.25E-07	2.15E-07	2.00E-07	3.28E-07
10100	3.93E-07	4.05E-07	2.42E-07	2.50E-07	2.26E-07	2.15E-07	2.77E-07	2.31E-07	2.26E-07	2.53E-07	2.44E-07	2.03E-07	2.24E-07	2.13E-07	1.98E-07	3.26E-07
10200	3.90E-07	4.02E-07	2.40E-07	2.48E-07	2.24E-07	2.13E-07	2.75E-07	2.29E-07	2.24E-07	2.50E-07	2.42E-07	2.01E-07	2.22E-07	2.12E-07	1.97E-07	3.23E-07
10300	3.87E-07	3.99E-07	2.38E-07	2.46E-07	2.22E-07	2.11E-07	2.72E-07	2.27E-07	2.22E-07	2.48E-07	2.39E-07	2.00E-07	2.20E-07	2.10E-07	1.95E-07	3.21E-07
10400	3.85E-07	3.96E-07	2.36E-07	2.44E-07	2.20E-07	2.09E-07	2.70E-07	2.25E-07	2.20E-07	2.46E-07	2.37E-07	1.98E-07	2.18E-07	2.08E-07	1.94E-07	3.18E-07
10500	3.82E-07	3.93E-07	2.35E-07	2.42E-07	2.18E-07	2.07E-07	2.67E-07	2.23E-07	2.18E-07	2.44E-07	2.35E-07	1.96E-07	2.16E-07	2.07E-07	1.92E-07	3.16E-07
10600	3.79E-07	3.91E-07	2.33E-07	2.40E-07	2.17E-07	2.06E-07	2.65E-07	2.21E-07	2.16E-07	2.41E-07	2.33E-07	1.95E-07	2.14E-07	2.05E-07	1.91E-07	3.14E-07
10700	3.76E-07	3.88E-07	2.31E-07	2.38E-07	2.15E-07	2.04E-07	2.63E-07	2.19E-07	2.14E-07	2.39E-07	2.31E-07	1.93E-07	2.13E-07	2.03E-07	1.89E-07	3.11E-07
10800	3.74E-07	3.85E-07	2.29E-07	2.37E-07	2.13E-07	2.02E-07	2.60E-07	2.17E-07	2.12E-07	2.37E-07	2.29E-07	1.91E-07	2.11E-07	2.02E-07	1.88E-07	3.09E-07
10900	3.71E-07	3.82E-07	2.28E-07	2.35E-07	2.11E-07	2.00E-07	2.58E-07	2.15E-07	2.10E-07	2.35E-07	2.27E-07	1.90E-07	2.09E-07	2.00E-07	1.87E-07	3.07E-07
11000	3.68E-07	3.80E-07	2.26E-07	2.33E-07	2.09E-07	1.99E-07	2.56E-07	2.13E-07	2.08E-07	2.33E-07	2.25E-07	1.88E-07	2.07E-07	1.99E-07	1.85E-07	3.04E-07
11100	3.66E-07	3.77E-07	2.25E-07	2.31E-07	2.08E-07	1.97E-07	2.54E-07	2.11E-07	2.06E-07	2.31E-07	2.23E-07	1.87E-07	2.06E-07	1.97E-07	1.84E-07	3.02E-07
11200	3.63E-07	3.74E-07	2.23E-07	2.29E-07	2.06E-07	1.95E-07	2.51E-07	2.10E-07	2.04E-07	2.29E-07	2.21E-07	1.85E-07	2.04E-07	1.96E-07	1.82E-07	3.00E-07
11300	3.61E-07	3.72E-07	2.21E-07	2.27E-07	2.04E-07	1.94E-07	2.49E-07	2.08E-07	2.03E-07	2.27E-07	2.19E-07	1.84E-07	2.03E-07	1.94E-07	1.81E-07	2.98E-07
11400	3.58E-07	3.69E-07	2.20E-07	2.25E-07	2.03E-07	1.92E-07	2.47E-07	2.06E-07	2.01E-07	2.25E-07	2.18E-07	1.82E-07	2.01E-07	1.93E-07	1.80E-07	2.95E-07
11500	3.56E-07	3.67E-07	2.18E-07	2.24E-07	2.01E-07	1.90E-07	2.45E-07	2.04E-07	1.99E-07	2.23E-07	2.16E-07	1.81E-07	1.99E-07	1.91E-07	1.78E-07	2.93E-07
11600	3.53E-07	3.64E-07	2.17E-07	2.22E-07	1.99E-07	1.89E-07	2.43E-07	2.03E-07	1.97E-07	2.21E-07	2.14E-07	1.79E-07	1.98E-07	1.90E-07	1.77E-07	2.91E-07
11700	3.51E-07	3.62E-07	2.15E-07	2.20E-07	1.98E-07	1.87E-07	2.41E-07	2.01E-07	1.96E-07	2.19E-07	2.12E-07	1.78E-07	1.96E-07	1.89E-07	1.76E-07	2.89E-07
11800	3.48E-07	3.59E-07	2.14E-07	2.19E-07	1.96E-07	1.86E-07	2.39E-07	1.99E-07	1.94E-07	2.17E-07	2.11E-07	1.76E-07	1.95E-07	1.87E-07	1.74E-07	2.87E-07

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
11900	3.46E-07	3.57E-07	2.12E-07	2.17E-07	1.95E-07	1.84E-07	2.37E-07	1.97E-07	1.92E-07	2.15E-07	2.09E-07	1.75E-07	1.93E-07	1.86E-07	1.73E-07	2.85E-07
12000	3.43E-07	3.54E-07	2.11E-07	2.15E-07	1.93E-07	1.83E-07	2.35E-07	1.96E-07	1.91E-07	2.13E-07	2.07E-07	1.74E-07	1.92E-07	1.84E-07	1.72E-07	2.83E-07
13000	3.21E-07	3.31E-07	1.96E-07	2.00E-07	1.79E-07	1.69E-07	2.16E-07	1.81E-07	1.76E-07	1.97E-07	1.91E-07	1.61E-07	1.78E-07	1.72E-07	1.60E-07	2.64E-07
14000	3.00E-07	3.10E-07	1.84E-07	1.86E-07	1.66E-07	1.56E-07	2.00E-07	1.67E-07	1.63E-07	1.82E-07	1.77E-07	1.49E-07	1.65E-07	1.60E-07	1.50E-07	2.46E-07
15000	2.82E-07	2.92E-07	1.72E-07	1.74E-07	1.55E-07	1.45E-07	1.86E-07	1.56E-07	1.52E-07	1.69E-07	1.65E-07	1.39E-07	1.54E-07	1.50E-07	1.40E-07	2.31E-07
16000	2.66E-07	2.75E-07	1.62E-07	1.63E-07	1.45E-07	1.36E-07	1.74E-07	1.45E-07	1.41E-07	1.58E-07	1.54E-07	1.31E-07	1.45E-07	1.41E-07	1.32E-07	2.17E-07
17000	2.51E-07	2.59E-07	1.53E-07	1.53E-07	1.36E-07	1.27E-07	1.63E-07	1.36E-07	1.33E-07	1.48E-07	1.45E-07	1.23E-07	1.36E-07	1.32E-07	1.24E-07	2.05E-07
18000	2.37E-07	2.45E-07	1.44E-07	1.44E-07	1.28E-07	1.20E-07	1.53E-07	1.28E-07	1.25E-07	1.39E-07	1.36E-07	1.15E-07	1.28E-07	1.25E-07	1.17E-07	1.93E-07
19000	2.25E-07	2.32E-07	1.37E-07	1.36E-07	1.21E-07	1.13E-07	1.44E-07	1.20E-07	1.17E-07	1.31E-07	1.28E-07	1.09E-07	1.21E-07	1.18E-07	1.11E-07	1.83E-07
20000	2.13E-07	2.21E-07	1.30E-07	1.29E-07	1.14E-07	1.06E-07	1.36E-07	1.14E-07	1.11E-07	1.23E-07	1.21E-07	1.03E-07	1.15E-07	1.12E-07	1.05E-07	1.74E-07
21000	2.03E-07	2.10E-07	1.23E-07	1.22E-07	1.08E-07	1.01E-07	1.29E-07	1.08E-07	1.05E-07	1.17E-07	1.15E-07	9.79E-08	1.09E-07	1.07E-07	1.00E-07	1.65E-07
22000	1.94E-07	2.00E-07	1.17E-07	1.16E-07	1.03E-07	9.57E-08	1.22E-07	1.02E-07	9.98E-08	1.11E-07	1.09E-07	9.31E-08	1.03E-07	1.02E-07	9.53E-08	1.57E-07
23000	1.85E-07	1.91E-07	1.12E-07	1.11E-07	9.78E-08	9.10E-08	1.16E-07	9.72E-08	9.49E-08	1.06E-07	1.04E-07	8.86E-08	9.85E-08	9.69E-08	9.10E-08	1.50E-07
24000	1.77E-07	1.83E-07	1.07E-07	1.05E-07	9.32E-08	8.67E-08	1.11E-07	9.26E-08	9.05E-08	1.01E-07	9.91E-08	8.46E-08	9.41E-08	9.25E-08	8.70E-08	1.43E-07
25000	1.69E-07	1.75E-07	1.02E-07	1.01E-07	8.91E-08	8.28E-08	1.06E-07	8.84E-08	8.64E-08	9.60E-08	9.47E-08	8.09E-08	8.99E-08	8.86E-08	8.33E-08	1.37E-07
26000	1.62E-07	1.68E-07	9.82E-08	9.65E-08	8.52E-08	7.91E-08	1.01E-07	8.45E-08	8.27E-08	9.17E-08	9.06E-08	7.74E-08	8.61E-08	8.49E-08	7.98E-08	1.32E-07
27000	1.56E-07	1.62E-07	9.42E-08	9.25E-08	8.17E-08	7.58E-08	9.69E-08	8.09E-08	7.92E-08	8.78E-08	8.68E-08	7.42E-08	8.26E-08	8.15E-08	7.66E-08	1.26E-07
28000	1.50E-07	1.55E-07	9.06E-08	8.88E-08	7.84E-08	7.27E-08	9.29E-08	7.76E-08	7.60E-08	8.42E-08	8.33E-08	7.13E-08	7.93E-08	7.83E-08	7.37E-08	1.21E-07
29000	1.44E-07	1.50E-07	8.71E-08	8.53E-08	7.53E-08	6.98E-08	8.92E-08	7.45E-08	7.30E-08	8.09E-08	8.00E-08	6.85E-08	7.63E-08	7.53E-08	7.09E-08	1.17E-07
30000	1.39E-07	1.44E-07	8.39E-08	8.21E-08	7.24E-08	6.71E-08	8.58E-08	7.17E-08	7.02E-08	7.78E-08	7.69E-08	6.59E-08	7.34E-08	7.25E-08	6.83E-08	1.13E-07

TABLE 4.11-3: INDIVIDUAL EFFECTIVE DOSE FOR ADULTS BY ALL ROUTES OF EXPOSURE AND INTRODUCTION OF THE PROJECTED GASEOUS AND AEROSOL RELEASES OF AP-1000, SV

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
600	7.63E-08	6.01E-08	3.12E-08	3.01E-08	3.95E-08	4.91E-08	8.90E-08	5.30E-08	8.59E-08	9.38E-08	8.67E-08	5.06E-08	6.69E-08	5.72E-08	5.52E-08	7.16E-08
700	9.88E-08	7.72E-08	3.98E-08	3.86E-08	4.97E-08	6.19E-08	1.23E-07	7.67E-08	1.15E-07	1.24E-07	1.12E-07	6.55E-08	8.64E-08	7.10E-08	7.15E-08	9.11E-08
800	1.22E-07	9.62E-08	4.91E-08	4.82E-08	6.03E-08	7.47E-08	1.58E-07	1.03E-07	1.44E-07	1.55E-07	1.38E-07	8.22E-08	1.06E-07	8.48E-08	8.80E-08	1.11E-07

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
900	1.45E-07	1.16E-07	5.91E-08	5.87E-08	7.17E-08	8.81E-08	1.93E-07	1.32E-07	1.72E-07	1.86E-07	1.63E-07	9.98E-08	1.25E-07	9.84E-08	1.04E-07	1.32E-07
1000	1.67E-07	1.36E-07	6.94E-08	7.02E-08	8.40E-08	1.02E-07	2.26E-07	1.60E-07	2.00E-07	2.16E-07	1.87E-07	1.18E-07	1.43E-07	1.12E-07	1.19E-07	1.52E-07
1100	1.88E-07	1.55E-07	7.99E-08	8.26E-08	9.72E-08	1.16E-07	2.57E-07	1.87E-07	2.25E-07	2.44E-07	2.10E-07	1.35E-07	1.60E-07	1.24E-07	1.32E-07	1.72E-07
1200	2.07E-07	1.73E-07	9.04E-08	9.58E-08	1.11E-07	1.31E-07	2.84E-07	2.12E-07	2.47E-07	2.70E-07	2.31E-07	1.51E-07	1.74E-07	1.36E-07	1.44E-07	1.91E-07
1300	2.23E-07	1.89E-07	1.01E-07	1.10E-07	1.25E-07	1.46E-07	3.08E-07	2.34E-07	2.67E-07	2.92E-07	2.49E-07	1.66E-07	1.88E-07	1.47E-07	1.54E-07	2.07E-07
1400	2.38E-07	2.04E-07	1.10E-07	1.24E-07	1.40E-07	1.60E-07	3.29E-07	2.54E-07	2.84E-07	3.12E-07	2.65E-07	1.80E-07	2.00E-07	1.56E-07	1.63E-07	2.22E-07
1500	2.51E-07	2.17E-07	1.19E-07	1.38E-07	1.54E-07	1.74E-07	3.47E-07	2.70E-07	2.98E-07	3.29E-07	2.79E-07	1.92E-07	2.11E-07	1.65E-07	1.70E-07	2.35E-07
1600	2.61E-07	2.29E-07	1.28E-07	1.51E-07	1.67E-07	1.87E-07	3.62E-07	2.85E-07	3.10E-07	3.43E-07	2.91E-07	2.03E-07	2.20E-07	1.73E-07	1.77E-07	2.47E-07
1700	2.71E-07	2.39E-07	1.36E-07	1.64E-07	1.80E-07	2.00E-07	3.74E-07	2.96E-07	3.20E-07	3.55E-07	3.01E-07	2.12E-07	2.28E-07	1.80E-07	1.82E-07	2.57E-07
1800	2.79E-07	2.48E-07	1.43E-07	1.76E-07	1.92E-07	2.11E-07	3.84E-07	3.06E-07	3.27E-07	3.64E-07	3.10E-07	2.20E-07	2.35E-07	1.86E-07	1.86E-07	2.65E-07
1900	2.85E-07	2.56E-07	1.49E-07	1.87E-07	2.03E-07	2.21E-07	3.92E-07	3.13E-07	3.33E-07	3.72E-07	3.16E-07	2.27E-07	2.41E-07	1.91E-07	1.89E-07	2.72E-07
2000	2.91E-07	2.64E-07	1.56E-07	1.97E-07	2.12E-07	2.30E-07	3.98E-07	3.19E-07	3.38E-07	3.77E-07	3.21E-07	2.32E-07	2.46E-07	1.95E-07	1.92E-07	2.78E-07
2100	2.97E-07	2.71E-07	1.61E-07	2.06E-07	2.21E-07	2.37E-07	4.02E-07	3.24E-07	3.41E-07	3.81E-07	3.25E-07	2.37E-07	2.50E-07	1.99E-07	1.94E-07	2.84E-07
2200	3.02E-07	2.77E-07	1.66E-07	2.15E-07	2.28E-07	2.44E-07	4.05E-07	3.27E-07	3.43E-07	3.84E-07	3.28E-07	2.41E-07	2.53E-07	2.03E-07	1.96E-07	2.89E-07
2300	3.06E-07	2.84E-07	1.71E-07	2.22E-07	2.35E-07	2.50E-07	4.07E-07	3.29E-07	3.44E-07	3.85E-07	3.30E-07	2.44E-07	2.56E-07	2.06E-07	1.97E-07	2.93E-07
2400	3.11E-07	2.90E-07	1.76E-07	2.29E-07	2.41E-07	2.55E-07	4.08E-07	3.31E-07	3.44E-07	3.86E-07	3.32E-07	2.46E-07	2.59E-07	2.08E-07	1.99E-07	2.97E-07
2500	3.15E-07	2.96E-07	1.81E-07	2.35E-07	2.46E-07	2.59E-07	4.08E-07	3.32E-07	3.44E-07	3.86E-07	3.33E-07	2.48E-07	2.61E-07	2.11E-07	2.00E-07	3.00E-07
2600	3.20E-07	3.02E-07	1.85E-07	2.41E-07	2.51E-07	2.62E-07	4.08E-07	3.32E-07	3.43E-07	3.85E-07	3.33E-07	2.50E-07	2.62E-07	2.13E-07	2.01E-07	3.04E-07
2700	3.24E-07	3.08E-07	1.89E-07	2.46E-07	2.54E-07	2.65E-07	4.07E-07	3.32E-07	3.42E-07	3.84E-07	3.33E-07	2.51E-07	2.64E-07	2.15E-07	2.02E-07	3.07E-07
2800	3.29E-07	3.14E-07	1.93E-07	2.50E-07	2.58E-07	2.68E-07	4.06E-07	3.31E-07	3.41E-07	3.83E-07	3.33E-07	2.52E-07	2.65E-07	2.17E-07	2.03E-07	3.10E-07
2900	3.33E-07	3.20E-07	1.97E-07	2.54E-07	2.61E-07	2.70E-07	4.04E-07	3.30E-07	3.39E-07	3.81E-07	3.32E-07	2.53E-07	2.66E-07	2.19E-07	2.04E-07	3.13E-07
3000	3.38E-07	3.25E-07	2.01E-07	2.58E-07	2.63E-07	2.71E-07	4.03E-07	3.29E-07	3.37E-07	3.79E-07	3.31E-07	2.53E-07	2.66E-07	2.20E-07	2.05E-07	3.16E-07
3100	3.42E-07	3.31E-07	2.05E-07	2.61E-07	2.65E-07	2.72E-07	4.01E-07	3.28E-07	3.35E-07	3.77E-07	3.30E-07	2.54E-07	2.67E-07	2.22E-07	2.06E-07	3.19E-07
3200	3.46E-07	3.36E-07	2.08E-07	2.64E-07	2.67E-07	2.73E-07	3.98E-07	3.26E-07	3.33E-07	3.74E-07	3.29E-07	2.54E-07	2.67E-07	2.23E-07	2.07E-07	3.21E-07
3300	3.50E-07	3.42E-07	2.11E-07	2.66E-07	2.68E-07	2.74E-07	3.96E-07	3.25E-07	3.30E-07	3.72E-07	3.28E-07	2.54E-07	2.67E-07	2.25E-07	2.08E-07	3.24E-07
3400	3.54E-07	3.47E-07	2.14E-07	2.69E-07	2.69E-07	2.74E-07	3.93E-07	3.23E-07	3.28E-07	3.69E-07	3.27E-07	2.53E-07	2.68E-07	2.26E-07	2.09E-07	3.26E-07
3500	3.58E-07	3.51E-07	2.17E-07	2.71E-07	2.70E-07	2.74E-07	3.91E-07	3.21E-07	3.25E-07	3.66E-07	3.25E-07	2.53E-07	2.67E-07	2.27E-07	2.09E-07	3.28E-07
3600	3.62E-07	3.56E-07	2.20E-07	2.72E-07	2.70E-07	2.74E-07	3.88E-07	3.19E-07	3.23E-07	3.63E-07	3.23E-07	2.52E-07	2.67E-07	2.27E-07	2.10E-07	3.30E-07
3700	3.65E-07	3.60E-07	2.22E-07	2.73E-07	2.71E-07	2.73E-07	3.85E-07	3.17E-07	3.20E-07	3.60E-07	3.21E-07	2.52E-07	2.67E-07	2.28E-07	2.11E-07	3.31E-07

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
3800	3.68E-07	3.64E-07	2.25E-07	2.75E-07	2.71E-07	2.72E-07	3.82E-07	3.14E-07	3.17E-07	3.57E-07	3.20E-07	2.51E-07	2.66E-07	2.29E-07	2.11E-07	3.33E-07
3900	3.71E-07	3.68E-07	2.27E-07	2.75E-07	2.71E-07	2.72E-07	3.79E-07	3.12E-07	3.14E-07	3.54E-07	3.18E-07	2.50E-07	2.66E-07	2.29E-07	2.11E-07	3.34E-07
4000	3.73E-07	3.71E-07	2.29E-07	2.76E-07	2.70E-07	2.71E-07	3.76E-07	3.10E-07	3.12E-07	3.51E-07	3.16E-07	2.49E-07	2.65E-07	2.29E-07	2.11E-07	3.35E-07
4100	3.75E-07	3.74E-07	2.30E-07	2.76E-07	2.70E-07	2.69E-07	3.73E-07	3.07E-07	3.09E-07	3.47E-07	3.13E-07	2.48E-07	2.64E-07	2.30E-07	2.12E-07	3.36E-07
4200	3.77E-07	3.77E-07	2.32E-07	2.77E-07	2.69E-07	2.68E-07	3.70E-07	3.05E-07	3.06E-07	3.44E-07	3.11E-07	2.47E-07	2.63E-07	2.30E-07	2.12E-07	3.37E-07
4300	3.79E-07	3.79E-07	2.33E-07	2.77E-07	2.68E-07	2.67E-07	3.66E-07	3.02E-07	3.03E-07	3.41E-07	3.09E-07	2.46E-07	2.62E-07	2.30E-07	2.11E-07	3.37E-07
4400	3.81E-07	3.81E-07	2.34E-07	2.76E-07	2.67E-07	2.65E-07	3.63E-07	3.00E-07	3.00E-07	3.38E-07	3.07E-07	2.44E-07	2.61E-07	2.29E-07	2.11E-07	3.37E-07
4500	3.82E-07	3.83E-07	2.35E-07	2.76E-07	2.66E-07	2.64E-07	3.60E-07	2.97E-07	2.97E-07	3.34E-07	3.04E-07	2.43E-07	2.60E-07	2.29E-07	2.11E-07	3.37E-07
4600	3.83E-07	3.84E-07	2.36E-07	2.75E-07	2.65E-07	2.62E-07	3.56E-07	2.94E-07	2.94E-07	3.31E-07	3.02E-07	2.41E-07	2.59E-07	2.29E-07	2.11E-07	3.37E-07
4700	3.84E-07	3.86E-07	2.36E-07	2.75E-07	2.64E-07	2.60E-07	3.53E-07	2.92E-07	2.91E-07	3.28E-07	3.00E-07	2.40E-07	2.57E-07	2.28E-07	2.10E-07	3.37E-07
4800	3.84E-07	3.87E-07	2.37E-07	2.74E-07	2.62E-07	2.59E-07	3.50E-07	2.89E-07	2.88E-07	3.24E-07	2.97E-07	2.38E-07	2.56E-07	2.28E-07	2.10E-07	3.37E-07
4900	3.84E-07	3.87E-07	2.37E-07	2.73E-07	2.61E-07	2.57E-07	3.46E-07	2.86E-07	2.85E-07	3.21E-07	2.95E-07	2.37E-07	2.54E-07	2.27E-07	2.09E-07	3.36E-07
5000	3.84E-07	3.88E-07	2.37E-07	2.72E-07	2.59E-07	2.55E-07	3.43E-07	2.84E-07	2.82E-07	3.17E-07	2.92E-07	2.35E-07	2.53E-07	2.26E-07	2.08E-07	3.35E-07
5100	3.84E-07	3.88E-07	2.37E-07	2.71E-07	2.57E-07	2.53E-07	3.39E-07	2.81E-07	2.79E-07	3.14E-07	2.89E-07	2.33E-07	2.51E-07	2.25E-07	2.08E-07	3.34E-07
5200	3.84E-07	3.88E-07	2.37E-07	2.70E-07	2.56E-07	2.51E-07	3.36E-07	2.78E-07	2.76E-07	3.11E-07	2.87E-07	2.32E-07	2.50E-07	2.24E-07	2.07E-07	3.34E-07
5300	3.84E-07	3.88E-07	2.37E-07	2.68E-07	2.54E-07	2.49E-07	3.33E-07	2.75E-07	2.73E-07	3.08E-07	2.84E-07	2.30E-07	2.48E-07	2.23E-07	2.06E-07	3.32E-07
5400	3.83E-07	3.88E-07	2.36E-07	2.67E-07	2.52E-07	2.47E-07	3.29E-07	2.73E-07	2.71E-07	3.04E-07	2.82E-07	2.28E-07	2.46E-07	2.22E-07	2.05E-07	3.31E-07
5500	3.82E-07	3.88E-07	2.36E-07	2.66E-07	2.50E-07	2.45E-07	3.26E-07	2.70E-07	2.68E-07	3.01E-07	2.79E-07	2.26E-07	2.44E-07	2.21E-07	2.04E-07	3.30E-07
5600	3.81E-07	3.87E-07	2.35E-07	2.64E-07	2.48E-07	2.43E-07	3.23E-07	2.67E-07	2.65E-07	2.98E-07	2.77E-07	2.24E-07	2.43E-07	2.20E-07	2.03E-07	3.29E-07
5700	3.80E-07	3.86E-07	2.35E-07	2.63E-07	2.46E-07	2.40E-07	3.19E-07	2.65E-07	2.62E-07	2.94E-07	2.74E-07	2.23E-07	2.41E-07	2.19E-07	2.02E-07	3.27E-07
5800	3.79E-07	3.85E-07	2.34E-07	2.61E-07	2.45E-07	2.38E-07	3.16E-07	2.62E-07	2.59E-07	2.91E-07	2.71E-07	2.21E-07	2.39E-07	2.18E-07	2.01E-07	3.26E-07
5900	3.78E-07	3.84E-07	2.33E-07	2.59E-07	2.43E-07	2.36E-07	3.13E-07	2.59E-07	2.56E-07	2.88E-07	2.69E-07	2.19E-07	2.37E-07	2.16E-07	2.00E-07	3.24E-07
6000	3.76E-07	3.83E-07	2.32E-07	2.57E-07	2.41E-07	2.34E-07	3.09E-07	2.57E-07	2.54E-07	2.85E-07	2.66E-07	2.17E-07	2.35E-07	2.15E-07	1.99E-07	3.22E-07
6100	3.75E-07	3.82E-07	2.31E-07	2.56E-07	2.39E-07	2.32E-07	3.06E-07	2.54E-07	2.51E-07	2.82E-07	2.64E-07	2.15E-07	2.33E-07	2.14E-07	1.97E-07	3.20E-07
6200	3.73E-07	3.80E-07	2.30E-07	2.54E-07	2.37E-07	2.30E-07	3.03E-07	2.51E-07	2.48E-07	2.79E-07	2.61E-07	2.13E-07	2.31E-07	2.12E-07	1.96E-07	3.19E-07
6300	3.72E-07	3.79E-07	2.29E-07	2.52E-07	2.35E-07	2.27E-07	3.00E-07	2.49E-07	2.45E-07	2.76E-07	2.59E-07	2.11E-07	2.29E-07	2.11E-07	1.95E-07	3.17E-07
6400	3.70E-07	3.77E-07	2.28E-07	2.50E-07	2.33E-07	2.25E-07	2.97E-07	2.46E-07	2.43E-07	2.73E-07	2.56E-07	2.09E-07	2.27E-07	2.10E-07	1.94E-07	3.15E-07
6500	3.68E-07	3.75E-07	2.27E-07	2.48E-07	2.30E-07	2.23E-07	2.93E-07	2.44E-07	2.40E-07	2.70E-07	2.54E-07	2.07E-07	2.26E-07	2.08E-07	1.92E-07	3.13E-07
6600	3.66E-07	3.74E-07	2.26E-07	2.47E-07	2.28E-07	2.21E-07	2.90E-07	2.41E-07	2.38E-07	2.67E-07	2.51E-07	2.06E-07	2.24E-07	2.07E-07	1.91E-07	3.11E-07

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
6700	3.64E-07	3.72E-07	2.25E-07	2.45E-07	2.26E-07	2.19E-07	2.87E-07	2.39E-07	2.35E-07	2.64E-07	2.49E-07	2.04E-07	2.22E-07	2.05E-07	1.90E-07	3.09E-07
6800	3.62E-07	3.70E-07	2.23E-07	2.43E-07	2.24E-07	2.17E-07	2.84E-07	2.36E-07	2.32E-07	2.61E-07	2.46E-07	2.02E-07	2.20E-07	2.04E-07	1.88E-07	3.07E-07
6900	3.60E-07	3.68E-07	2.22E-07	2.41E-07	2.22E-07	2.15E-07	2.81E-07	2.34E-07	2.30E-07	2.58E-07	2.44E-07	2.00E-07	2.18E-07	2.02E-07	1.87E-07	3.05E-07
7000	3.58E-07	3.66E-07	2.21E-07	2.39E-07	2.20E-07	2.13E-07	2.78E-07	2.31E-07	2.27E-07	2.55E-07	2.41E-07	1.98E-07	2.16E-07	2.01E-07	1.86E-07	3.03E-07
7100	3.56E-07	3.64E-07	2.20E-07	2.37E-07	2.18E-07	2.11E-07	2.75E-07	2.29E-07	2.25E-07	2.53E-07	2.39E-07	1.96E-07	2.14E-07	1.99E-07	1.84E-07	3.01E-07
7200	3.54E-07	3.62E-07	2.18E-07	2.35E-07	2.16E-07	2.09E-07	2.73E-07	2.27E-07	2.23E-07	2.50E-07	2.37E-07	1.95E-07	2.12E-07	1.98E-07	1.83E-07	2.99E-07
7300	3.52E-07	3.60E-07	2.17E-07	2.33E-07	2.14E-07	2.06E-07	2.70E-07	2.24E-07	2.20E-07	2.47E-07	2.34E-07	1.93E-07	2.10E-07	1.96E-07	1.82E-07	2.97E-07
7400	3.49E-07	3.58E-07	2.15E-07	2.31E-07	2.12E-07	2.04E-07	2.67E-07	2.22E-07	2.18E-07	2.44E-07	2.32E-07	1.91E-07	2.09E-07	1.95E-07	1.80E-07	2.94E-07
7500	3.47E-07	3.56E-07	2.14E-07	2.29E-07	2.11E-07	2.02E-07	2.64E-07	2.20E-07	2.16E-07	2.42E-07	2.30E-07	1.89E-07	2.07E-07	1.93E-07	1.79E-07	2.92E-07
7600	3.45E-07	3.53E-07	2.13E-07	2.27E-07	2.09E-07	2.00E-07	2.61E-07	2.17E-07	2.13E-07	2.39E-07	2.27E-07	1.87E-07	2.05E-07	1.92E-07	1.78E-07	2.90E-07
7700	3.43E-07	3.51E-07	2.11E-07	2.26E-07	2.07E-07	1.99E-07	2.59E-07	2.15E-07	2.11E-07	2.37E-07	2.25E-07	1.86E-07	2.03E-07	1.90E-07	1.76E-07	2.88E-07
7800	3.40E-07	3.49E-07	2.10E-07	2.24E-07	2.05E-07	1.97E-07	2.56E-07	2.13E-07	2.09E-07	2.34E-07	2.23E-07	1.84E-07	2.01E-07	1.89E-07	1.75E-07	2.86E-07
7900	3.38E-07	3.47E-07	2.08E-07	2.22E-07	2.03E-07	1.95E-07	2.53E-07	2.11E-07	2.07E-07	2.32E-07	2.21E-07	1.82E-07	1.99E-07	1.87E-07	1.73E-07	2.84E-07
8000	3.36E-07	3.44E-07	2.07E-07	2.20E-07	2.01E-07	1.93E-07	2.51E-07	2.09E-07	2.04E-07	2.29E-07	2.19E-07	1.81E-07	1.98E-07	1.86E-07	1.72E-07	2.82E-07
8100	3.34E-07	3.42E-07	2.06E-07	2.18E-07	1.99E-07	1.91E-07	2.48E-07	2.07E-07	2.02E-07	2.27E-07	2.16E-07	1.79E-07	1.96E-07	1.84E-07	1.71E-07	2.79E-07
8200	3.31E-07	3.40E-07	2.04E-07	2.16E-07	1.97E-07	1.89E-07	2.46E-07	2.04E-07	2.00E-07	2.25E-07	2.14E-07	1.77E-07	1.94E-07	1.83E-07	1.69E-07	2.77E-07
8300	3.29E-07	3.38E-07	2.03E-07	2.14E-07	1.96E-07	1.87E-07	2.43E-07	2.02E-07	1.98E-07	2.22E-07	2.12E-07	1.76E-07	1.92E-07	1.81E-07	1.68E-07	2.75E-07
8400	3.27E-07	3.35E-07	2.01E-07	2.13E-07	1.94E-07	1.85E-07	2.41E-07	2.00E-07	1.96E-07	2.20E-07	2.10E-07	1.74E-07	1.91E-07	1.80E-07	1.67E-07	2.73E-07
8500	3.24E-07	3.33E-07	2.00E-07	2.11E-07	1.92E-07	1.84E-07	2.38E-07	1.98E-07	1.94E-07	2.18E-07	2.08E-07	1.72E-07	1.89E-07	1.78E-07	1.65E-07	2.71E-07
8600	3.22E-07	3.31E-07	1.98E-07	2.09E-07	1.90E-07	1.82E-07	2.36E-07	1.96E-07	1.92E-07	2.16E-07	2.06E-07	1.71E-07	1.87E-07	1.77E-07	1.64E-07	2.69E-07
8700	3.20E-07	3.28E-07	1.97E-07	2.07E-07	1.89E-07	1.80E-07	2.34E-07	1.95E-07	1.90E-07	2.13E-07	2.04E-07	1.69E-07	1.86E-07	1.75E-07	1.63E-07	2.67E-07
8800	3.18E-07	3.26E-07	1.95E-07	2.05E-07	1.87E-07	1.78E-07	2.31E-07	1.93E-07	1.88E-07	2.11E-07	2.02E-07	1.68E-07	1.84E-07	1.74E-07	1.62E-07	2.65E-07
8900	3.15E-07	3.24E-07	1.94E-07	2.04E-07	1.85E-07	1.77E-07	2.29E-07	1.91E-07	1.86E-07	2.09E-07	2.00E-07	1.66E-07	1.82E-07	1.73E-07	1.60E-07	2.63E-07
9000	3.13E-07	3.22E-07	1.93E-07	2.02E-07	1.83E-07	1.75E-07	2.27E-07	1.89E-07	1.85E-07	2.07E-07	1.98E-07	1.65E-07	1.81E-07	1.71E-07	1.59E-07	2.61E-07
9100	3.11E-07	3.19E-07	1.91E-07	2.00E-07	1.82E-07	1.73E-07	2.25E-07	1.87E-07	1.83E-07	2.05E-07	1.97E-07	1.63E-07	1.79E-07	1.70E-07	1.58E-07	2.59E-07
9200	3.09E-07	3.17E-07	1.90E-07	1.99E-07	1.80E-07	1.72E-07	2.22E-07	1.85E-07	1.81E-07	2.03E-07	1.95E-07	1.62E-07	1.78E-07	1.69E-07	1.57E-07	2.57E-07
9300	3.06E-07	3.15E-07	1.88E-07	1.97E-07	1.79E-07	1.70E-07	2.20E-07	1.83E-07	1.79E-07	2.01E-07	1.93E-07	1.60E-07	1.76E-07	1.67E-07	1.55E-07	2.55E-07
9400	3.04E-07	3.13E-07	1.87E-07	1.95E-07	1.77E-07	1.69E-07	2.18E-07	1.82E-07	1.78E-07	1.99E-07	1.91E-07	1.59E-07	1.75E-07	1.66E-07	1.54E-07	2.53E-07
9500	3.02E-07	3.11E-07	1.86E-07	1.94E-07	1.75E-07	1.67E-07	2.16E-07	1.80E-07	1.76E-07	1.97E-07	1.89E-07	1.58E-07	1.73E-07	1.64E-07	1.53E-07	2.51E-07

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
9600	3.00E-07	3.08E-07	1.84E-07	1.92E-07	1.74E-07	1.66E-07	2.14E-07	1.78E-07	1.74E-07	1.95E-07	1.88E-07	1.56E-07	1.72E-07	1.63E-07	1.52E-07	2.49E-07
9700	2.98E-07	3.06E-07	1.83E-07	1.90E-07	1.72E-07	1.64E-07	2.12E-07	1.77E-07	1.72E-07	1.93E-07	1.86E-07	1.55E-07	1.70E-07	1.62E-07	1.51E-07	2.47E-07
9800	2.95E-07	3.04E-07	1.82E-07	1.89E-07	1.71E-07	1.63E-07	2.10E-07	1.75E-07	1.71E-07	1.91E-07	1.84E-07	1.53E-07	1.69E-07	1.61E-07	1.49E-07	2.45E-07
9900	2.93E-07	3.02E-07	1.80E-07	1.87E-07	1.69E-07	1.61E-07	2.08E-07	1.73E-07	1.69E-07	1.90E-07	1.83E-07	1.52E-07	1.67E-07	1.59E-07	1.48E-07	2.43E-07
10000	2.91E-07	3.00E-07	1.79E-07	1.86E-07	1.68E-07	1.60E-07	2.06E-07	1.72E-07	1.68E-07	1.88E-07	1.81E-07	1.51E-07	1.66E-07	1.58E-07	1.47E-07	2.41E-07
10100	2.89E-07	2.98E-07	1.78E-07	1.84E-07	1.66E-07	1.58E-07	2.04E-07	1.70E-07	1.66E-07	1.86E-07	1.79E-07	1.49E-07	1.64E-07	1.57E-07	1.46E-07	2.40E-07
10200	2.87E-07	2.95E-07	1.76E-07	1.83E-07	1.65E-07	1.57E-07	2.02E-07	1.69E-07	1.64E-07	1.84E-07	1.78E-07	1.48E-07	1.63E-07	1.56E-07	1.45E-07	2.38E-07
10300	2.85E-07	2.93E-07	1.75E-07	1.81E-07	1.63E-07	1.55E-07	2.00E-07	1.67E-07	1.63E-07	1.82E-07	1.76E-07	1.47E-07	1.62E-07	1.54E-07	1.44E-07	2.36E-07
10400	2.83E-07	2.91E-07	1.74E-07	1.80E-07	1.62E-07	1.54E-07	1.99E-07	1.66E-07	1.61E-07	1.81E-07	1.74E-07	1.46E-07	1.60E-07	1.53E-07	1.43E-07	2.34E-07
10500	2.81E-07	2.89E-07	1.72E-07	1.78E-07	1.61E-07	1.53E-07	1.97E-07	1.64E-07	1.60E-07	1.79E-07	1.73E-07	1.44E-07	1.59E-07	1.52E-07	1.41E-07	2.32E-07
10600	2.79E-07	2.87E-07	1.71E-07	1.77E-07	1.59E-07	1.51E-07	1.95E-07	1.63E-07	1.59E-07	1.78E-07	1.71E-07	1.43E-07	1.58E-07	1.51E-07	1.40E-07	2.31E-07
10700	2.77E-07	2.85E-07	1.70E-07	1.75E-07	1.58E-07	1.50E-07	1.93E-07	1.61E-07	1.57E-07	1.76E-07	1.70E-07	1.42E-07	1.56E-07	1.50E-07	1.39E-07	2.29E-07
10800	2.75E-07	2.83E-07	1.69E-07	1.74E-07	1.57E-07	1.49E-07	1.91E-07	1.60E-07	1.56E-07	1.74E-07	1.68E-07	1.41E-07	1.55E-07	1.48E-07	1.38E-07	2.27E-07
10900	2.73E-07	2.81E-07	1.68E-07	1.73E-07	1.55E-07	1.47E-07	1.90E-07	1.58E-07	1.54E-07	1.73E-07	1.67E-07	1.40E-07	1.54E-07	1.47E-07	1.37E-07	2.26E-07
11000	2.71E-07	2.79E-07	1.66E-07	1.71E-07	1.54E-07	1.46E-07	1.88E-07	1.57E-07	1.53E-07	1.71E-07	1.66E-07	1.38E-07	1.53E-07	1.46E-07	1.36E-07	2.24E-07
11100	2.69E-07	2.77E-07	1.65E-07	1.70E-07	1.53E-07	1.45E-07	1.86E-07	1.55E-07	1.52E-07	1.70E-07	1.64E-07	1.37E-07	1.51E-07	1.45E-07	1.35E-07	2.22E-07
11200	2.67E-07	2.75E-07	1.64E-07	1.68E-07	1.51E-07	1.44E-07	1.85E-07	1.54E-07	1.50E-07	1.68E-07	1.63E-07	1.36E-07	1.50E-07	1.44E-07	1.34E-07	2.21E-07
11300	2.65E-07	2.73E-07	1.63E-07	1.67E-07	1.50E-07	1.42E-07	1.83E-07	1.53E-07	1.49E-07	1.67E-07	1.61E-07	1.35E-07	1.49E-07	1.43E-07	1.33E-07	2.19E-07
11400	2.63E-07	2.71E-07	1.62E-07	1.66E-07	1.49E-07	1.41E-07	1.82E-07	1.52E-07	1.48E-07	1.65E-07	1.60E-07	1.34E-07	1.48E-07	1.42E-07	1.32E-07	2.17E-07
11500	2.62E-07	2.70E-07	1.60E-07	1.65E-07	1.48E-07	1.40E-07	1.80E-07	1.50E-07	1.46E-07	1.64E-07	1.59E-07	1.33E-07	1.47E-07	1.41E-07	1.31E-07	2.16E-07
11600	2.60E-07	2.68E-07	1.59E-07	1.63E-07	1.47E-07	1.39E-07	1.79E-07	1.49E-07	1.45E-07	1.62E-07	1.57E-07	1.32E-07	1.45E-07	1.40E-07	1.30E-07	2.14E-07
11700	2.58E-07	2.66E-07	1.58E-07	1.62E-07	1.45E-07	1.38E-07	1.77E-07	1.48E-07	1.44E-07	1.61E-07	1.56E-07	1.31E-07	1.44E-07	1.39E-07	1.29E-07	2.13E-07
11800	2.56E-07	2.64E-07	1.57E-07	1.61E-07	1.44E-07	1.36E-07	1.76E-07	1.46E-07	1.43E-07	1.60E-07	1.55E-07	1.30E-07	1.43E-07	1.38E-07	1.28E-07	2.11E-07
11900	2.54E-07	2.62E-07	1.56E-07	1.59E-07	1.43E-07	1.35E-07	1.74E-07	1.45E-07	1.42E-07	1.58E-07	1.54E-07	1.29E-07	1.42E-07	1.37E-07	1.27E-07	2.10E-07
12000	2.53E-07	2.60E-07	1.55E-07	1.58E-07	1.42E-07	1.34E-07	1.73E-07	1.44E-07	1.40E-07	1.57E-07	1.52E-07	1.28E-07	1.41E-07	1.36E-07	1.26E-07	2.08E-07
13000	2.36E-07	2.44E-07	1.44E-07	1.47E-07	1.31E-07	1.24E-07	1.59E-07	1.33E-07	1.29E-07	1.45E-07	1.41E-07	1.18E-07	1.31E-07	1.26E-07	1.18E-07	1.94E-07
14000	2.21E-07	2.28E-07	1.35E-07	1.37E-07	1.22E-07	1.15E-07	1.47E-07	1.23E-07	1.20E-07	1.34E-07	1.31E-07	1.10E-07	1.22E-07	1.18E-07	1.10E-07	1.81E-07
15000	2.07E-07	2.14E-07	1.27E-07	1.28E-07	1.14E-07	1.07E-07	1.37E-07	1.14E-07	1.11E-07	1.24E-07	1.22E-07	1.03E-07	1.14E-07	1.10E-07	1.03E-07	1.70E-07
16000	1.95E-07	2.02E-07	1.19E-07	1.20E-07	1.06E-07	9.98E-08	1.28E-07	1.07E-07	1.04E-07	1.16E-07	1.14E-07	9.60E-08	1.06E-07	1.03E-07	9.68E-08	1.60E-07

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
17000	1.84E-07	1.91E-07	1.12E-07	1.12E-07	9.98E-08	9.35E-08	1.20E-07	1.00E-07	9.75E-08	1.09E-07	1.06E-07	9.01E-08	9.99E-08	9.74E-08	9.12E-08	1.50E-07
18000	1.74E-07	1.80E-07	1.06E-07	1.06E-07	9.39E-08	8.79E-08	1.13E-07	9.40E-08	9.16E-08	1.02E-07	1.00E-07	8.49E-08	9.42E-08	9.20E-08	8.62E-08	1.42E-07
19000	1.65E-07	1.71E-07	1.00E-07	9.99E-08	8.86E-08	8.28E-08	1.06E-07	8.85E-08	8.63E-08	9.62E-08	9.44E-08	8.02E-08	8.90E-08	8.70E-08	8.16E-08	1.35E-07
20000	1.57E-07	1.62E-07	9.53E-08	9.46E-08	8.38E-08	7.83E-08	1.00E-07	8.36E-08	8.16E-08	9.08E-08	8.93E-08	7.59E-08	8.43E-08	8.25E-08	7.74E-08	1.28E-07
21000	1.49E-07	1.55E-07	9.06E-08	8.98E-08	7.95E-08	7.41E-08	9.48E-08	7.92E-08	7.73E-08	8.60E-08	8.46E-08	7.20E-08	8.00E-08	7.84E-08	7.36E-08	1.21E-07
22000	1.42E-07	1.47E-07	8.63E-08	8.53E-08	7.55E-08	7.04E-08	9.00E-08	7.52E-08	7.34E-08	8.16E-08	8.04E-08	6.84E-08	7.61E-08	7.47E-08	7.01E-08	1.16E-07
23000	1.36E-07	1.41E-07	8.24E-08	8.13E-08	7.19E-08	6.69E-08	8.56E-08	7.15E-08	6.98E-08	7.76E-08	7.65E-08	6.52E-08	7.25E-08	7.12E-08	6.69E-08	1.10E-07
24000	1.30E-07	1.35E-07	7.87E-08	7.76E-08	6.86E-08	6.38E-08	8.16E-08	6.81E-08	6.66E-08	7.39E-08	7.29E-08	6.22E-08	6.92E-08	6.81E-08	6.40E-08	1.05E-07
25000	1.25E-07	1.29E-07	7.53E-08	7.41E-08	6.55E-08	6.09E-08	7.78E-08	6.50E-08	6.36E-08	7.06E-08	6.96E-08	5.95E-08	6.61E-08	6.51E-08	6.12E-08	1.01E-07
26000	1.19E-07	1.24E-07	7.22E-08	7.10E-08	6.27E-08	5.82E-08	7.44E-08	6.22E-08	6.08E-08	6.75E-08	6.66E-08	5.69E-08	6.33E-08	6.24E-08	5.87E-08	9.68E-08
27000	1.15E-07	1.19E-07	6.93E-08	6.80E-08	6.01E-08	5.57E-08	7.13E-08	5.95E-08	5.82E-08	6.46E-08	6.38E-08	5.46E-08	6.07E-08	5.99E-08	5.64E-08	9.29E-08
28000	1.10E-07	1.14E-07	6.66E-08	6.53E-08	5.76E-08	5.34E-08	6.83E-08	5.71E-08	5.59E-08	6.20E-08	6.12E-08	5.24E-08	5.83E-08	5.76E-08	5.42E-08	8.93E-08
29000	1.06E-07	1.10E-07	6.41E-08	6.27E-08	5.54E-08	5.13E-08	6.56E-08	5.48E-08	5.37E-08	5.95E-08	5.88E-08	5.04E-08	5.61E-08	5.54E-08	5.21E-08	8.60E-08
30000	1.02E-07	1.06E-07	6.17E-08	6.04E-08	5.33E-08	4.93E-08	6.31E-08	5.27E-08	5.16E-08	5.72E-08	5.66E-08	4.85E-08	5.40E-08	5.34E-08	5.02E-08	8.28E-08

TABLE 4.11-4: INDIVIDUAL EFFECTIVE DOSE FOR ADULTS BY ALL ROUTES OF EXPOSURE AND INTRODUCTION OF THE PROJECTED GASEOUS AND AEROSOL RELEASES OF AES BBEP-1000/B466, SV

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
600	4.81E-10	4.25E-10	2.04E-10	2.02E-10	2.44E-10	2.96E-10	5.19E-10	3.15E-10	5.06E-10	5.55E-10	5.28E-10	3.46E-10	4.42E-10	3.78E-10	3.48E-10	4.53E-10
700	5.96E-10	5.06E-10	2.46E-10	2.44E-10	2.96E-10	3.63E-10	7.00E-10	4.41E-10	6.58E-10	7.14E-10	6.60E-10	4.18E-10	5.38E-10	4.44E-10	4.32E-10	5.52E-10
800	7.16E-10	6.00E-10	2.94E-10	2.92E-10	3.52E-10	4.30E-10	8.89E-10	5.86E-10	8.15E-10	8.79E-10	7.95E-10	5.02E-10	6.39E-10	5.13E-10	5.17E-10	6.56E-10
900	8.38E-10	7.01E-10	3.46E-10	3.47E-10	4.12E-10	5.01E-10	1.08E-09	7.40E-10	9.69E-10	1.05E-09	9.29E-10	5.94E-10	7.38E-10	5.83E-10	6.01E-10	7.65E-10
1000	9.56E-10	8.04E-10	4.01E-10	4.08E-10	4.78E-10	5.76E-10	1.26E-09	8.95E-10	1.12E-09	1.21E-09	1.06E-09	6.87E-10	8.31E-10	6.51E-10	6.79E-10	8.74E-10
1100	1.07E-09	9.03E-10	4.57E-10	4.74E-10	5.49E-10	6.53E-10	1.43E-09	1.04E-09	1.25E-09	1.36E-09	1.18E-09	7.78E-10	9.17E-10	7.17E-10	7.51E-10	9.79E-10
1200	1.17E-09	9.96E-10	5.13E-10	5.45E-10	6.23E-10	7.32E-10	1.58E-09	1.18E-09	1.37E-09	1.50E-09	1.29E-09	8.65E-10	9.95E-10	7.78E-10	8.14E-10	1.08E-09
1300	1.26E-09	1.08E-09	5.67E-10	6.19E-10	7.01E-10	8.12E-10	1.71E-09	1.30E-09	1.48E-09	1.62E-09	1.39E-09	9.45E-10	1.07E-09	8.35E-10	8.68E-10	1.17E-09
1400	1.33E-09	1.16E-09	6.19E-10	6.95E-10	7.79E-10	8.91E-10	1.82E-09	1.40E-09	1.57E-09	1.73E-09	1.48E-09	1.02E-09	1.13E-09	8.87E-10	9.15E-10	1.25E-09

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
1500	1.40E-09	1.23E-09	6.69E-10	7.71E-10	8.56E-10	9.68E-10	1.92E-09	1.49E-09	1.65E-09	1.82E-09	1.56E-09	1.08E-09	1.19E-09	9.33E-10	9.54E-10	1.32E-09
1600	1.46E-09	1.29E-09	7.15E-10	8.44E-10	9.30E-10	1.04E-09	2.00E-09	1.57E-09	1.72E-09	1.90E-09	1.62E-09	1.14E-09	1.24E-09	9.74E-10	9.87E-10	1.38E-09
1700	1.51E-09	1.35E-09	7.57E-10	9.14E-10	9.99E-10	1.11E-09	2.07E-09	1.64E-09	1.77E-09	1.96E-09	1.67E-09	1.19E-09	1.28E-09	1.01E-09	1.01E-09	1.43E-09
1800	1.55E-09	1.40E-09	7.96E-10	9.79E-10	1.06E-09	1.17E-09	2.12E-09	1.69E-09	1.81E-09	2.01E-09	1.72E-09	1.23E-09	1.32E-09	1.04E-09	1.03E-09	1.48E-09
1900	1.59E-09	1.44E-09	8.31E-10	1.04E-09	1.12E-09	1.22E-09	2.16E-09	1.73E-09	1.84E-09	2.05E-09	1.75E-09	1.27E-09	1.35E-09	1.07E-09	1.05E-09	1.51E-09
2000	1.62E-09	1.48E-09	8.64E-10	1.09E-09	1.17E-09	1.27E-09	2.19E-09	1.76E-09	1.86E-09	2.08E-09	1.78E-09	1.30E-09	1.37E-09	1.09E-09	1.07E-09	1.55E-09
2100	1.65E-09	1.52E-09	8.94E-10	1.14E-09	1.22E-09	1.31E-09	2.22E-09	1.79E-09	1.88E-09	2.10E-09	1.80E-09	1.32E-09	1.39E-09	1.11E-09	1.08E-09	1.58E-09
2200	1.67E-09	1.55E-09	9.23E-10	1.19E-09	1.26E-09	1.35E-09	2.23E-09	1.80E-09	1.89E-09	2.12E-09	1.82E-09	1.34E-09	1.41E-09	1.13E-09	1.09E-09	1.60E-09
2300	1.70E-09	1.58E-09	9.50E-10	1.23E-09	1.30E-09	1.38E-09	2.24E-09	1.82E-09	1.90E-09	2.13E-09	1.83E-09	1.36E-09	1.43E-09	1.15E-09	1.10E-09	1.62E-09
2400	1.72E-09	1.62E-09	9.75E-10	1.27E-09	1.33E-09	1.41E-09	2.25E-09	1.82E-09	1.90E-09	2.13E-09	1.84E-09	1.37E-09	1.44E-09	1.16E-09	1.10E-09	1.65E-09
2500	1.75E-09	1.65E-09	1.00E-09	1.30E-09	1.36E-09	1.43E-09	2.25E-09	1.83E-09	1.90E-09	2.13E-09	1.84E-09	1.38E-09	1.45E-09	1.17E-09	1.11E-09	1.66E-09
2600	1.77E-09	1.68E-09	1.02E-09	1.33E-09	1.38E-09	1.45E-09	2.25E-09	1.83E-09	1.89E-09	2.13E-09	1.84E-09	1.39E-09	1.46E-09	1.18E-09	1.12E-09	1.68E-09
2700	1.80E-09	1.71E-09	1.05E-09	1.36E-09	1.40E-09	1.46E-09	2.24E-09	1.83E-09	1.89E-09	2.12E-09	1.84E-09	1.40E-09	1.47E-09	1.20E-09	1.12E-09	1.70E-09
2800	1.82E-09	1.74E-09	1.07E-09	1.38E-09	1.42E-09	1.48E-09	2.24E-09	1.82E-09	1.88E-09	2.11E-09	1.84E-09	1.40E-09	1.47E-09	1.21E-09	1.13E-09	1.72E-09
2900	1.84E-09	1.78E-09	1.09E-09	1.40E-09	1.44E-09	1.49E-09	2.23E-09	1.82E-09	1.87E-09	2.10E-09	1.84E-09	1.40E-09	1.48E-09	1.21E-09	1.13E-09	1.73E-09
3000	1.87E-09	1.81E-09	1.11E-09	1.42E-09	1.45E-09	1.49E-09	2.22E-09	1.81E-09	1.86E-09	2.09E-09	1.83E-09	1.41E-09	1.48E-09	1.22E-09	1.14E-09	1.75E-09
3100	1.89E-09	1.84E-09	1.13E-09	1.44E-09	1.46E-09	1.50E-09	2.21E-09	1.81E-09	1.85E-09	2.08E-09	1.83E-09	1.41E-09	1.48E-09	1.23E-09	1.14E-09	1.76E-09
3200	1.91E-09	1.87E-09	1.15E-09	1.46E-09	1.47E-09	1.51E-09	2.19E-09	1.80E-09	1.83E-09	2.06E-09	1.82E-09	1.41E-09	1.48E-09	1.24E-09	1.15E-09	1.78E-09
3300	1.94E-09	1.89E-09	1.17E-09	1.47E-09	1.48E-09	1.51E-09	2.18E-09	1.79E-09	1.82E-09	2.05E-09	1.81E-09	1.41E-09	1.48E-09	1.24E-09	1.15E-09	1.79E-09
3400	1.96E-09	1.92E-09	1.18E-09	1.48E-09	1.48E-09	1.51E-09	2.17E-09	1.78E-09	1.81E-09	2.03E-09	1.80E-09	1.40E-09	1.48E-09	1.25E-09	1.15E-09	1.80E-09
3500	1.98E-09	1.95E-09	1.20E-09	1.49E-09	1.49E-09	1.51E-09	2.15E-09	1.77E-09	1.79E-09	2.02E-09	1.79E-09	1.40E-09	1.48E-09	1.26E-09	1.16E-09	1.81E-09
3600	2.00E-09	1.97E-09	1.21E-09	1.50E-09	1.49E-09	1.51E-09	2.14E-09	1.75E-09	1.78E-09	2.00E-09	1.78E-09	1.40E-09	1.48E-09	1.26E-09	1.16E-09	1.82E-09
3700	2.01E-09	1.99E-09	1.23E-09	1.51E-09	1.49E-09	1.50E-09	2.12E-09	1.74E-09	1.76E-09	1.99E-09	1.77E-09	1.39E-09	1.48E-09	1.26E-09	1.16E-09	1.83E-09
3800	2.03E-09	2.01E-09	1.24E-09	1.51E-09	1.49E-09	1.50E-09	2.10E-09	1.73E-09	1.75E-09	1.97E-09	1.76E-09	1.39E-09	1.48E-09	1.27E-09	1.17E-09	1.84E-09
3900	2.05E-09	2.03E-09	1.25E-09	1.52E-09	1.49E-09	1.50E-09	2.09E-09	1.72E-09	1.73E-09	1.95E-09	1.75E-09	1.38E-09	1.47E-09	1.27E-09	1.17E-09	1.84E-09
4000	2.06E-09	2.05E-09	1.26E-09	1.52E-09	1.49E-09	1.49E-09	2.07E-09	1.70E-09	1.72E-09	1.93E-09	1.74E-09	1.38E-09	1.47E-09	1.27E-09	1.17E-09	1.85E-09
4100	2.07E-09	2.07E-09	1.27E-09	1.52E-09	1.49E-09	1.48E-09	2.05E-09	1.69E-09	1.70E-09	1.91E-09	1.73E-09	1.37E-09	1.46E-09	1.27E-09	1.17E-09	1.85E-09
4200	2.08E-09	2.08E-09	1.28E-09	1.52E-09	1.48E-09	1.48E-09	2.03E-09	1.68E-09	1.69E-09	1.90E-09	1.72E-09	1.37E-09	1.46E-09	1.27E-09	1.17E-09	1.86E-09
4300	2.09E-09	2.10E-09	1.28E-09	1.52E-09	1.48E-09	1.47E-09	2.02E-09	1.66E-09	1.67E-09	1.88E-09	1.70E-09	1.36E-09	1.45E-09	1.27E-09	1.17E-09	1.86E-09

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
4400	2.10E-09	2.11E-09	1.29E-09	1.52E-09	1.47E-09	1.46E-09	2.00E-09	1.65E-09	1.65E-09	1.86E-09	1.69E-09	1.35E-09	1.44E-09	1.27E-09	1.17E-09	1.86E-09
4500	2.11E-09	2.12E-09	1.29E-09	1.52E-09	1.47E-09	1.45E-09	1.98E-09	1.63E-09	1.64E-09	1.84E-09	1.68E-09	1.34E-09	1.44E-09	1.27E-09	1.17E-09	1.86E-09
4600	2.11E-09	2.12E-09	1.30E-09	1.52E-09	1.46E-09	1.44E-09	1.96E-09	1.62E-09	1.62E-09	1.82E-09	1.67E-09	1.33E-09	1.43E-09	1.26E-09	1.16E-09	1.86E-09
4700	2.11E-09	2.13E-09	1.30E-09	1.51E-09	1.45E-09	1.43E-09	1.94E-09	1.61E-09	1.60E-09	1.80E-09	1.65E-09	1.33E-09	1.42E-09	1.26E-09	1.16E-09	1.86E-09
4800	2.12E-09	2.14E-09	1.30E-09	1.51E-09	1.44E-09	1.42E-09	1.92E-09	1.59E-09	1.59E-09	1.79E-09	1.64E-09	1.32E-09	1.41E-09	1.26E-09	1.16E-09	1.86E-09
4900	2.12E-09	2.14E-09	1.31E-09	1.50E-09	1.44E-09	1.41E-09	1.91E-09	1.58E-09	1.57E-09	1.77E-09	1.62E-09	1.31E-09	1.41E-09	1.25E-09	1.15E-09	1.85E-09
5000	2.12E-09	2.14E-09	1.31E-09	1.50E-09	1.43E-09	1.40E-09	1.89E-09	1.56E-09	1.55E-09	1.75E-09	1.61E-09	1.30E-09	1.40E-09	1.25E-09	1.15E-09	1.85E-09
5100	2.12E-09	2.14E-09	1.31E-09	1.49E-09	1.42E-09	1.39E-09	1.87E-09	1.55E-09	1.54E-09	1.73E-09	1.60E-09	1.29E-09	1.39E-09	1.25E-09	1.15E-09	1.84E-09
5200	2.12E-09	2.14E-09	1.31E-09	1.49E-09	1.41E-09	1.38E-09	1.85E-09	1.53E-09	1.52E-09	1.71E-09	1.58E-09	1.28E-09	1.38E-09	1.24E-09	1.14E-09	1.84E-09
5300	2.11E-09	2.14E-09	1.30E-09	1.48E-09	1.40E-09	1.37E-09	1.83E-09	1.52E-09	1.51E-09	1.69E-09	1.57E-09	1.27E-09	1.37E-09	1.23E-09	1.14E-09	1.83E-09
5400	2.11E-09	2.14E-09	1.30E-09	1.47E-09	1.39E-09	1.36E-09	1.81E-09	1.50E-09	1.49E-09	1.68E-09	1.55E-09	1.26E-09	1.36E-09	1.23E-09	1.13E-09	1.83E-09
5500	2.11E-09	2.14E-09	1.30E-09	1.46E-09	1.38E-09	1.35E-09	1.79E-09	1.49E-09	1.47E-09	1.66E-09	1.54E-09	1.25E-09	1.35E-09	1.22E-09	1.13E-09	1.82E-09
5600	2.10E-09	2.14E-09	1.30E-09	1.45E-09	1.37E-09	1.34E-09	1.78E-09	1.47E-09	1.46E-09	1.64E-09	1.53E-09	1.24E-09	1.34E-09	1.22E-09	1.12E-09	1.81E-09
5700	2.10E-09	2.13E-09	1.29E-09	1.45E-09	1.36E-09	1.32E-09	1.76E-09	1.46E-09	1.44E-09	1.62E-09	1.51E-09	1.23E-09	1.33E-09	1.21E-09	1.11E-09	1.80E-09
5800	2.09E-09	2.13E-09	1.29E-09	1.44E-09	1.35E-09	1.31E-09	1.74E-09	1.44E-09	1.43E-09	1.60E-09	1.50E-09	1.22E-09	1.32E-09	1.20E-09	1.11E-09	1.79E-09
5900	2.08E-09	2.12E-09	1.28E-09	1.43E-09	1.34E-09	1.30E-09	1.72E-09	1.43E-09	1.41E-09	1.59E-09	1.48E-09	1.21E-09	1.31E-09	1.20E-09	1.10E-09	1.79E-09
6000	2.07E-09	2.11E-09	1.28E-09	1.42E-09	1.32E-09	1.29E-09	1.70E-09	1.41E-09	1.40E-09	1.57E-09	1.47E-09	1.20E-09	1.30E-09	1.19E-09	1.10E-09	1.78E-09
6100	2.07E-09	2.11E-09	1.27E-09	1.41E-09	1.31E-09	1.28E-09	1.68E-09	1.40E-09	1.38E-09	1.55E-09	1.45E-09	1.19E-09	1.29E-09	1.18E-09	1.09E-09	1.77E-09
6200	2.06E-09	2.10E-09	1.27E-09	1.40E-09	1.30E-09	1.26E-09	1.67E-09	1.38E-09	1.37E-09	1.54E-09	1.44E-09	1.18E-09	1.28E-09	1.17E-09	1.08E-09	1.76E-09
6300	2.05E-09	2.09E-09	1.26E-09	1.39E-09	1.29E-09	1.25E-09	1.65E-09	1.37E-09	1.35E-09	1.52E-09	1.43E-09	1.17E-09	1.27E-09	1.16E-09	1.08E-09	1.75E-09
6400	2.04E-09	2.08E-09	1.26E-09	1.38E-09	1.28E-09	1.24E-09	1.63E-09	1.35E-09	1.34E-09	1.50E-09	1.41E-09	1.16E-09	1.26E-09	1.16E-09	1.07E-09	1.74E-09
6500	2.03E-09	2.07E-09	1.25E-09	1.37E-09	1.27E-09	1.23E-09	1.62E-09	1.34E-09	1.32E-09	1.49E-09	1.40E-09	1.15E-09	1.25E-09	1.15E-09	1.06E-09	1.72E-09
6600	2.02E-09	2.06E-09	1.24E-09	1.36E-09	1.26E-09	1.22E-09	1.60E-09	1.33E-09	1.31E-09	1.47E-09	1.38E-09	1.14E-09	1.24E-09	1.14E-09	1.05E-09	1.71E-09
6700	2.01E-09	2.05E-09	1.24E-09	1.35E-09	1.25E-09	1.20E-09	1.58E-09	1.31E-09	1.29E-09	1.45E-09	1.37E-09	1.13E-09	1.22E-09	1.13E-09	1.05E-09	1.70E-09
6800	2.00E-09	2.04E-09	1.23E-09	1.34E-09	1.24E-09	1.19E-09	1.56E-09	1.30E-09	1.28E-09	1.44E-09	1.36E-09	1.12E-09	1.21E-09	1.12E-09	1.04E-09	1.69E-09
6900	1.98E-09	2.03E-09	1.22E-09	1.33E-09	1.22E-09	1.18E-09	1.55E-09	1.29E-09	1.27E-09	1.42E-09	1.34E-09	1.10E-09	1.20E-09	1.12E-09	1.03E-09	1.68E-09
7000	1.97E-09	2.02E-09	1.22E-09	1.32E-09	1.21E-09	1.17E-09	1.53E-09	1.27E-09	1.25E-09	1.41E-09	1.33E-09	1.09E-09	1.19E-09	1.11E-09	1.02E-09	1.67E-09
7100	1.96E-09	2.01E-09	1.21E-09	1.31E-09	1.20E-09	1.16E-09	1.52E-09	1.26E-09	1.24E-09	1.39E-09	1.32E-09	1.08E-09	1.18E-09	1.10E-09	1.02E-09	1.66E-09
7200	1.95E-09	2.00E-09	1.20E-09	1.29E-09	1.19E-09	1.15E-09	1.50E-09	1.25E-09	1.23E-09	1.38E-09	1.30E-09	1.07E-09	1.17E-09	1.09E-09	1.01E-09	1.65E-09

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
7300	1.94E-09	1.98E-09	1.19E-09	1.28E-09	1.18E-09	1.14E-09	1.48E-09	1.23E-09	1.21E-09	1.36E-09	1.29E-09	1.06E-09	1.16E-09	1.08E-09	1.00E-09	1.63E-09
7400	1.92E-09	1.97E-09	1.19E-09	1.27E-09	1.17E-09	1.13E-09	1.47E-09	1.22E-09	1.20E-09	1.35E-09	1.28E-09	1.05E-09	1.15E-09	1.07E-09	9.94E-10	1.62E-09
7500	1.91E-09	1.96E-09	1.18E-09	1.26E-09	1.16E-09	1.11E-09	1.45E-09	1.21E-09	1.19E-09	1.33E-09	1.27E-09	1.04E-09	1.14E-09	1.07E-09	9.86E-10	1.61E-09
7600	1.90E-09	1.95E-09	1.17E-09	1.25E-09	1.15E-09	1.10E-09	1.44E-09	1.20E-09	1.17E-09	1.32E-09	1.25E-09	1.04E-09	1.13E-09	1.06E-09	9.79E-10	1.60E-09
7700	1.89E-09	1.94E-09	1.16E-09	1.24E-09	1.14E-09	1.09E-09	1.42E-09	1.18E-09	1.16E-09	1.30E-09	1.24E-09	1.03E-09	1.12E-09	1.05E-09	9.71E-10	1.59E-09
7800	1.87E-09	1.92E-09	1.16E-09	1.23E-09	1.13E-09	1.08E-09	1.41E-09	1.17E-09	1.15E-09	1.29E-09	1.23E-09	1.02E-09	1.11E-09	1.04E-09	9.64E-10	1.57E-09
7900	1.86E-09	1.91E-09	1.15E-09	1.22E-09	1.12E-09	1.07E-09	1.39E-09	1.16E-09	1.14E-09	1.28E-09	1.22E-09	1.01E-09	1.10E-09	1.03E-09	9.56E-10	1.56E-09
8000	1.85E-09	1.90E-09	1.14E-09	1.21E-09	1.11E-09	1.06E-09	1.38E-09	1.15E-09	1.13E-09	1.26E-09	1.20E-09	9.97E-10	1.09E-09	1.02E-09	9.49E-10	1.55E-09
8100	1.84E-09	1.89E-09	1.13E-09	1.20E-09	1.10E-09	1.05E-09	1.37E-09	1.14E-09	1.11E-09	1.25E-09	1.19E-09	9.88E-10	1.08E-09	1.02E-09	9.42E-10	1.54E-09
8200	1.82E-09	1.87E-09	1.12E-09	1.19E-09	1.09E-09	1.04E-09	1.35E-09	1.13E-09	1.10E-09	1.24E-09	1.18E-09	9.79E-10	1.07E-09	1.01E-09	9.34E-10	1.53E-09
8300	1.81E-09	1.86E-09	1.12E-09	1.18E-09	1.08E-09	1.03E-09	1.34E-09	1.11E-09	1.09E-09	1.22E-09	1.17E-09	9.70E-10	1.06E-09	1.00E-09	9.27E-10	1.52E-09
8400	1.80E-09	1.85E-09	1.11E-09	1.17E-09	1.07E-09	1.02E-09	1.32E-09	1.10E-09	1.08E-09	1.21E-09	1.16E-09	9.61E-10	1.05E-09	9.92E-10	9.20E-10	1.50E-09
8500	1.79E-09	1.84E-09	1.10E-09	1.16E-09	1.06E-09	1.01E-09	1.31E-09	1.09E-09	1.07E-09	1.20E-09	1.15E-09	9.52E-10	1.04E-09	9.84E-10	9.12E-10	1.49E-09
8600	1.77E-09	1.82E-09	1.09E-09	1.15E-09	1.05E-09	1.00E-09	1.30E-09	1.08E-09	1.06E-09	1.19E-09	1.14E-09	9.43E-10	1.03E-09	9.76E-10	9.05E-10	1.48E-09
8700	1.76E-09	1.81E-09	1.08E-09	1.14E-09	1.04E-09	9.92E-10	1.29E-09	1.07E-09	1.05E-09	1.17E-09	1.13E-09	9.35E-10	1.03E-09	9.68E-10	8.98E-10	1.47E-09
8800	1.75E-09	1.80E-09	1.08E-09	1.13E-09	1.03E-09	9.82E-10	1.27E-09	1.06E-09	1.04E-09	1.16E-09	1.11E-09	9.26E-10	1.02E-09	9.60E-10	8.91E-10	1.46E-09
8900	1.74E-09	1.79E-09	1.07E-09	1.12E-09	1.02E-09	9.73E-10	1.26E-09	1.05E-09	1.03E-09	1.15E-09	1.10E-09	9.18E-10	1.01E-09	9.53E-10	8.84E-10	1.45E-09
9000	1.72E-09	1.77E-09	1.06E-09	1.11E-09	1.01E-09	9.64E-10	1.25E-09	1.04E-09	1.02E-09	1.14E-09	1.09E-09	9.10E-10	9.98E-10	9.45E-10	8.77E-10	1.44E-09
9100	1.71E-09	1.76E-09	1.05E-09	1.10E-09	1.00E-09	9.55E-10	1.24E-09	1.03E-09	1.01E-09	1.13E-09	1.08E-09	9.01E-10	9.90E-10	9.37E-10	8.70E-10	1.43E-09
9200	1.70E-09	1.75E-09	1.04E-09	1.09E-09	9.91E-10	9.46E-10	1.22E-09	1.02E-09	9.97E-10	1.12E-09	1.07E-09	8.93E-10	9.81E-10	9.30E-10	8.63E-10	1.41E-09
9300	1.69E-09	1.74E-09	1.04E-09	1.08E-09	9.83E-10	9.37E-10	1.21E-09	1.01E-09	9.87E-10	1.11E-09	1.06E-09	8.85E-10	9.72E-10	9.22E-10	8.56E-10	1.40E-09
9400	1.67E-09	1.72E-09	1.03E-09	1.08E-09	9.74E-10	9.28E-10	1.20E-09	1.00E-09	9.77E-10	1.10E-09	1.05E-09	8.77E-10	9.64E-10	9.15E-10	8.50E-10	1.39E-09
9500	1.66E-09	1.71E-09	1.02E-09	1.07E-09	9.65E-10	9.20E-10	1.19E-09	9.90E-10	9.68E-10	1.08E-09	1.04E-09	8.70E-10	9.56E-10	9.08E-10	8.43E-10	1.38E-09
9600	1.65E-09	1.70E-09	1.01E-09	1.06E-09	9.57E-10	9.11E-10	1.18E-09	9.81E-10	9.59E-10	1.07E-09	1.03E-09	8.62E-10	9.47E-10	9.00E-10	8.36E-10	1.37E-09
9700	1.64E-09	1.69E-09	1.01E-09	1.05E-09	9.48E-10	9.03E-10	1.17E-09	9.72E-10	9.49E-10	1.06E-09	1.02E-09	8.54E-10	9.39E-10	8.93E-10	8.30E-10	1.36E-09
9800	1.63E-09	1.68E-09	1.00E-09	1.04E-09	9.40E-10	8.94E-10	1.15E-09	9.62E-10	9.40E-10	1.05E-09	1.02E-09	8.47E-10	9.31E-10	8.86E-10	8.23E-10	1.35E-09
9900	1.61E-09	1.66E-09	9.92E-10	1.03E-09	9.32E-10	8.86E-10	1.14E-09	9.54E-10	9.32E-10	1.04E-09	1.01E-09	8.40E-10	9.23E-10	8.79E-10	8.17E-10	1.34E-09
10000	1.60E-09	1.65E-09	9.85E-10	1.02E-09	9.23E-10	8.78E-10	1.13E-09	9.45E-10	9.23E-10	1.03E-09	9.97E-10	8.32E-10	9.16E-10	8.72E-10	8.10E-10	1.33E-09
10100	1.59E-09	1.64E-09	9.78E-10	1.01E-09	9.15E-10	8.70E-10	1.12E-09	9.36E-10	9.14E-10	1.02E-09	9.88E-10	8.25E-10	9.08E-10	8.65E-10	8.04E-10	1.32E-09

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
10200	1.58E-09	1.63E-09	9.71E-10	1.01E-09	9.07E-10	8.63E-10	1.11E-09	9.27E-10	9.06E-10	1.01E-09	9.79E-10	8.18E-10	9.00E-10	8.58E-10	7.98E-10	1.31E-09
10300	1.57E-09	1.62E-09	9.64E-10	9.98E-10	9.00E-10	8.55E-10	1.10E-09	9.19E-10	8.97E-10	1.00E-09	9.70E-10	8.11E-10	8.93E-10	8.52E-10	7.92E-10	1.30E-09
10400	1.56E-09	1.61E-09	9.56E-10	9.89E-10	8.92E-10	8.47E-10	1.09E-09	9.11E-10	8.89E-10	9.96E-10	9.62E-10	8.04E-10	8.85E-10	8.45E-10	7.86E-10	1.29E-09
10500	1.55E-09	1.59E-09	9.49E-10	9.81E-10	8.84E-10	8.40E-10	1.08E-09	9.02E-10	8.81E-10	9.86E-10	9.53E-10	7.97E-10	8.78E-10	8.38E-10	7.80E-10	1.28E-09
10600	1.54E-09	1.58E-09	9.43E-10	9.73E-10	8.77E-10	8.32E-10	1.07E-09	8.94E-10	8.73E-10	9.77E-10	9.45E-10	7.90E-10	8.71E-10	8.32E-10	7.74E-10	1.27E-09
10700	1.52E-09	1.57E-09	9.36E-10	9.66E-10	8.69E-10	8.25E-10	1.06E-09	8.86E-10	8.65E-10	9.69E-10	9.37E-10	7.84E-10	8.63E-10	8.25E-10	7.68E-10	1.26E-09
10800	1.51E-09	1.56E-09	9.29E-10	9.58E-10	8.62E-10	8.18E-10	1.05E-09	8.78E-10	8.57E-10	9.60E-10	9.28E-10	7.77E-10	8.56E-10	8.19E-10	7.62E-10	1.25E-09
10900	1.50E-09	1.55E-09	9.22E-10	9.50E-10	8.55E-10	8.11E-10	1.04E-09	8.71E-10	8.50E-10	9.51E-10	9.20E-10	7.71E-10	8.49E-10	8.13E-10	7.56E-10	1.24E-09
11000	1.49E-09	1.54E-09	9.15E-10	9.42E-10	8.48E-10	8.04E-10	1.03E-09	8.63E-10	8.42E-10	9.43E-10	9.13E-10	7.64E-10	8.42E-10	8.07E-10	7.50E-10	1.23E-09
11100	1.48E-09	1.53E-09	9.09E-10	9.35E-10	8.41E-10	7.97E-10	1.03E-09	8.56E-10	8.35E-10	9.34E-10	9.05E-10	7.58E-10	8.36E-10	8.00E-10	7.45E-10	1.22E-09
11200	1.47E-09	1.52E-09	9.02E-10	9.28E-10	8.34E-10	7.90E-10	1.02E-09	8.48E-10	8.27E-10	9.26E-10	8.97E-10	7.52E-10	8.29E-10	7.94E-10	7.39E-10	1.21E-09
11300	1.46E-09	1.51E-09	8.96E-10	9.20E-10	8.27E-10	7.83E-10	1.01E-09	8.41E-10	8.20E-10	9.18E-10	8.90E-10	7.46E-10	8.22E-10	7.88E-10	7.34E-10	1.21E-09
11400	1.45E-09	1.50E-09	8.89E-10	9.13E-10	8.20E-10	7.77E-10	9.99E-10	8.34E-10	8.13E-10	9.10E-10	8.82E-10	7.40E-10	8.16E-10	7.82E-10	7.28E-10	1.20E-09
11500	1.44E-09	1.49E-09	8.83E-10	9.06E-10	8.13E-10	7.70E-10	9.91E-10	8.26E-10	8.06E-10	9.02E-10	8.75E-10	7.34E-10	8.09E-10	7.76E-10	7.23E-10	1.19E-09
11600	1.43E-09	1.48E-09	8.77E-10	8.99E-10	8.07E-10	7.64E-10	9.82E-10	8.19E-10	7.99E-10	8.94E-10	8.67E-10	7.28E-10	8.03E-10	7.71E-10	7.18E-10	1.18E-09
11700	1.42E-09	1.47E-09	8.71E-10	8.92E-10	8.00E-10	7.57E-10	9.74E-10	8.13E-10	7.93E-10	8.87E-10	8.60E-10	7.22E-10	7.96E-10	7.65E-10	7.12E-10	1.17E-09
11800	1.41E-09	1.46E-09	8.64E-10	8.85E-10	7.94E-10	7.51E-10	9.66E-10	8.06E-10	7.86E-10	8.79E-10	8.53E-10	7.16E-10	7.90E-10	7.59E-10	7.07E-10	1.16E-09
11900	1.40E-09	1.45E-09	8.58E-10	8.78E-10	7.87E-10	7.45E-10	9.58E-10	7.99E-10	7.79E-10	8.72E-10	8.46E-10	7.10E-10	7.84E-10	7.54E-10	7.02E-10	1.15E-09
12000	1.39E-09	1.44E-09	8.52E-10	8.71E-10	7.81E-10	7.39E-10	9.50E-10	7.92E-10	7.73E-10	8.64E-10	8.39E-10	7.05E-10	7.78E-10	7.48E-10	6.97E-10	1.15E-09
13000	1.30E-09	1.34E-09	7.95E-10	8.08E-10	7.23E-10	6.82E-10	8.76E-10	7.31E-10	7.12E-10	7.96E-10	7.75E-10	6.53E-10	7.21E-10	6.96E-10	6.49E-10	1.07E-09
14000	1.22E-09	1.26E-09	7.44E-10	7.52E-10	6.71E-10	6.32E-10	8.11E-10	6.77E-10	6.60E-10	7.37E-10	7.19E-10	6.07E-10	6.71E-10	6.50E-10	6.06E-10	9.98E-10
15000	1.14E-09	1.18E-09	6.97E-10	7.03E-10	6.26E-10	5.88E-10	7.54E-10	6.30E-10	6.14E-10	6.85E-10	6.70E-10	5.66E-10	6.27E-10	6.08E-10	5.68E-10	9.35E-10
16000	1.08E-09	1.11E-09	6.56E-10	6.58E-10	5.85E-10	5.49E-10	7.04E-10	5.88E-10	5.73E-10	6.39E-10	6.26E-10	5.30E-10	5.87E-10	5.71E-10	5.34E-10	8.79E-10
17000	1.01E-09	1.05E-09	6.18E-10	6.18E-10	5.49E-10	5.15E-10	6.59E-10	5.50E-10	5.37E-10	5.98E-10	5.87E-10	4.98E-10	5.52E-10	5.38E-10	5.03E-10	8.28E-10
18000	9.59E-10	9.94E-10	5.84E-10	5.83E-10	5.17E-10	4.84E-10	6.19E-10	5.17E-10	5.04E-10	5.62E-10	5.52E-10	4.69E-10	5.20E-10	5.07E-10	4.75E-10	7.82E-10
19000	9.09E-10	9.42E-10	5.53E-10	5.50E-10	4.88E-10	4.56E-10	5.83E-10	4.87E-10	4.75E-10	5.29E-10	5.21E-10	4.42E-10	4.91E-10	4.80E-10	4.50E-10	7.41E-10
20000	8.64E-10	8.95E-10	5.25E-10	5.21E-10	4.61E-10	4.31E-10	5.51E-10	4.60E-10	4.49E-10	5.00E-10	4.92E-10	4.19E-10	4.65E-10	4.55E-10	4.27E-10	7.03E-10
21000	8.22E-10	8.52E-10	4.99E-10	4.94E-10	4.37E-10	4.08E-10	5.22E-10	4.36E-10	4.26E-10	4.74E-10	4.66E-10	3.97E-10	4.41E-10	4.33E-10	4.06E-10	6.68E-10
22000	7.84E-10	8.12E-10	4.75E-10	4.70E-10	4.16E-10	3.87E-10	4.95E-10	4.14E-10	4.04E-10	4.49E-10	4.43E-10	3.78E-10	4.20E-10	4.12E-10	3.86E-10	6.37E-10

Distance, m	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
23000	7.48E-10	7.76E-10	4.53E-10	4.48E-10	3.96E-10	3.68E-10	4.71E-10	3.93E-10	3.84E-10	4.27E-10	4.21E-10	3.60E-10	4.00E-10	3.93E-10	3.69E-10	6.08E-10
24000	7.16E-10	7.42E-10	4.33E-10	4.27E-10	3.77E-10	3.51E-10	4.49E-10	3.75E-10	3.66E-10	4.07E-10	4.02E-10	3.43E-10	3.82E-10	3.75E-10	3.52E-10	5.81E-10
25000	6.86E-10	7.11E-10	4.15E-10	4.08E-10	3.61E-10	3.35E-10	4.28E-10	3.58E-10	3.50E-10	3.89E-10	3.84E-10	3.28E-10	3.65E-10	3.59E-10	3.37E-10	5.56E-10
26000	6.58E-10	6.82E-10	3.97E-10	3.91E-10	3.45E-10	3.20E-10	4.10E-10	3.42E-10	3.35E-10	3.72E-10	3.67E-10	3.14E-10	3.50E-10	3.44E-10	3.24E-10	5.33E-10
27000	6.32E-10	6.55E-10	3.81E-10	3.74E-10	3.31E-10	3.07E-10	3.92E-10	3.28E-10	3.21E-10	3.56E-10	3.52E-10	3.01E-10	3.35E-10	3.31E-10	3.11E-10	5.12E-10
28000	6.07E-10	6.30E-10	3.67E-10	3.59E-10	3.17E-10	2.94E-10	3.76E-10	3.14E-10	3.08E-10	3.41E-10	3.37E-10	2.89E-10	3.22E-10	3.18E-10	2.99E-10	4.92E-10
29000	5.85E-10	6.07E-10	3.53E-10	3.45E-10	3.05E-10	2.82E-10	3.61E-10	3.02E-10	2.95E-10	3.28E-10	3.24E-10	2.78E-10	3.10E-10	3.06E-10	2.87E-10	4.73E-10
30000	5.64E-10	5.85E-10	3.40E-10	3.32E-10	2.93E-10	2.72E-10	3.47E-10	2.90E-10	2.84E-10	3.15E-10	3.12E-10	2.68E-10	2.98E-10	2.94E-10	2.77E-10	4.56E-10

Figure 4.11-3 presents the distribution of individual effective doses in the 30 km zone around Kozloduy NPP.

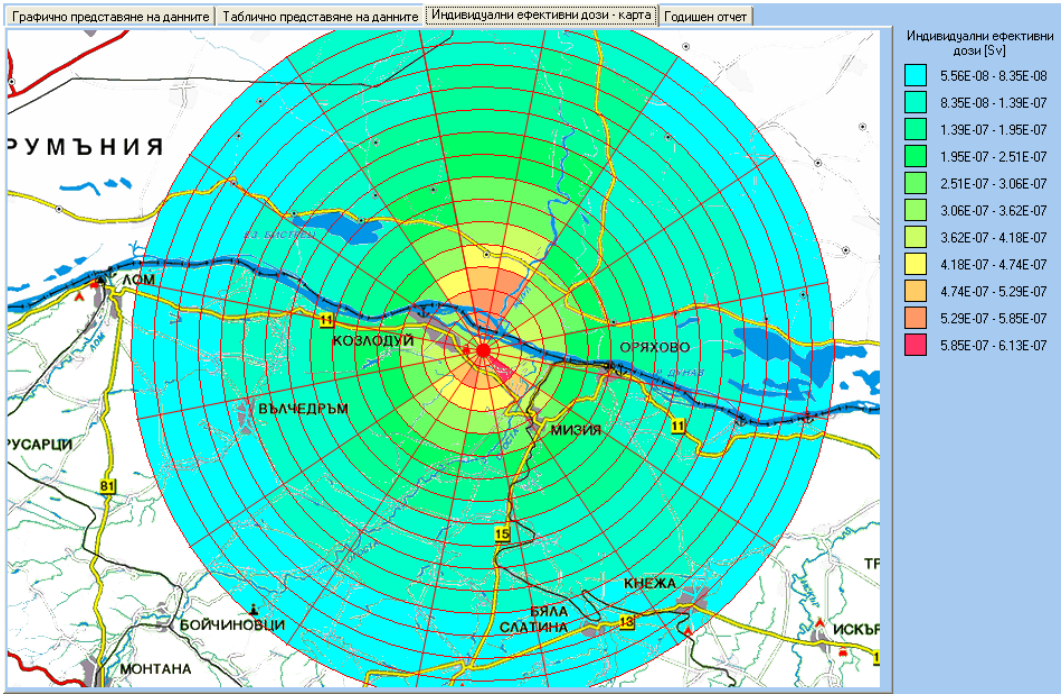


FIGURE 4.11-3: DISTRIBUTION OF THE INDIVIDUAL EFFECTIVE DOSE FOR ADULTS FOR ALL ROUTES OF EXPOSURE AND INTRODUCTION OF RADIOACTIVE EMISSIONS IN THE ATMOSPHERE IN ACCORDANCE WITH EUR, SV

TABLE 4.11-5: INDIVIDUAL EFFECTIVE DOSE OF THE GASEOUS AND AEROSOL RELEASES IN THE ENVIRONMENT BY NNU

NNU	Individual effective dose [Sv]	Comparison of the maximum individual does in accordance with		
		BNRP-2012 1 mSv	NRA instructions 0.05 mSv	Background radiation 2.4 mSv
EUR limits of releases	$2.46.10^{-8}$ - $6.13.10^{-7}$	0.061%	1.226%	0.026%
AP-1000	$3.10.10^{-8}$ – $5.99.10^{-7}$	0.0599%	1.198%	0.025%
AES BBEP-1000/B466	$1.93.10^{-10}$ – $1.79.10^{-8}$	0.0018%	0.0358%	0.0007%

TABLE 4.11-6: COLLECTIVE DOSE OF THE GASEOUS AND AEROSOL RELEASES IN THE ENVIRONMENT BY NNU

NNU	Collective dose [manSv]	Normalized collective dose [manSv/GW.a]	Comparison with the normalized dose UNSCEAR-2008 $2.2.10^{-1}$ [manSv/GW.a]
EUR limits of releases	$2.49.10^{-2}$	**$1.84.10^{-2}$**	11.3%
AP 1000	**$1.93.10^{-2}$**	**$1.79.10^{-2}$**	8.14%
AES BBEP-1000/B466	$1.59.10^{-4}$	$1.77.10^{-4}$	0.07%

The collective annual dose from radioactive emissions in the atmosphere is estimated, in accordance with EUR, at $2.49x10^{-2}$ manSv/a. The normalized collective annual dose to the population in the 30 km zone from gaseous and aerosol emissions amounts to $1.84x10^{-2}$ manSv/GW.a.

In respect to gaseous and aerosol emissions from AP 1000 in the atmosphere, the collective annual dose is estimated at $1.93x10^{-2}$ manSv/a. The normalized collective annual dose to the population in the 30 km zone from gaseous and aerosol emissions amounts to $1.79x10^{-2}$ manSv/GW.a.

In respect to gaseous and aerosol emissions from ASE VVER-1000 in the atmosphere, the collective annual dose is estimated at $1.59x10^{-4}$ manSv/a. The normalized collective annual dose to the population in the 30 km zone from gaseous and aerosol emissions amounts to $1.77.10^{-4}$ manSv/GW.a.

The NNU estimates are fully compatible with data for a large number of PWR reactors in various parts of the world (UNSCEAR–2000, 2008).

4.11.1.2 DOSES FROM LIQUID RELEASES

The liquid radioactive releases in the Danube River proliferate as a result of the mainstream flows and sedimentation processes. The main routes leading to radiation of humans are: external radiation due to contact with aqueous medium and bottom depositions, consumption of food obtained by the river, using water from the river for drinking purposes, consumption of food from crops and grasslands irrigated with water from the river.

Each of these routes is considered in the EIAR. Account is taken of the physical movement and dispersion of water masses, together with the radioactive decay of radio nuclides. The resulting concentrations of radioactive substances in the water and the bottom depositions are used at inputs for calculation of the human intake by contact with the environment and ingestion, and the consequent individual and collective doses.

As input data are used the radionuclides composition and the activity of release in the de-balanced waters.

The hydrological data necessary for the dose burden assessment are: average river speed, average depth, distance, average river width; location and flow of the receiver – the river.

The statistical data is the data on habits and population consumption. The demographic data is data on the population by age groups.

4.11.1.2.1 Input data

- ✓ Demographic data and data on consumption and habits:
  - Bulgarian territory: Annual report, Results from the radiation monitoring of Kozloduy NPP environment in 2012, No. 13.RM.DOC.175,
  - Romanian territory: Letter from the Romanian Ministry of Environment and Forests, No. 3672/RP/18.10.2012.

- ✓ Hydrological data:
  - Annual report, Results from the radiation monitoring of Kozloduy NPP environment in 2012, No. 13.RM.DOC.175
- ✓ Emissions into water:
  - Annual report, Results from the radiation monitoring of Kozloduy NPP environment in 2012, No. 13.RM.DOC.175,
  - Data on emissions into water from NNU.

TABLE 4.11-7: RADIONUCLIDES IN THE LIQUID RELEASES DURING REGULAR OPERATION AND EXPECTED OPERATION EVENTS, BQ/A

Nuclide	Westinghouse AP-1000
Te-131m	3.33E+06
Te-131	1.11E+06
I-131	5.23E+08
Te-132	8.88E+06
I-132	6.07E+07
I-133	2.48E+08
I-134	3.00E+07
Cs-134	3.67E+08
I-135	1.84E+08
Cs-136	2.33E+07
Cs-137	4.93E+08
Ba-137m	4.61E+08
Ba-140	2.04E+08
La-140	2.75E+08
Ce-141	3.33E+06
Ce-143	7.03E+06
Pr-143	4.81E+06
Ce-144	1.17E+08
Pr-144	1.17E+08
All other	7.40E+05
H-3	3.74E+13

For AES BBEP-1000/B466: In the emission volume from de-balanced water into the environment can be released about $8.5.10^{12}$ Bq/year tritium[48].

- Requirements described in EUR – European Utility Requirements for LWR Nuclear Power Plants

The limits of liquid radioactive emissions according to EUR during regular operation and expected operation events are:

– Liquid with the exception of tritium 10 GBq. (*This reference value is determined on the base of 1500 MW_e*)

[48] Data provided by the Client, letter No. 828/13.08.2013

For completeness and conservativeness of the evaluation to determine the normalized annual collective doses the following power values of the NNU were taken into account: AP 1000 – 1200 MWe, AES BBEP-1000/B466 – 1000 MWe, in accordance with the set in EUR – 1500 MWe and availability of 90%.

4.11.1.2.2 Models and software used for the assessment

To assess the dose of the population from liquid releases the software modeling program DARR-CM was used, as adapted to the hydrology of the area of Kozloduy NPP, applying a conservative assessment of exposure dose to the critical group of the population. The program is based on the adopted by the EU (European Union) methodology CREAM (Consequences of Releases to the Environment Assessment Methodology) Radiation Protection 72 – Methodology for assessing the radiological consequences of routine releases of radionuclides to the environment.

The methodology contains series of interrelated models depicting the transfer of radionuclides through different sectors of the environment, the routs of impact to influence the people.

The methodology takes into account both the external and internal impact of radioactive contaminated water and assesses the individual annual dose per "reference individual" and to the critical group, as well as the collective dose to the population for three age groups – babies (0 – 1 year), children (1- 10 years) and adults (above 10 years) in the settlements along the Danube River.

This methodology is based on three types of mathematical models: 1) hydrological models, 2) routs of impact (terrestrial model) and 3) dosimetric models.

Figure 4.11-4 illustrates the relations among these models, which are applicable to the results analyses for Kozloduy NPP reactors. The annual radionuclides release in the expansion system is the starting point for these analyses.

The expansion hydrological models describe the transfer and detention in the expansion systems and assess the annual releases into the water of the Danube River. These models also present the dilution in the Danube River.

The transportation models for surface waters are mainly used to present the concentration of radionuclides in places of the environment, where they can impact humans and bionts. Transportation of the released activity into surface waters is considered part of the terrestrial model because dilution in surface waters is described through mixing factors and the respective transit times.

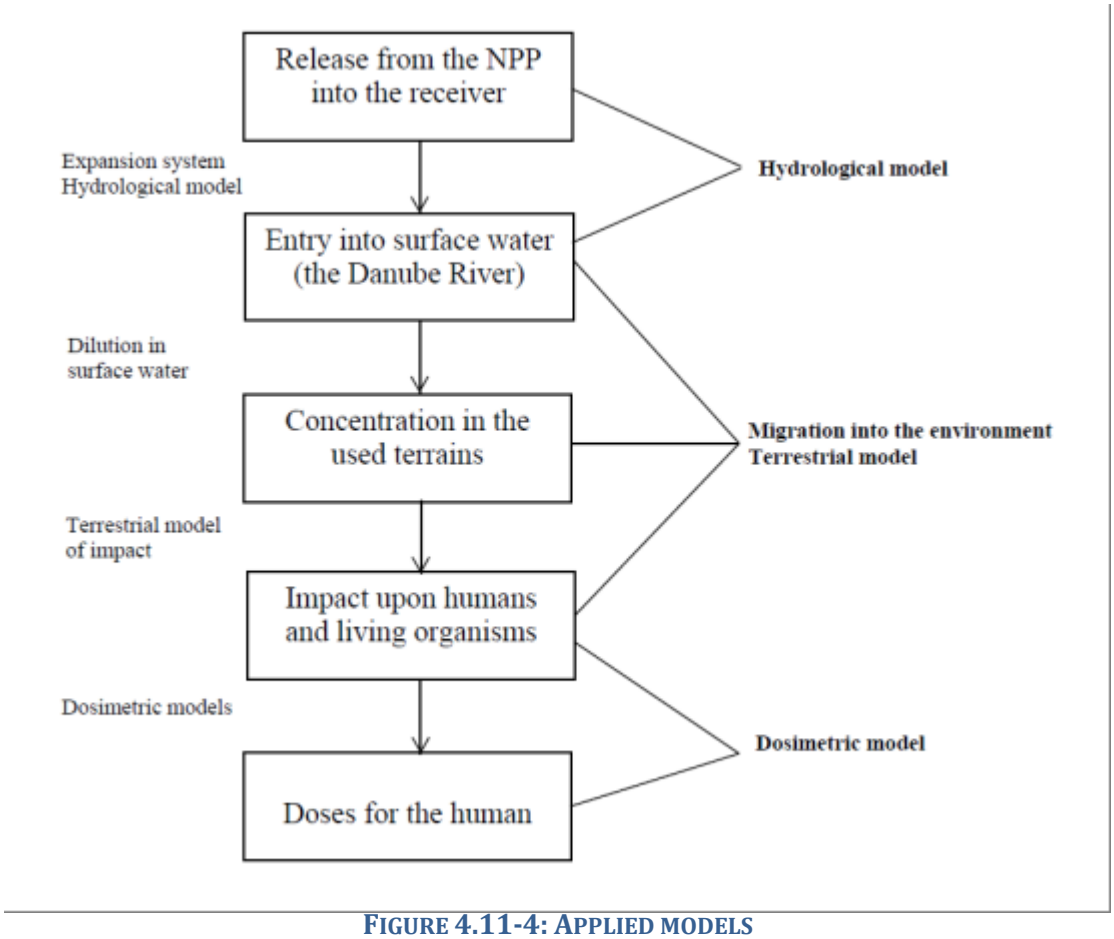


FIGURE 4.11-4: APPLIED MODELS

The terrestrial models assess the consumption (through ingestion) of radionuclides, which are contained in various food products (incl. fish, water, water plants and agricultural products). Agricultural products contamination is a result of using contaminated water for irrigation. External exposure can occur in case of swimming, boating and other activities along the river bank.

The dosimetric models are related to using factors to recalculate the doses.

The hydrological models describe the effect upon the bio systems from the concentration of radionuclides released into the water as well as the transportation and dilution of radionuclides into the Danube River.

In the development of the model of interaction between the reservoir-cooler and the Danube River are taken into account the specific conditions of the river in the nearest 30 km along the river and a realistic assessment is made of the process of mixing of waters and the contribution of the liquid radioactive releases into the specific volume activity into the Danube River.

The liquid radioactive releases into the Danube River are distributed as a result of the main water movement and the sedimentation processes. The impact routs of the radioactive contaminated reservoir on the human are various but they can be combined into two

groups: external and internal exposure. The first one is related to human presence immediately by the river (for ex. swimming, boating, etc.). The second route (**Figure 4.11-5**) is related to human consumption of food and water and the receipt of radionuclides into the human organism through the food chains, which contain products directly from the water body or such products for the production of which is used water from the water body (watering of livestock, irrigation).

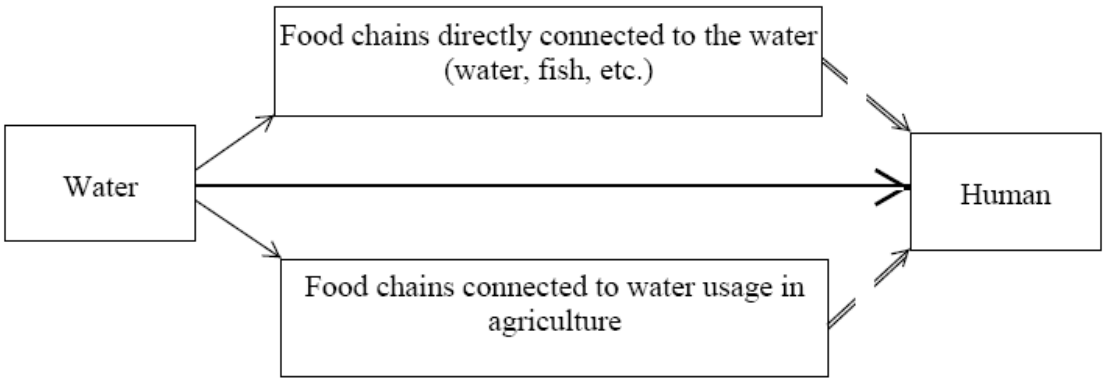


FIGURE 4.11-5: INTERNAL EXPOSURE

All these routes are considered. The physical movement and dispersion of water masses is taken into account along with the radioactive decay of the radionuclides. The resulting concentration of radioactive substances in the water and the bottom depositions form the input for calculating the intake by the human through contact with the environment and ingestion, as well as the resulting individual and collective doses.

The modelling programs used for assessment of the individual and collective efficient doses of population from radioactive releases in the environment are verified and validated

4.11.1.2.3 Results

By assessing the doses from liquid releases is used a model of complete mixing in the Danube River and there is no differentiation between left and right bank. On that basis it is stated that the doses for the respective kilometre on both banks of the Danube River are identical.

The maximum individual effective dose in the 30 km zone from liquid releases is estimated, in accordance with EUR, at 3.07×10^{-7} Sv/a, and for a representative of the critical group of the population along Danube river (town of Oryahovo, village of Leskovets, village of Ostrov and village of Gorni Vadin) it is estimated at 2.26×10^{-6} Sv/a – **Table 4.11-8**.

TABLE 4.11-8: INDIVIDUAL DOSE IN THE 30 ZONE FROM LIQUID RELEASES FROM NNU

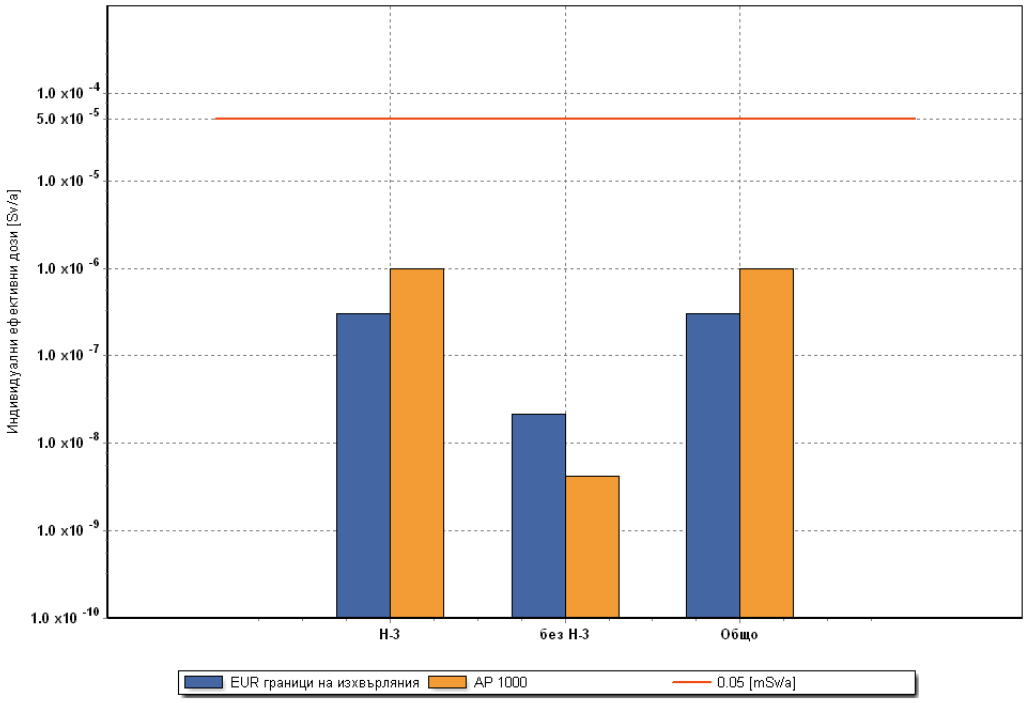
NNU	Individual efficient dose, [Sv]					
	For the population in the 30 km zone			For the critical group		
	^3H	without ^3H	Total	^3H	without ^3H	Total
EUR limits of releases	$1.64.10^{-7}$-$3.07.10^{-7}$	$1.67.10^{-10}$-$2.13.10^{-8}$	$1.71.10^{-7}$-**$3.07.10^{-7}$**	$2.16.10^{-6}$	$1.03.10^{-7}$	**$2.26.10^{-6}$**
AP-1000	$5.29.10^{-7}$-$9.89.10^{-7}$	$1.03.10^{-10}$-$4.23.10^{-9}$	$5.32.10^{-7}$-**$9.89.10^{-7}$**	$6.95.10^{-6}$	$1.93.10^{-8}$	**$6.97.10^{-6}$**
AES BBEP-1000/B466	$1.2.10^{-7}$-$2.25.10^{-7}$	No data	$1.2.10^{-7}$-$2.25.10^{-7}$	$1.58.10^{-6}$	No data	**$1.58.10^{-6}$**

This exposure is negligibly low and represents less than 0.7% of the annual limit of the effective dose – 1 mSv (BNRP-2012) and is hundreds of times lower than the exposure to the natural radiation background (2.33 mSv/a). Compared to the radiation limit for radioactive releases from NNU under all operation conditions (NRA instructions by letter No. 47-00-171/12.02.2013), determined as 0.05 mSv/a, the maximum calculated dose amounts to only 0.6% of the quota.

The maximum individual effective dose in the 30 km zone for the design basis liquid releases from AP-1000 is estimated at $9.89x10^{-7}$ Sv/a, and for a representative of the critical group of the population along Danube river (town of Oryahovo, village of Leskovets, village of Ostrov and village of Gorni Vadin) it is estimated at $6.97x10^{-6}$ Sv/a.

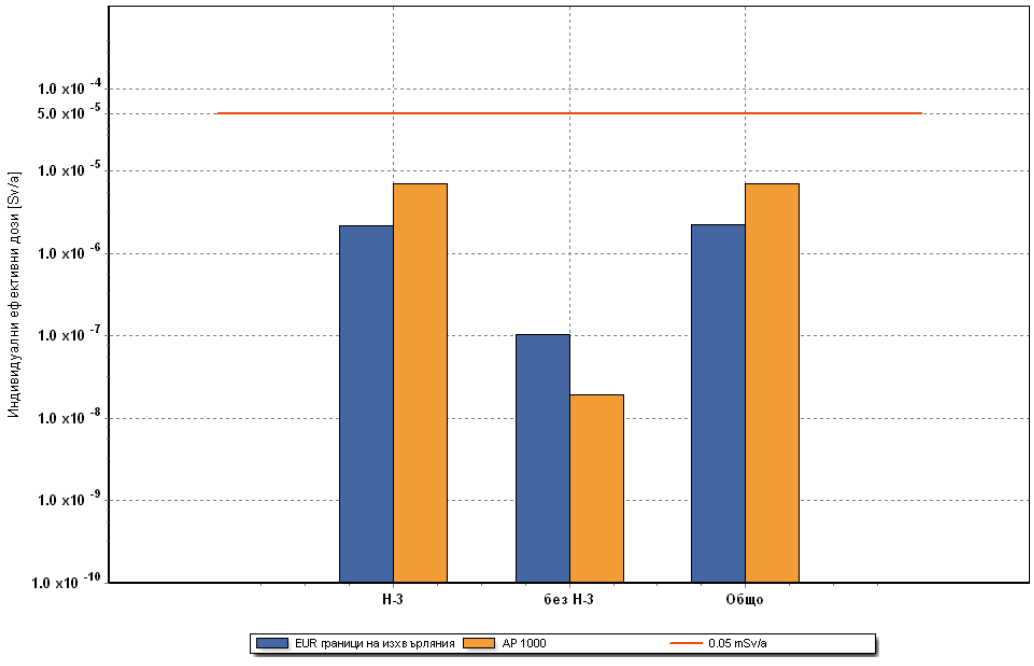
This exposure is negligibly low and represents less than 0.1% of the annual limit of the effective dose of 1 mSv (BNRP-2012) and is hundreds of times lower than the exposure to the natural radiation background (2.33 mSv/a). Compared to the radiation limit for radioactive releases from NNU under all operation conditions (NRA instructions by letter No. 47-00-171/12.02.2013), determined as 0.05 mSv/a, the maximum calculated dose amounts to only 2% of the quota.

The results of the achieved assessments of the maximum individual efficient dose in the 30 km zone and the critical group of population along the Danube River are graphically presented in **Figure 4.11-6** and **Figure 4.11-7**.



Blue: EUR limits of release; Orange: AP 1000

FIGURE 4.11-6: MAXIMUM DOSE BURDEN FROM LIQUID RELEASES IN THE 30 KM ZONE



Blue: EUR limits of release; Orange: AP 1000

FIGURE 4.11-7: MAXIMUM DOSE BURDEN FROM LIQUID RELEASES FOR THE CRITICAL GROUP IN THE 30 KM ZONE

TABLE 4.11-9: COLLECTIVE DOSES IN THE 30 KM ZONE FROM LIQUID RELEASES

NNU	Liquid releases					
	Collective dose [man.Sv]	Normalized collective dose [man.Sv/GW.a]			Comparison with UNSCEAR-2000	
		^{3}H	without ^{3}H	TOTAL	^{3}H $1.4.10^{-2}$ [man.Sv/GW.a]	without ^{3}H. $6.0.10^{-3}$ [man.Sv/GW.a]
EUR limits of releases	$2.45.10^{-3}$	$1.67.10^{-3}$	$1.42.10^{-4}$	$1.81.10^{-3}$	12%	2.4%
AP-1000	$7.32.10^{-3}$	$5.39.10^{-3}$	$2.86.10^{-5}$	$5.42.10^{-3}$	38.5%	0.05%
AES BBEP-1000/B466	$1.65.10^{-3}$	$1.22.10^{-3}$	No data	$1.22.10^{-3}$	8.7%	No data

The collective dose to the population in the 30 km zone from liquid radioactive releases is estimated, in accordance with EUR, at $2.45x10^{-3}$ man.Sv/a. The normalised collective dose per unit of generated electricity is $1.81x10^{-3}$ man.Sv/GW.a.

The collective dose to the population in the 30 km zone from design basis liquid releases of AP-1000 is estimated at $7.32x10^{-3}$man.Sv/a. The normalised collective dose per unit of generated electricity is $5.42x10^{-3}$man.Sv/GW.a.

Taking into account the demographic factors for the Romanian part (another 75 150 people), the collective efficient dose for the entire zone can be nearly doubled. This data is entirely compatible with the established practice for PWR reactors around the world.

The NNU estimates are entirely compatible with data for a large number of PWR reactors in various parts of the world (UNSCEAR–2000, 2008).

4.11.1.3 ASSESSMENT OF RADIOBIOLOGICAL EFFECTS AND RADIATION RISK FOR THE REFERENCE INDIVIDUAL

4.11.1.3.1 Models and software for assessment of the radiobiological effects and the radiation risk for the reference individual

The assessment of the radiobiological effects and the radiation risk to a reference individual for radioactive releases from NNU is carried out with the program HeConEmpPop (Health consequences for employees and population). The modelling program formalizes the assessment methodology for radiobiological effects and radiation risk according to ICRP Publication 103. The 2007 Recommendations of the International Commission on Radiological Protection.

The usage of radioactive substances and ionizing radiation poses risk to human health. The risks and benefits to human health are the two sides of the application of radioactive substances and ionizing radiation. They are equally important and therefore have to be assessed concurrently. This concept makes sense, but its practical application is difficult because the risks and benefits should be quantified. For this purpose, the International Commission on Radiobiological Protection has developed a methodology for assessment of the risk from ionizing radiation.

As a result the modelling program assesses the risk of tissue reactions (deterministic effects), radiation-induced cancer, hereditary diseases.

4.11.1.3.1.1 *Deterministic effects*

Deterministic are the effects, demonstrated at radiation with a high dose, which causes death to a significant number of cells and irreversible damage to the affected organ or system, as well as to the entire organism. The deterministic effects are threshold-based – they are demonstrated at radiation with received dose above 1-2 Gy, as the effect severity increases rapidly with the dose increase. Such effects can be, for example, leukemia, radiation cataracts, infertility as well as malformations and mental developmental delays due to in utero exposure.

The dose dependence of radiation-induced tissue reactions (deterministic effects) in adults and children has the property of a real dose threshold. There are no severe reactions caused in the majority of tissues in the body in case of exposure to annual doses lower than 0.1 Gy for many years. The threshold doses for tissue and organ reactions for the most radio-sensitive body tissues are presented. The threshold doses for the entire body are also presented, corresponding to a 1% resulting in morbidity and mortality as a result of damage to organs and tissues.

The restriction, introduced by limits of annual efficient dose of 1 mSv for the population and efficient dose of 20 mSv annually for the staff, guarantees non-allowance of deterministic effects for almost all organs and tissues. However, the restriction is not sufficient for the eye lens and the skin, which have higher radio-sensitivity. This necessitates the introduction of an equivalent dose restricting deterministic effects for them.

4.11.1.3.1.2 *Stochastic effects*

Even at lower doses of radiation exposure it can turn out that in a given critical volume of the cell such energy can be transferred that would be sufficient to change or destroy the cell. The death of one or few in number cells does not result in change of the tissue function in most of the cases. The changes in a single cell, such as genetical modification or transformation, however, can result in the development of malignancy with serious consequences. These effects that are the result of a single cell malformation are caused stochastic effects. There is certain probability of stochastic events to occur even at very low doses of radiation, therefore there is no dose threshold, and since there is none, then there is a dose level below which all damages can be restored. By increasing the dose the occurrence of such events increases but in the absence of other modifying factors the weight of the occurring effect is not expected to grow, which differentiates them from the tissue reactions. Most of the tissue reactions are more pronounced, the bigger the volume of exposed tissue is. Tissues vary not only by the dynamic of reaction to exposure but also by their radio-sensitivity. Some of the most radio-sensitive tissues are the ovaries and testicles, bone marrow and eye lens. The relation dose – effect for such tissues has a

sigmoidal shape when illustrated in linear scale and the effect increases with the dose increase. The weight of tissue and organ reactions also varies depending on the dose.

The modelling program presents additional and summarized assessments of the ingested dose limits in case of whole-body exposure of an adult corresponding to 1% morbidity and mortality. Effects in different organs and tissues are presented depending on the time of occurrence after the exposure.

Risk of radiation-induced cancer. Assessment of cancer risk: The coefficients of nominal risk are obtained through the average assessments of the risk for life by gender and age at the moment of radiation exposure of a representative population. The assessments of the risk for life are calculated on the base of risk assessment to develop cancer in different locations of the human organism.

The radiation damage concept is used for quantification of the harmful effects from the sources of ionizing radiation on various organs. It is determined starting from nominal risk factors, accounting for the severity of diseases as determined from mortality and years of lost life. The aggregate damage is the sum of the damage caused to each part of the body (tissues and/or organs).

The nominal cancer risk and the weight factors for the tissues are assessed for 12 organs and tissues (oesophagus, stomach, large intestine, liver, lungs, bones, skin, mammary gland, ovaries, urinary bladder, thyroid gland and red bone marrow), and the remaining organs and tissues were grouped under the category “other”.

The background levels of morbidity for composed populations are calculated by averaging the data for six different groups by including the results for cancer of the oesophagus, stomach, large intestine, liver, lungs, bones, skin, breast cancer for women, ovaries, urinary bladder, thyroid gland, leukaemia (excluding chronic lymphocytic leukemia) and all solid tumors.

The hereditary risks are also assessed.

The risk modelling and the estimates of disability from the diseases use new data about risk of radiation-induced cancer and hereditary effects in order to assess the coefficients of nominal risk.

Based on these estimations, nominal risk factors accounting for cancer mortality are suggested and are equal to 5.5×10^{-2} Sv^{-1} for the population as a whole and to 4.1×10^{-2} Sv^{-1} for the working population between 18 and 64 years of age. The nominal risk factors for hereditary effects, accounting for mortality, are 0.2×10^{-2} Sv^{-1} for the population as a whole and – 0.1×10^{-2} Sv^{-1} for the working population.

The software provides detailed estimation of the damage: mortality, weight of non-lethal cases and relative loss of life for various cancer locations in the human body.

4.11.1.3.1.3 *Risk of hereditary diseases*

The term “genetic risk” refers to the probability of harmful genetic effects emerging in the offspring of a population exposed to exposure. These effects are manifested in increased

background frequency of genetic diseases in the population per unit of exposure of low Linear Energy Transmission at chronic exposure to small doses.

The software provides the risk factors for the reproductive part of the population and the entire population estimated for two generations and risk factors only for the first generation after the exposure.

The modelling software used for evaluation of individual and collective effective doses to the population from radioactive releases in the environment are verified and validated.

4.11.1.3.2 Results

The obtained estimates of the dose impacts from NNU releases are entirely compatible with the worldwide practice according to official data provided by the UN (UNSCEAR-2000, 2008).

According to census data of the National Statistical Institute, as at 01.02.2011 the population in the 30 km zone around NPP Kozloduy in the territory of Bulgaria was 65 994 persons and on the territory of Romania it was 75 150 persons. For this population, the following conclusions can be made concerning the radiobiological effects and radiation risk resulting from the operation of the NNU:

Deterministic effects

There is no risk for development of deterministic effects for the population in the 30 km zone around NPP Kozloduy.

The individual doses from gaseous and aerosol releases are in the range of $1.79.10^{-8} \div 6.13.10^{-7}$Sv.

These doses are much lower than the threshold determined by BNRP in Art. 10 as a limit of the annual effective dose, which is 1 mSv for the population.

On this basis it can be maintained that there is no risk for development of deterministic effects for the population in the 30 km zone around NPP Kozloduy.

Stochastic effects

The risk of stochastic effects is negligibly low.

The probability of occurrence of radiation-induced cancer for the entire population is accordingly: $3.29x10^{-8}$ for AP-1000, $9.85x10^{-10}$ for AES VVER-1000/B466 and $3.37x10^{-8}$ for EUR release limits, and the probability of hereditary diseases is accordingly: $1.2x10^{-9}$ for AP-1000, $3.58x10^{-11}$ for AES VVER-1000/B466 and $1.23x10^{-9}$ for EUR release limits.

In the tables below are presented detailed assessments for NNU regarding:

- ✓ **Table 4.11-10 –** Risks, taking into account the damage from radiation-induced cancer and hereditary diseases for the general population and for those of working age;
- ✓ **Table 4.11-11** – Risks and damages of some tissues for the population as a whole;

- ✓ **Table 4.11-12 ÷ Table 4.11-14** – Risks of hereditary diseases for the reproductive part of the population, assessed for two generations in case of exposure of one generation after the other and assessed for the first generation after the exposure.

TABLE 4.11-10: RISKS, TAKING INTO ACCOUNT THE DAMAGE FROM RADIATION-INDUCED CANCER AND HEREDITARY DISEASES FOR THE GENERAL POPULATION AND FOR THOSE OF WORKING AGE

NNU	Cancer		Hereditary effects		Total	
	Entire population	Persons of working age	Entire population	Persons of working age	Entire population	Persons of working age
EUR limits of releases	3.37E-8	2.51E-8	1.23E-9	6.13E-10	3.49E-8	2.57E-8
AP-1000	3.29E-8	2.46E-8	1.20E-9	5.99E-10	3.41E-8	2.52E-8
AES BBEP-1000/ B466	9.85E-10	7.34E-10	3.58E-11	1.79E-11	1.02E-9	7.52E-10

TABLE 4.11-11: ASSESSMENTS OF THE RISK AND DAMAGES OF SOME TISSUES FOR THE POPULATION AS A WHOLE

Tissue/Organ	Nominal risk (cases per 10 000 people)			Nominal risk considering deaths			Damage		
	EUR limits of release	AP-1000	AES BBEP-1000/B466	EUR limits of release	AP-1000	AES BBEP-1000/B466	EUR limits of release	AP-1000	AESBBEP-1000/B466
Oesophagus	9.19E-06	8.98E-06	2.69E-07	9.26E-06	9.04E-06	2.70E-07	8.05E-06	7.87E-06	2.35E-07
Stomach	4.84E-05	4.73E-05	1.41E-06	4.72E-05	4.61E-05	1.38E-06	4.15E-05	4.06E-05	1.21E-06
Large intestine	3.98E-05	3.89E-05	1.16E-06	3.03E-05	2.96E-05	8.84E-07	2.94E-05	2.87E-05	8.58E-07
Liver	1.84E-05	1.80E-05	5.37E-07	1.85E-05	1.81E-05	5.41E-07	1.63E-05	1.59E-05	4.76E-07
Lungs	6.99E-05	6.83E-05	2.04E-06	6.92E-05	6.76E-05	2.02E-06	5.54E-05	5.41E-05	1.62E-06
Bones	4.29E-06	4.19E-06	1.25E-07	3.13E-06	3.05E-06	9.13E-08	3.13E-06	3.05E-06	9.13E-08
Skin	6.13E-04	5.99E-04	1.79E-05	2.45E-06	2.40E-06	7.16E-08	2.45E-06	2.40E-06	7.16E-08
Mammary gland	6.87E-05	6.71E-05	2.00E-06	3.79E-05	3.71E-05	1.11E-06	4.89E-05	4.78E-05	1.43E-06
Ovaries	6.74E-06	6.59E-06	1.97E-07	5.39E-06	5.27E-06	1.58E-07	6.04E-06	5.90E-06	1.76E-07
Urinary bladder	2.64E-05	2.58E-05	7.70E-07	1.44E-05	1.41E-05	4.21E-07	1.02E-05	9.99E-06	2.99E-07
Thyroid gland	2.02E-05	1.98E-05	5.91E-07	6.01E-06	5.87E-06	1.75E-07	7.75E-06	7.57E-06	2.26E-07
Bone marrow	2.57E-05	2.52E-05	7.52E-07	2.31E-05	2.26E-05	6.75E-07	3.77E-05	3.68E-05	1.10E-06
Other solid	8.83E-05	8.63E-05	2.58E-06	6.76E-05	6.60E-05	1.97E-06	6.96E-05	6.80E-05	2.03E-06
Gonads	1.23E-05	1.20E-05	3.58E-07	1.18E-05	1.16E-05	3.45E-07	1.56E-05	1.53E-05	4.56E-07
Total	1.05E-03	1.03E-03	3.07E-05	3.46E-04	3.38E-04	1.01E-05	3.52E-04	3.44E-04	1.03E-05

TABLE 4.11-12: ASSESSMENT OF RISKS OF HEREDETARY DISEASES

Illness classification	Two generations			First generation		
	for the entire population average in %			for the entire population average in %		
	EUR limits of release	AP 1000	AES BBEP-1000/B466	EUR limits of release	AP 1000	AES BBEP-1000/B466
Mendelian diseases	4.90E-08	4.79E-08	1.43E-09	3.06E-08	3.00E-08	8.95E-10
Chronic diseases	1.84E-08	1.80E-08	5.37E-10	1.84E-08	1.80E-08	5.37E-10
Congenital anomalies	6.74E-08	6.59E-08	1.97E-09	4.90E-08	4.79E-08	1.43E-09
Total	1.35E-07	1.32E-07	3.94E-09	9.80E-08	9.59E-08	2.86E-09

TABLE 4.11-13: ASSESSMENT OF RISKS OF HEREDITARY DISEASES FOR THE REPRODUCTIVE PART OF THE POPULATION, ASSESSED FOR TWO GENERATIONS (EXPOSURE OF ONE GENERATION AFTER THE OTHER)

Illness classification	Reproductive population	
	range in %	average in %
EUR limits of release		
Mendelian diseases	7.969E-08 – 1.533E-07	1.16E-07
Chronic diseases	1.839E-08 – 7.356E-08	4.90E-08
Congenital anomalies	1.471E-07 – 1.839E-07	1.66E-07
	Total	**3.31E-07**
AP-1000		
Mendelian diseases	7.787E-08 – 1.498E-07	1.14E-07
Chronic diseases	1.797E-08 – 7.188E-08	4.79E-08
Congenital anomalies	1.438E-07 – 1.797E-07	1.62E-07
	Total	**3.24E-07**
AES BBEP-1000/B466		
Mendelian diseases	2.327E-09 – 4.475E-09	3.40E-09
Chronic diseases	5.37E-10 – 2.148E-09	1.43E-09
Congenital anomalies	4.296E-09 – 5.37E-09	4.83E-09
	Total	**9.66E-09**

TABLE 4.11-14: ASSESSMENT OF RISKS OF HEREDITARY DISEASES FOR THE REPRODUCTIVE PART OF THE POPULATION, ASSESSED FOR THE FIRST GENERATION AFTER THE EXPOSURE

Illness classification	Reproductive population	
	range in %	range in %
EUR limits of release		
Mendelian diseases	4.597E-08 – 9.195E-08	6.74E-08
Chronic diseases	1.536E-08 – 7.356E-08	4.29E-08
Congenital anomalies	---	1.23E-07

Illness classification	Reproductive population	
	range in %	range in %
	Total	**2.33E-07**
AP 1000		
Mendelian diseases	4.493E-08 – 8.985E-08	6.59E-08
Chronic diseases	1.498E-08 – 7.188E-08	4.19E-08
Congenital anomalies	---	1.20E-07
	Total	**2.28E-07**
AES BBEP-1000/B466		
Mendelian diseases	1.343E09 – 2.685E-09	1.97E-09
Chronic diseases	4.475E-10 – 2.148E-09	1.25E-09
Congenital anomalies	---	3.58E-09
	Total	**6.80E-09**

4.11.2 CONCLUSION

Table 4.11-15 presents the maximum values of radiation exposure in the surveillance zone around Kozloduy NPP to gaseous and aerosol and liquid emissions from NNU.

TABLE 4.11-15: MAXIMUM RADIATION EXPOSURE IN THE 30 KM ZONE TO GASEOUS AND AEROSOL AND LIQUID EMISSIONS FROM NNU

Description of the source	Maximum individual efficient dose of gaseous and aerosol emissions	Maximum individual efficient dose of liquid emissions	Maximum individual efficient dose TOTAL
	[Sv]		
AP 1000	5.99E-07	9.89E-07	1.59E-06
AES BBEP-1000/ B466	1.79E-08	(*)	1.79E-08
EUR limits of release	6.13E-07	3.07E-07	9.20E-07

(*) – For AES BBEP-1000/ B466there is no data provided for liquid releases.

The maximum annual efficient dose for the population in the 30 km zone of Kozloduy NPP as a result of liquid and gaseous and aerosol emissions into the environment by NNU is assessed to 1.59 μSv/a, which is 3.18% of the quota of 0.05 mSv/a (NRA instructions by letter No. 47-00-171/12.02.2013r) and is about 0.07% of that of the natural radiation background (2.33 mSv).

In terms of the Project's dose impact both technology alternatives conform to the regulatory requirements and the instructions of the NRA, namely that the annual individual effective dose per capita caused by the impacts of liquid and gaseous

releases in the environment at all operational conditions must be limited to 0.05 mSv (letter No. **47-00-171/12.02.2013).**

There is no risk to the population during the construction phase.

The radiation risk to the population during the operations phase is one of very low probability, temporary, short-term, without cumulative effect and reversible.

Radiation risk for the population during the decommissioning phase is not expected.

4.12 EXPECTED IMPACT ON SITES OF IMMOVABLE CULTURAL AND HISTORICAL HERITAGE

The impact on immovable cultural heritage is expected to be direct:

1. During construction: Earthmoving works for massive structures, facilities, fixed underground and aboveground utilities, etc. are related to irreversible damage to the genuine landscape and the existing land surface. The construction of facilities on embankments suggests full-fledged damage of the landscape and surface that have taken millennia to form. The usage of lands as depots for earth, inert and other materials and for disposal of building and other waste also involves damage to the existing surface.

Archaeological artefacts and various types of remains from ancient anthropological activity are contained exactly in subsurface depositions in the soil. The archaeological structures created as a result of ancient inhabitancy and activity are very frequently of "negative" nature (buried under the level of the ancient terrain), i.e. they cannot be seen and identified by visual inspection of the surface, especially when the terrain is overgrown with vegetation or covered with artificial embankments made in present times.

If **Sites 1 and 2** are selected, cultural and historic assets unknown thus far may be discovered.

The selection of **Site 3** may lead to the discovery of archaeological sites and structures related with the usage of *Via Danubiana* in the Roman epoch and the Roman fortress in the locality Magura Piatra (Regiana). There can also be sites and structures of "negative" nature, which do not have observable traces on the present surface (from prehistoric or early medieval times).

2. During operation: direct impacts are not expected, unless it becomes necessary to "acquire" new lands for operational purposes. Cumulative impact is not expected.

3. During decommissioning: impacts are not expected, unless there are plans to use new areas with undamaged genuine surface.

The expected impact on sites of cultural heritage by activities related with construction of new assets (at any of the sites) is evaluated as **direct, positive (**the discovered artefacts will be in the public domain**) and highly important** for the preservation of the cultural and historic heritage.

4.13 ASSESSMENT OF POTENTIAL IMPACTS

Table 4.13-1 e presents an assessment of the potential impacts on each component of the environment and human health.

TABLE 4.13-1: MATRIX TO ASSESS THE POTENTIAL IMPACTS OF THE INVESTMENT PROJECT

Component/factor	Stage	Probability of impact occurence[1]	Territorial scope of impact[2]	Type of impact			Level of impact[3]	Characteristics of impact			Reversability [7]
				Positive/ Negative	Direct/ Indirect	Secondary		Frequency[4]	Duration[5]	Cumulative effect[6]	
SITE 1											
Ambient air	Construction	Expected	NPP site+NNU	negative	direct	primary	low	temporary	short-term	no	reversible
	Operations	Not expected									
	Decommissioning	Expected	NPP site+NNU	negative	direct	primary	low	temporary	short-term	no	reversible
Surface water	Construction	Expected	NPP site+NNU	negative	indirect	secondary	low	temporary	short-term	no	reversible
	Operations	Expected	NPP site+NNU	negative	direct	primary	low	permanent	long-term	yes	reversible
	Decommissioning	Expected	NPP site+NNU	negative	direct	primary	low	temporary	medium-term	no	reversible
Groundwater	Construction	Expected	NNU	negative	direct	secondary	high	permanent	long-term	yes	irreversible
	Operations	Expected	NNU	negative	direct	primary	moderate	permanent	long-term	yes	irreversible
	Decommissioning	Expected	NNU	negative	direct	primary	low	temporary	short-term	yes	reversible
Non-radioactive land and soil	Construction	Expected	NNU	negative	direct	primary	low	temporary	short-term	no	irreversible
	Operations	Not expected									
	Decommissioning	Not expected									
Radioactive soil	Construction	Not expected									
	Operations	Expected	SZ – 30km	negative	direct	primary	very low	permanent	long-term	no	reversible
	Decommissioning	Expected	NNU	negative	direct	primary	very low	permanent	long-term	no	irreversible
Landscape	Construction	Expected	NNU	negative	direct	secondary	moderate	permanent	long-term	no	irreversible
	Operations	Not expected									
	Decommissioning	Not expected									
Landscape	Construction	Expected	NNU	negative	direct	primary	moderate	permanent	long-term	no	irreversible
	Operations	Not expected									
	Decommissioning	Not expected									
Non-radioactive waste	Construction	Expected	NPP site+NNU	negative	indirect		moderate	temporary	short-term	no	reversible
	Operations	Expected	NPP site+NNU	negative	indirect		moderate	temporary	temporary	no	reversible
	Decommissioning	Expected	NPP site+NNU	negative	indirect		moderate	temporary	temporary	no	reversible
Solid and liquid radioactive waste	Construction	Not expected									
	Operations	Expected	NPP site	negative	indirect	secondary	low	permanent	long-term	yes	reversible
	Decommissioning	Expected	NPP site	negative	indirect	secondary	low	permanent	long-term	yes	reversible

Component/factor	Stage	Probability of impact occurence[1]	Territorial scope of impact[2]	Type of impact			Level of impact[3]	Characteristics of impact			Reversability [7]
				Positive/ Negative	Direct/ Indirect	Secondary		Frequency[4]	Duration[5]	Cumulative effect[6]	
Hazardous substances	Construction	Expected	NNU	negative	direct		moderate	temporary	short-term	no	reversible
	Operations	Expected	NNU	negative	direct		moderate	temporary	short-term	no	reversible
	Decommissioning	Expected	NNU	negative	direct		moderate	temporary	short-term	no	reversible
Flora	Construction	Expected	NNU	negative	direct	primary	low	permanent	long-term	no	irreversible
	Operations	Not expected									
	Decommissioning	Not expected									
Fauna	Construction	Expected	NNU	negative	direct	primary	low	permanent	long-term	no	irreversible
	Operations	Not expected									
	Decommissioning	Not expected									
Noise	Construction	Expected	NPP site+NNU	negative	direct	primary	very low	temporary	short-term	yes	reversible
	Operations	Expected	NPP site+NNU	negative	direct	primary	very low	permanent	long-term	yes	reversible
	Decommissioning	Expected	NPP site+NNU	negative	direct	primary	moderate	temporary	long-term	yes	reversible
Vibration	Construction	Not expected									
	Operations										
	Decommissioning										
Non-ionizing radiation	Construction	Not expected	-								
	Operations	Expected	Servitude zone	negative	direct		very low	permanent	long-term	no	reversible
	Decommissioning	Not expected									
Health and hygienic aspects – Staff	Construction	Expected	NNU	negative	direct	primary	low	temporary	short-term	no	reversible
	Operations	Expected	NNU	negative	direct	primary	low	permanent	long-term	yes	reversible
	Decommissioning	Expected	NNU	negative	direct	primary	low	permanent	long-term	yes	reversible
Health and hygienic aspects – Population	Construction	Not expected									
	Operations	Expected	SZ – 30km	negative	indirect	secondary	very low	permanent	long-term	yes	reversible
	Decommissioning	Expected	SZ – 30km	negative	indirect	secondary	very low	permanent	long-term	yes	reversible
Cultural heritage	Construction	*Expected*	*NNU*	*positive*	*direct*	*primary*	*very high*	*permanent*	*long-term*	*no*	*irreversible*
	Operations	Not expected									
	Decommissioning	Not expected									
SITE 2											
Ambient air	Construction	Expected	NPP site+NNU	negative	direct	primary	low	permanent	short-term	no	reversible

Component/factor	Stage	Probability of impact occurence[1]	Territorial scope of impact[2]	Type of impact			Level of impact[3]	Characteristics of impact			Reversability [7]
				Positive/ Negative	Direct/ Indirect	Secondary		Frequency[4]	Duration[5]	Cumulative effect[6]	
Surface water	Operations	Not expected									
	Decommissioning	Expected	NPP site+NNU	negative	direct	primary	low	temporary	short-term	no	reversible
	Construction	Expected	NPP site+NNU	negative	indirect	secondary	low	temporary	short-term	no	reversible
	Operations	Expected	NPP site+NNU	negative	direct	primary	low	permanent	long-term	yes	reversible
Groundwater	Decommissioning	Expected	NPP site+NNU	negative	direct	primary	low	temporary	medium-term	no	reversible
	Construction	Expected	NNU	negative	direct	secondary	moderate	permanent	long-term	yes	irreversible
	Operations	Expected	NNU	negative	direct	primary	moderate	permanent	long-term	yes	irreversible
	Decommissioning	Expected	NNU	negative	direct	primary	low	temporary	short-term	yes	reversible
Non-radioactive land and soil	Construction	Expected	NNU	negative	direct	primary	low	temporary	short-term	no	irreversible
	Operations	Not expected									
	Decommissioning	Not expected									
Radioactive soil	Construction	Not expected									
	Operations	Expected	SZ – 30km	negative	direct	primary	very low	permanent	long-term	no	reversible
	Decommissioning	Expected	NNU	negative	direct	primary	very low	permanent	long-term	no	irreversible
Earth interior	Construction	Expected	NNU	negative	direct	primary	moderate	permanent	long-term	no	irreversible
	Operations	Not expected									
	Decommissioning	Not expected									
Landscape	Construction	Expected	NNU	negative	direct	primary	moderate	permanent	long-term	no	irreversible
	Operations	Not expected									
	Decommissioning	Not expected									
Non-radioactive waste	Construction	Expected	NPP site+NNU	negative	indirect		moderate	temporary	short-term	no	reversible
	Operations	Expected	NPP site+NNU	negative	indirect		moderate	temporary	temporary	no	reversible
	Decommissioning	Expected	NPP site+NNU	negative	indirect		moderate	temporary	temporary	no	reversible
Solid and liquid radioactive waste	Construction	Not expected									
	Operations	Expected	NPP site	negative	indirect	secondary	low	permanent	long-term	yes	reversible
	Decommissioning	Expected	NPP site	negative	indirect	secondary	low	permanent	long-term	yes	reversible
Hazardous substances	Construction	Expected	NNU	negative	direct		moderate	temporary	short-term	no	reversible
	Operations	Expected	NNU	negative	direct		moderate	temporary	short-term	no	reversible
	Decommissioning	Expected	NNU	negative	direct		moderate	temporary	short-term	no	reversible

Component/factor	Stage	Probability of impact occurence[1]	Territorial scope of impact[2]	Type of impact			Level of impact[3]	Characteristics of impact			Reversability [7]
				Positive/ Negative	Direct/ Indirect	Secondary		Frequency[4]	Duration[5]	Cumulative effect[6]	
Flora	Construction	Expected	NNU	negative	direct	primary	very low	permanent	long-term	no	irreversible
	Operations	Not expected									
	Decommissioning	Not expected									
Fauna	Construction	Expected	NNU	negative	direct	primary	very low	permanent	long-term	no	irreversible
	Operations	Not expected									
	Decommissioning	Not expected									
Noise	Construction	Expected	NPP site	negative	direct	primary	low	temporary	medium-term	yes	reversible
	Operations	Expected	NPP site+NNU	negative	direct	primary	low	permanent	long-term	yes	reversible
	Decommissioning	Expected	NPP site+NNU	negative	direct	primary	moderate	temporary	long-term	yes	reversible
Vibration	Construction	Not expected									
	Operations										
	Decommissioning										
Non-ionizing radiation	Construction	Not expected	-								
	Operations	Expected	Servitude zone	negative	direct		very low	permanent	long-term	no	reversible
	Decommissioning	Not expected									
Health and hygienic aspects – Staff	Construction	Expected	NNU	negative	direct	primary	low	temporary	short-term	no	reversible
	Operations	Expected	NNU	negative	direct	primary	low	permanent	long-term	yes	reversible
	Decommissioning	Expected	NNU	negative	direct	primary	low	permanent	long-term	yes	reversible
Health and hygienic aspects – Population	Construction	Not expected									
	Operations	Expected	SZ – 30km	negative	indirect	secondary	very low	permanent	long-term	yes	reversible
	Decommissioning	Expected	SZ – 30km	negative	indirect	secondary	very low	permanent	long-term	yes	reversible
Cultural heritage	Construction	*Expected*	*NNU*	*positive*	*direct*	*primary*	*very high*	*permanent*	*long-term*	*no*	*irreversible*
	Operations	Not expected									
	Decommissioning	Not expected									
SITE 3											
Ambient air	Construction	Expected	NPP site+NNU	negative	direct	primary	low	temporary	short-term	no	reversible
	Operations	Not expected									
	Decommissioning	Expected	NPP site+NNU	negative	direct	primary	low	temporary	short-term	no	reversible
Surface water	Construction	Expected	NPP site+NNU	negative	indirect	secondary	low	temporary	short-term	no	reversible

Component/factor	Stage	Probability of impact occurence[1]	Territorial scope of impact[2]	Type of impact			Level of impact[3]	Characteristics of impact			Reversability [7]
				Positive/ Negative	Direct/ Indirect	Secondary		Frequency[4]	Duration[5]	Cumulative effect[6]	
Groundwater	Operations	Expected	NPP site+NNU	negative	direct	primary	low	permanent	long-term	yes	reversible
	Decommissioning	Expected	NPP site+NNU	negative	direct	primary	low	temporary	medium-term	no	reversible
	Construction	Expected	NNU	negative	direct	secondary	high	permanent	long-term	yes	irreversible
Non-radioactive land and soil	Operations	Expected	NNU	negative	direct	primary	moderate	permanent	long-term	yes	irreversible
	Decommissioning	Expected	NNU	negative	direct	primary	low	temporary	short-term	yes	reversible
	Construction	Expected	NNU	negative	direct	primary	low	temporary	short-term	no	irreversible
Radioactive soil	Operations	Not expected									
	Decommissioning	Not expected									
	Construction	Not expected									
Earth interior	Operations	Expected	SZ – 30km	negative	direct	primary	very low	permanent	long-term	no	reversible
	Decommissioning	Expected	NNU	negative	direct	primary	very low	permanent	long-term	no	irreversible
	Construction	Expected	NNU	negative	direct	secondary	moderate	permanent	long-term	no	irreversible
Landscape	Operations	Not expected									
	Decommissioning	Not expected									
	Construction	Expected	NNU	negative	direct	primary	moderate	permanent	long-term	no	irreversible
Non-radioactive waste	Operations	Not expected									
	Decommissioning	Not expected									
	Construction	Expected	NPP site+NNU	negative	indirect		moderate	temporary	short-term	no	reversible
	Operations	Expected	NPP site+NNU	negative	indirect		moderate	temporary	temporary	no	reversible
	Decommissioning	Expected	NPP site+NNU	negative	indirect		moderate	temporary	temporary	no	reversible
Solid and liquid radioactive waste	Construction	Not expected									
	Operations	Expected	NPP site	negative	indirect	secondary	low	permanent	long-term	yes	reversible
	Decommissioning	Expected	NPP site	negative	indirect	secondary	low	permanent	long-term	yes	reversible
Hazardous substances	Construction	Expected	NNU	negative	direct		moderate	temporary	short-term	no	reversible
	Operations	Expected	NNU	negative	direct		moderate	temporary	short-term	no	reversible
	Decommissioning	Expected	NNU	negative	direct		moderate	temporary	short-term	no	reversible
Flora	Construction	Expected	NNU	negative	direct	primary	low	permanent	long-term	no	irreversible
	Operations	Not expected									
	Decommissioning	Not expected									

Component/factor	Stage	Probability of impact occurence[1]	Territorial scope of impact[2]	Type of impact			Level of impact[3]	Characteristics of impact			Reversability [7]
				Positive/ Negative	Direct/ Indirect	Secondary		Frequency[4]	Duration[5]	Cumulative effect[6]	
Fauna	Construction	Expected	NNU	negative	direct	primary	low	permanent	long-term	no	irreversible
	Operations	Not expected									
	Decommissioning	Not expected									
Noise	Construction	Expected	NPP site+NNU	negative	direct	primary	low	temporary	medium-term	yes	reversible
	Operations	Expected	NPP site+NNU	negative	direct	primary	low	permanent	long-term	yes	reversible
	Decommissioning	Expected	NPP site+NNU	negative	direct	primary	moderate	temporary	long-term	yes	reversible
Vibration	Construction	Not expected									
	Operations										
	Decommissioning										
Non-ionizing radiation	Construction	Not expected	-								
	Operations	Expected	Servitude zone	negative	direct		very low	permanent	long-term	no	reversible
	Decommissioning	Not expected									
Health and hygienic aspects – Staff	Construction	Expected	NNU	negative	direct	primary	low	temporary	short-term	no	reversible
	Operations	Expected	NNU	negative	direct	primary	low	permanent	long-term	yes	reversible
	Decommissioning	Expected	NNU	negative	direct	primary	low	permanent	long-term	yes	reversible
Health and hygienic aspects – Population	Construction	Not expected									
	Operations	Expected	SZ – 30km	negative	indirect	secondary	very low	permanent	long-term	yes	reversible
	Decommissioning	Expected	SZ – 30km	negative	indirect	secondary	very low	permanent	long-term	yes	reversible
Cultural heritage	Construction	*Expected*	*NNU*	*positive*	*direct*	*primary*	*very high*	*permanent*	*long-term*	*no*	*irreversible*
	Operations	Not expected									
	Decommissioning	Not expected									
SITE 4											
Ambient air	Construction	Expected	NPP site+NNU	negative	direct	primary	low	temporary	short-term	no	reversible
	Operations	Not expected									
	Decommissioning	Expected	NPP site+NNU	negative	direct	primary	low	temporary	short-term	no	reversible
Surface water	Construction	Expected	NPP site+NNU	negative	indirect	secondary	low	temporary	short-term	no	reversible
	Operations	Expected	NPP site+NNU	negative	direct	primary	low	permanent	long-term	yes	reversible
	Decommissioning	Expected	NPP site+NNU	negative	direct	primary	low	temporary	medium-term	no	reversible
Groundwater	Construction	Expected	NNU	negative	direct	secondary	moderate	permanent	long-term	yes	irreversible

Component/factor	Stage	Probability of impact occurence[1]	Territorial scope of impact[2]	Type of impact			Level of impact[3]	Characteristics of impact			Reversability [7]
				Positive/ Negative	Direct/ Indirect	Secondary		Frequency[4]	Duration[5]	Cumulative effect[6]	
Non-radioactive land and soil	Operations	Expected	NNU	negative	direct	primary	moderate	permanent	long-term	yes	irreversible
	Decommissioning	Expected	NNU	negative	direct	primary	low	temporary	short-term	yes	reversible
	Construction	Expected	NNU	negative	direct	primary	low	temporary	short-term	no	irreversible
Radioactive soil	Operations	Not expected									
	Decommissioning	Not expected									
	Construction	Not expected									
Earth interior	Operations	Expected	SZ – 30km	negative	direct	primary	very low	permanent	long-term	no	reversible
	Decommissioning	Expected	NNU	negative	direct	primary	very low	permanent	long-term	no	irreversible
	Construction	Expected	NNU	negative	direct	secondary	moderate	permanent	long-term	no	irreversible
Landscape	Operations	Not expected									
	Decommissioning	Not expected									
	Construction	Expected	NNU	negative	direct	primary	moderate	permanent	long-term	no	irreversible
Non-radioactive waste	Operations	Not expected									
	Decommissioning	Not expected									
	Construction	Expected	NPP site+NNU	negative	indirect		moderate	temporary	short-term	no	reversible
	Operations	Expected	NPP site+NNU	negative	indirect		moderate	temporary	temporary	no	reversible
	Decommissioning	Expected	NPP site+NNU	negative	indirect		moderate	temporary	temporary	no	reversible
Solid and liquid radioactive waste	Construction	Not expected									
	Operations	Expected	NPP site	negative	indirect	secondary	low	permanent	long-term	yes	reversible
	Decommissioning	Expected	NPP site	negative	indirect	secondary	low	permanent	long-term	yes	reversible
Hazardous substances	Construction	Expected	NNU	negative	direct		moderate	temporary	short-term	no	reversible
	Operations	Expected	NNU	negative	direct		moderate	temporary	short-term	no	reversible
	Decommissioning	Expected	NNU	negative	direct		moderate	temporary	short-term	no	reversible
Flora	Construction	Not expected									
	Operations	Not expected									
	Decommissioning	Not expected									
Fauna	Construction	Not expected									
	Operations	Not expected									
	Decommissioning	Not expected									

Component/factor	Stage	Probability of impact occurence[1]	Territorial scope of impact[2]	Type of impact			Level of impact[3]	Characteristics of impact			Reversability [7]
				Positive/ Negative	Direct/ Indirect	Secondary		Frequency[4]	Duration[5]	Cumulative effect[6]	
Noise	Construction	Expected	NPP site+NNU	negative	direct	primary	high	temporary	medium-term	yes	reversible
	Operations	Expected	NPP site+NNU	negative	direct	primary	moderate	permanent	long-term	yes	reversible
	Decommissioning	Expected	NPP site+NNU	negative	direct	primary	high	temporary	long-term	yes	reversible
Vibration	Construction	Not expected									
	Operations										
	Decommissioning										
Non-ionizing radiation	Construction	Not expected	-								
	Operations	Expected	Servitude zone	negative	direct		very low	permanent	long-term	no	reversible
	Decommissioning	Not expected									
Health and hygienic aspects – Staff	Construction	Expected	NNU	negative	direct	primary	low	temporary	short-term	no	reversible
	Operations	Expected	NNU	negative	direct	primary	low	permanent	long-term	yes	reversible
	Decommissioning	Expected	NNU	negative	direct	primary	low	permanent	long-term	yes	reversible
Health and hygienic aspects – Population	Construction	Not expected									
	Operations	Expected	SZ – 30km	negative	indirect	secondary	very low	permanent	long-term	yes	reversible
	Decommissioning	Expected	SZ – 30km	negative	indirect	secondary	very low	permanent	long-term	yes	reversible
Cultural heritage	Construction	*Expected*	*NNU*	*positive*	*direct*	*primary*	*very high*	*permanent*	*long-term*	*no*	*irreversible*
	Operations	Not expected									
	Decommissioning	Not expected									

[1] expected, not expected;
[2] selected site, Kozloduy NPP site, servitude zone, local, transboundary;
[3] **1** – very low, **2** – low, **3** – moderate, **4** – high, **5** – very high;
[4] permanent, temporary;
[5] short-term, medium-term, long-term;
[6] no/yes;
[7] reversible, irreversible.

Italic font- elements of the matrix with positive effects.
Underlined font- elements of the matrix, which are not expected to have impact or elements of expected minor negative impact.
Bold font – elements of the matrix of expected significant negative impact.

4.14 RATIONALE OF THE CHOSEN ALTERNATIVE

4.14.1 RATIONAL OF THE CHOSEN ALTERNATIVE BY LOCATION

The designated for the location of NNU four alternative sites are pre-selected based on criteria, which exclude territories prohibited by law or which do not comply with the legislation on environmental protection.

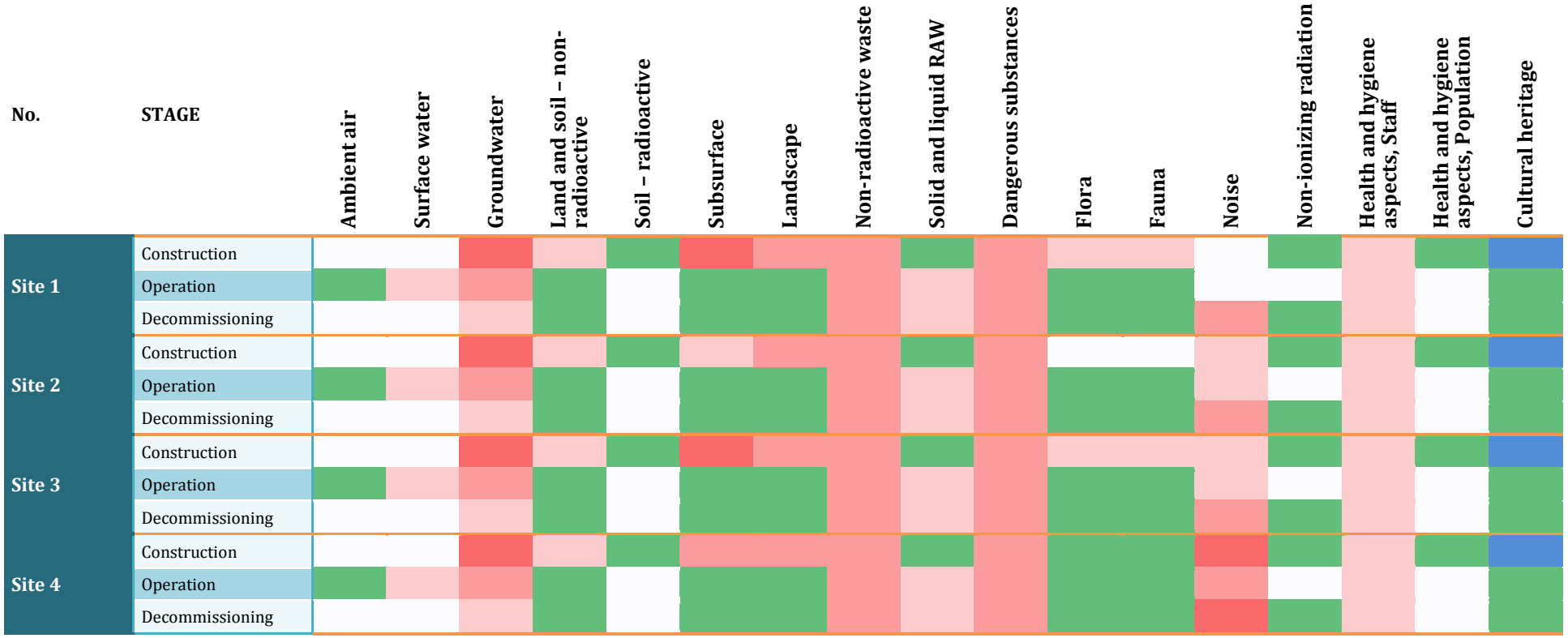
Based on the performed in the REIA impact assessment on the environment components and factors, illustrated in the matrix for assessment of the potential impacts of the realization of the investment proposal (Chapter 4, Table 4.13-1) is elaborated an integral approach to determine one of the alternative sites based on a colour code. Green marks the cell when no impact is expected from the IP on a certain component or factor of the environment, and from white to dark pink – the level of expected impact from 1 to 5.

Only by the component **Immovable cultural heritage** a positive impact is expected, which is coloured in blue.

In choosing a site the advantage is for that site, which has the lowest level of impact and provides the greatest safety to the staff, population and environment – **Table 4.14-1**.

The table can lead us to the conclusion that **SITE 2 is outlined as the most suitable one and it is suggested as an option for situating the NNU.**

TABLE 4.14-1: ASSESSMENT OF THE LEVEL OF IMPACT BY SEPARATE SITES



4.14.2 ALTERNATIVE FOR ACCOMPANYING INFRASTRUCTURE DURING CONSTRUCTION AND OPERATION

The planning of the proposed site for construction of the investment proposal should take into account several very important parameters: working elevation of the active site of the power plant, which is +35.00 m under the Baltic System of Heights, connection of the site, designated for the realization of NNU to the existing facilities that are important for its existence – connection to the cold intake channel (CC) and hot intake channel (HC), engineering acquisition and connection to the energy system via the outdoor switchgear, ownership of the necessary land that is to be alienated, approach to the necessary transport via deviations from the already existing road infrastructure, etc.

Table 4.14-2 presents the result of the developed approach for assessment. The columns list the eligibility criteria and the rows from **(1)÷(4)** assess with 1 to 5 the eligibility of the alternative sites in terms of accompanying infrastructure.

TABLE 4.14-2: ANALYSIS OF THE ELIGIBILITY OF THE ALTERNATIVE SITES

Site	Connection to the outdoor switchgear	Connection to old HC-1	Connection to CC-1	Floodability of the site	Destruction of the existing infrastructure	Areas for the construction of NNU	Lands to be alienated	Connection to the existing access roads	OVERALL assessment	% comparison	No. row
Criterion ranking	**4**	**5**	**5**	**5**	**2**	**2**	**3**	**3**			**(0)**
	Assessment (points 1÷5)										
Site 1	2	3	5	1	3	4	3	4	25		**(1)**
Site 2	4	5	4	4	4	4	2	4	31		**(2)**
Site 3	1	1	1	1	2	4	1	4	15		**(3)**
Site 4	4	2	4	4	1	1	5	4	25		**(4)**
	Weighted estimates (ranking * points)										
Site 1	8	15	25	5	6	8	9	12	88	25.4%	**(5)**
Site 2	16	25	20	20	8	8	6	12	**115**	**33.2%**	**(6)**
Site 3	4	5	5	5	4	8	3	12	46	13.3%	**(7)**
Site 4	16	10	20	20	2	2	15	12	97	28.0%	**(8)**

On row **(0)** from the table for more precision is introduced the ranking of the respective criteria, which determines the proportion by weight of this criterion in the integral assessment.

On rows **(5)÷(8)** the final eligibility assessment of the eligibility of the alternative sites is presented as percentage.

It is visible that **the most suitable** for the NNU realization in terms of connectivity to the already existing site of Kozloduy NPP is **SITE 2** – with eligibility assessment of **33.2 %.**

4.14.3 ALTERNATIVES ON THE EQUIPMENT OPTIONS FOR THE CONSTRUCTION OF NEW NUCLEAR UNIT

According to the Terms of Reference of the Client for the realization of the investment proposal there are two possible options for the construction of the new nuclear unit with reactor of the latest generation (III or III+ generation), meeting the modern requirements for safety operation:

- **A-1**: (Hybrid) Maximum usage of the equipment from the nuclear island ordered for Belene NPP and a turbine island from another supplier.
- **A-2**: Completely new project – two reactor models: AES-2006 and AP-1000, which should meet the safety criteria, set in the Bulgarian legislative documentation, in MAAE documentation and in European Utility Requirements (EUR) for LWR Nuclear Power Plants.

Not all components and factors of the environment identify impact from the type of equipment since all the three suggested options meet the requirements of the European operating organisations for NPP with light water reactors. The factors, for which impact that can be qualitatively assessed can be expected, are presented in **Table 4.14-3**.

TABLE 4.14-3: ASSESSMENT BY TYPE OF EQUIPMENT

Type of reactor	STAGE	Required water	Pollution load	RAW management	Radiation risk
		Non-radiation aspect		Radiation aspect	
AES-92	Operation				
	Decommissioning				
AP-1000	Operation				
	Decommissioning				
AES-2006	Operation				
	Decommissioning				

In non-radiation aspect two indicators are used for the assessment: water required for technological needs (for the turbine's condensers and for technological purposes at the chemical water treatment) and pollution load (BOD5, suspended solids, COD and other chemicals), and in radiation aspect – RAW management and radiation risk after modelling the impact of a given reactor option for gaseous and aerosol and liquid releases.

Light green marks the cell, when regarding this indicator the reactor option gives the lowest value (better than the other), and dark green – when for this indicator the assessment value is higher.

As it was mentioned all the three reactors meet the requirements of the European operating organisations for NPP with light water reactors, i. e. they do not exceed any norms, however the above-given assessment identifies the type of reactor, which is with lower indicators.

Based on the table it can be concluded that:

1. **in non-radiation aspect** regarding the surface water component with all the three reactors the permitted fresh water abstraction is not exceeded, while the freed quantity after the closure of Units 1÷4 is more than the necessary for NNU regardless of the type of equipment. AP-1000 is les disruptive since the fresh water quantity necessary for cooling and technical water supply from the Danube River is less. No violation of the IEL is expected for the discharged wastewater for all the three types of reactors,
2. **in radiation aspect:**
   a. regarding the gaseous and aerosol releases AES-92 and AES-2006 have lower project values than AP-1000 but this can be due to the highly conservative approach of Westinghouse while determining them. Modelling showed that the share of the individual efficient dose from gaseous and aerosol releases into the environment from NNU for AP-1000 model is significantly below the values of the administrative quota of 0.05 mSv, defined by NRA (letter No. 47-00-171/12.02.2013), and that is 1.198%. For AES-92 and AES-2006 the individual efficient dose from gaseous and aerosol releases into the environment is 0.0358%. Hence all the three reactor models meet the normative requirements.
   b. regarding the liquid releases modelling showed that the maximum individual efficient dose in the 30 km zone of the forecasted liquid releases from AP-1000 under all operation conditions is only 14% of the administrative quota of NRA of 0.05 mSv. (NRA instructions with letter No. 47-00-171/12.02.2013). Compared to the limit of EUR for forecasted liquid releases the modelling showed that for all operation conditions of the new unit the maximum dose is about 5% of the administrative quota. Since the reactors AES-92 and AES-2006 fully meet the requirements of EUR, the latter shows that they also meet the normative requirements.

Hence, **regarding environment protection (ecological aspect)** all the three reactors are suitable for the realization of NNU.

4.15 CONCLUSION

Considering the criteria related to environment protection by individual components and the factors, which have impact on the environment, incl. biological diversity preservation, the priority choice for the construction of NNU is Site 2.

Regarding the reactor type options no specific model can be identified since all the three technical solutions are options for the realization of the investment proposal.