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 6: CHARACTERISTICS OF ENVIRONMENTAL RISKS FROM POTENTIAL ACCIDENTS AND INCIDENTS

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6 CHARACTERISTICS OF THE ENVIRONMENTAL RISKS FROM POTENTIAL ACCIDENTS AND INCIDENTS

In accordance with the Basic Norms of Radiation Protection (BNRP-2012) and the internationally adopted definitions regarding events at nuclear power plants, any unintended event (including operating error, equipment failure or other mishap), the consequences (or potential consequences) of which are not negligible from the point of view of protection or safety, and which may lead to potential exposure, is defined as accident.

The impact of the environmental risks as a result of the implementation of the IP has been assessed in respect of:

- ***A design basis accident:*** in accordance with the REGULATION on Ensuring the Safety of Nuclear Power Plants (2004), this is an accident against which a nuclear power plant is designed according to established design limits, including damage to the fuel and release of radioactive material to the environment. Safety systems are designed to bring events of this class under control.
- ***A severe accident:*** in accordance with the REGULATION on Ensuring the Safety of Nuclear Power Plants (2004), this is an accident involving significant core degradation.

The present Chapter examines radiation and non-radiation risks related to the operation of a NNU and, for the purposes of the EIAR, information and data provided by the Client have been studied and analyzed regarding:

- Analysis of the stability of the project in events involving a total loss of an ultimate heat sink and total loss of off-site power, reckoning with the requirements of ENSREG to stress tests in the light of the events in Fukushima;
- Evaluation of the probability of core degradation (with severe core damage frequency for the new reactor lower than 1.10^{-5} events per NPP per year);
- Evaluation of the probability of large radioactive releases (the frequency of large radioactive releases being lower than 1.10^{-6} events per NPP per year);
- Assessment of the performance of the unit in severe accidents, so that changes in core geometry would be limited, ensuring conditions for long-term fuel cooling;
- Description of the technical measures for emergency response;
- Comparative analysis of the proposed sites from the point of view of nuclear safety and radiation protection;

- ✓ Analysis of the proposed sites from the point of view of nuclear safety and radiation protection, taking account of:
  - the influence of factors of human-induced and natural origin on the safety of the facility;
  - the radiation influence of the nuclear facility on the population and the environment;
  - the specific characteristics of the site which are relevant to the migration and accumulation of radioactive substances;
  - the possibilities to apply measures for protection of the population in case of an accident at the nuclear facility;
  - change of the emergency planning zone sizes.

6.1 RADIATION RISKS OF ACCIDENTS AND INCIDENTS

The present point examines the radiation risks related to the operation of the nuclear power plant. To this end, each of the two categories of emergency conditions, i.e. design basis accidents and severe accidents, have been modelled. In conclusion, a comment is presented on the results of the assessment and their influence on defining the emergency planning zone in the area surrounding the power plant.

6.1.1 NORMAL AND ABNORMAL OPERATION

In normal and abnormal operation of the NNU, the maximum dose limit in the critical group of the population should not be exceeded upon an overall release of radioactive substances, according to BNRP-2012.

6.1.1.1 EMERGENCY CONDITIONS

The assessment of emergency conditions is divided into an assessment of the so-called design basis accidents and the so-called severe accidents. These two types of emergency conditions differ not only in their probability of occurrence but also in their progression and seriousness.

The potential seriousness of the radiation consequences of accidents is related to the level of activity of the fission products in the reactor and to the level of damage to the barriers obstructing the release of radioactive substances to the environment. The fission products are present in the coolant of the first circuit, beneath the layer of fuel rods and above all in the fuel structure of the reactor core itself. The overall activity of the fission products in the core during power operation of the reactor depends above all on the quantity of fuel in the core and on its burn-up until the moment of the accident. The fission products in the coolant include mostly isotopes of iodine and caesium, but their activity in the coolant is one hundred thousand times lower than in the fuel. The rest of the isotopes, e.g. of Sr, Te, Ru, La, Ce, Ba etc., are present in the coolant in insignificant quantities. The activity of the isotopes in the gas gap represents just a fraction of the percentage of fuel activity. The seriousness of the radiation consequences varies widely, depending on whether only the integrity of the reactor cooling circuit has been compromised or the cladding of the fuel rods has been damaged, or the fuel has even melted down.

In design basis accidents, radioactive substances are liberated at most from the coolant in the first circuit in the containment and, in limited cases, gas leaks from the fuel rod cladding. It therefore becomes clear that the activity which has thus escaped in the containment represents a negligible quantity compared to the total inventory of radioactive substances contained in the core. Hence, the potential consequences of design basis accidents compared to the consequences of severe accidents are far less serious. On the INES Scale (see below), design basis accidents are classified at Levels 3 and 4.

In severe accidents, the reactor core is significantly degraded. In pressurized water reactors, 'severe accident' designates an accident in which the nuclear fuel melts down and, consequently, radioactive substances are released from the core to the containment and, subsequently, to the environment as well. On the INES International Scale, such accidents are classified at Levels 5 to 7.

The requirements applied to the design of new power plants differ substantially from the old projects in terms of the expanded use of defence-in-depth both to prevent severe accidents and to mitigate their effects. A severe accident may occur only after a multiple failure of the systems of the power plant or of the personnel at the various independent levels of defence-in-depth, e.g. upon failure of the primary coolant system followed by a persistent failure of off-site and, after that, of on-site power as well.

As a safeguard against such infinitesimally probable accidents, the new-generation nuclear power plants are equipped with special systems for management of such situations. The new nuclear power plants are designed in such a way that the probability of occurrence of severe accidents should be under 10^{-5} per reactor-year.

Regardless of the infinitesimal probability of occurrence of a severe accident in which the reactor itself would be damaged, a large quantity of radioactive substances could escape into the environment solely in case it comes to a release of these substances despite the next barrier: the air-tight shell (containment). Moreover, the containment is designed in such a way and is equipped with special systems so as to prevent the loss of its integrity even in severe accidents, e.g. upon interaction of the molten fuel with the concrete, upon combustion or explosion of hydrogen, upon impact of flying objects, upon overpressure etc. The cooling of the degraded core and the removal of heat from the containment is ensured in such a way that it would remain undamaged not only while the accident is in progress but also for a long time after that. A universally recognized international criterion of limiting a large radioactive release to the environment is the probability of occurrence of such circumstances of less than once in 1,000,000 years, i.e. 10^{-6} per reactor-year, which is ensured by an at least tenfold redundancy in the types of reactors in question.

The safety requirements to the new nuclear sources limit the possible radiological consequences of a severe accident, so that the release of radioactive substances should not cause either a significant public exposure or detriment to public health in immediate proximity to the nuclear power plant or lead to the imposition of long-term and large-area restrictions in the regulation of the food chains, in the use of the soil or of the water bodies. The limitation of radiological consequences must lead to a situation in which even a severe accident would not require an evacuation of the populated area in the nearest environs of the power plant nor other urgent protective actions (sheltering, iodine prophylaxis) outside the emergency planning zones of the nuclear power plant.

6.1.1.2 CHARACTERISTICS OF THE EVENTS ACCORDING TO THE INTERNATIONAL CLASSIFICATION SCALE

The International Nuclear and Radiological Event Scale (INES) was introduced in March 1990 simultaneously by the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency of the Organisation for Economic Cooperation and Development (OECD/NEA).

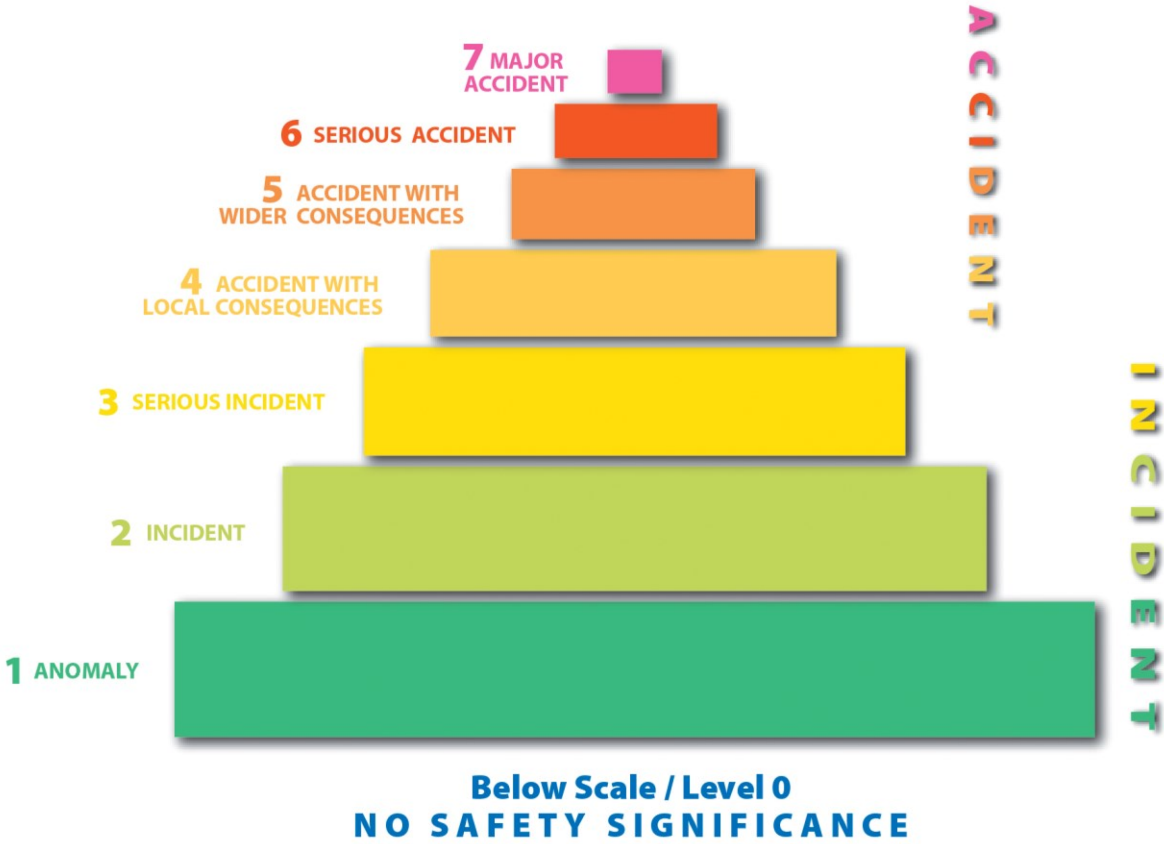


FIGURE 6.1-1: INES RATING SCALE FOR NUCLEAR EVENTS

The scale (**Figure 6.1-1**) classifies events at seven levels: the high levels (from 4 to 7) are designated “accidents”, and the low levels (from 1 to 3) are designated “incidents”. Events without any significance to nuclear safety are classified at Level 0 (Below Scale) and are called "deviations". Events unrelated to safety are designated "off-scale".

The expected impacts, radiological control and defences against events on this scale are set forth in **Table 6.1-1.**

TABLE 6.1-1: INTERNATIONAL NUCLEAR AND RADIOLOGICAL EVENT SCALE INES

Level	Hazard Rating Criteria		
	People and Environment	**Radiological Barriers and Control**	**Defence-in-Depth**
Level 7 ***Major Accident***	Major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures.		
Level 6 ***Serious Accident***	Significant release of radioactive material likely to require implementation of planned countermeasures.		
Level 5 ***Accident with Wider Consequences***	Limited release of radioactive material likely to require implementation of some planned countermeasures. Several deaths from radiation.	Severe damage to reactor core. Release of large quantities of radioactive material within an installation with a high probability of significant public exposure.	
Level 4 ***Accident with Local Consequences***	Minor release of radioactive material unlikely to result in implementation of planned countermeasures other than local food controls. At least one death from radiation.	Fuel melt or damage to fuel resulting in more than 0.1% release of core inventory. Release of significant quantities of radioactive material within a NPP with a high probability of significant public exposure.	
Level 3 ***Serious Incident***	Exposure in excess of ten times the statutory annual limit for workers. Non-lethal deterministic health effect (e.g., burns) from radiation.	Exposure rates of more than 1 Sv/h in an operating area. Severe contamination in an area not expected by design, with a low probability of significant public exposure.	Near accident with no safety provisions remaining. Lost or stolen highly radioactive sealed source. Misdelivered highly radioactive sealed source

Level	Hazard Rating Criteria		
	People and Environment	**Radiological Barriers and Control**	**Defence-in-Depth**
			without adequate procedures in place to handle it.
Level 2 ***Incident***	Exposure of a member of the public in excess of 10 mSv. Exposure of a worker in excess of the statutory annual limits.	Radiation levels in an operating area of more than 50 mSv/h. Significant contamination into an area not expected by design.	Significant failures in safety provisions but with no actual consequences. Found highly radioactive sealed orphan source, device or transport package with safety provisions intact. Inadequate packaging of a highly radioactive sealed source.
Level 1 ***Anomaly***			Overexposure of a member of the public in excess of statutory annual limits. Minor problems with safety components with significant defence-in-depth remaining. Low activity lost or stolen radioactive source, device or transport package.
Level 0 ***Below Scale***	No safety significance.		

One Level 7 accident (the Chernobyl accident) and one Level 6 accident (the accident at the Mayak nuclear fuel reprocessing plant) were registered until March 2011. On 12 April 2011, Japan's Nuclear Industrial and Safety Agency "provisionally" raised the incident at Fukushima to Level 7.

Figure 6.1-2 below presents the number of events between 2007 and 2011.

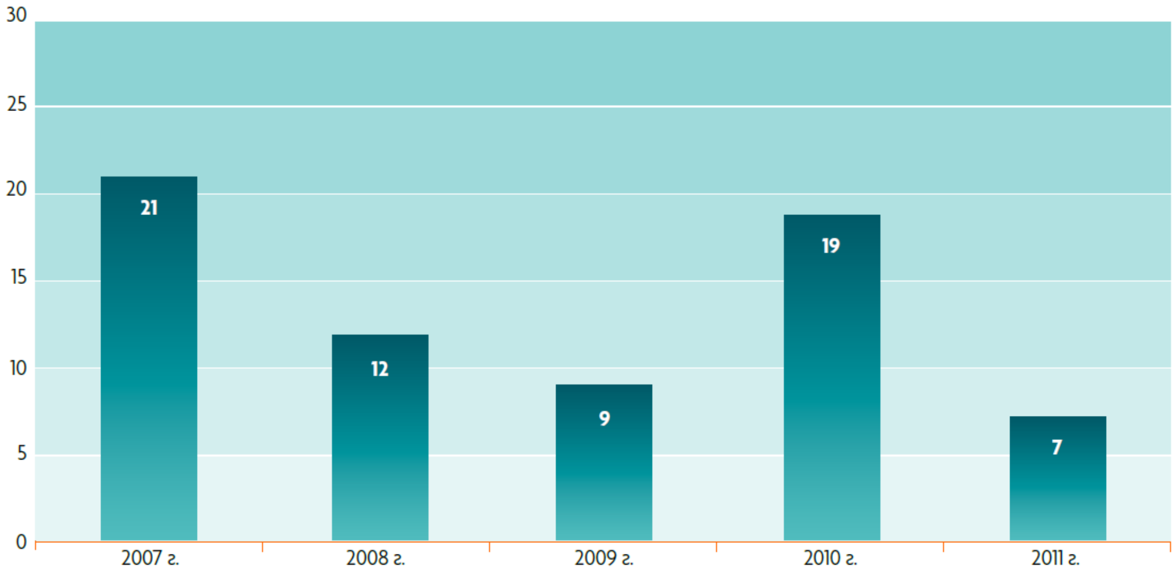


FIGURE 6.1-2: EVENTS ON THE INES SCALE WHICH HAVE OCCURRED AT THE KOZLODUY NPP SITE AND WHICH HAVE BEEN REPORTED TO THE NRA[1]

These events are as follows:

- ✓ For 2011, all seven events are rated as Level 0: below scale;
- ✓ For 2010, all 19 events are rated as Level 0: below scale;
- ✓ For 2009, nine operating events were registered, of which seven are rated at Level 0 (deviation), below the INES Scale, and two as off-scale. No events are rated at Level 1 (anomaly) or higher on the INES Scale;
- ✓ For 2008, one out of 12 operating events reported is rated "off-scale" in respect of the INES International Rating Scale for Nuclear Events, and 11 are classified at Level 0 (deviation): below the INES Scale;
- ✓ For 2007, out of a total of 21 registered operating events, two are rated "off-scale", and 19 are classified at Level 0 (deviation): below the INES Scale.

No event higher than Level 2 on the INES Scale has been registered for the entire operating experience of the existing units (some 150 reactor-years) at the site of the Kozloduy NPP. Overall, 52 Level 1 events and two Level 2 events have been registered and reported. No additional radiological impacts outside the Kozloduy NPP site have been identified for all these events.

6.1.2 CHARACTERISTICS OF THE ENVIRONMENTAL RISK OF RADIATION

After the release of radioactive substances from a nuclear facility, the population is immediately endangered by the moving cloud of radioactive gases and aerosols. The cloud

[1] Annual reports of the Kozloduy NPP EAD for 2007, 2008, 2009, 2010 and 2011.

is a source of both external and internal exposure as a result of the inhalation of radioactive substances.

During the movement of the cloud, radioactive aerosols are gradually deposited on the ground and contaminate it. The extent of ground contamination largely depends on whether rain has fallen during the movement of the cloud in the respective location. Even after the cloud has passed, the contamination of the ground surface causes internal and external exposure upon inhalation of the contaminated dust and may cause long-term environmental pollution, affecting to a varying degree humans, plants and animals. From the point of view of the health hazard, the significant transfer of radioactivity to the food chains is relevant to the population, as a result of which internal exposure is caused by ingestion, i.e. above all through consumption of contaminated farm produce.

The risk related to the potential effects of a radiation mishap (i.e. an event having as a consequence an uncontrolled release of radioactive material to the environment) can be assessed according to the scope of the actions necessary to protect the endangered population and according to the extent of contamination of the environment affected.

The exposure of humans and of the environment in a radiological emergency is limited by taking protective actions such as:

a. immediate protective actions, including sheltering, iodine prophylaxis and evacuation;
b. follow-up protective actions, including relocation, control of the ingestion of radionuclides from contaminated food and water and control of the ingestion of radionuclides from contaminated animal feed.

Protective actions in radiological emergencies are taken always when justified as more significant compared to the costs of the measures and damage triggered by the protective actions themselves, and must be optimized in respect of form, content and duration, so as to produce the most meaningful result possible.

Urgent protective actions are applied in the first hours and days after the occurrence of a nuclear or radiological emergency and include: provision of information; protection of the respiratory tract; sheltering; iodine prophylaxis; evacuation; individual and radiation monitoring; use of protective clothing; decontamination of victims and additional requirements to public and personal hygiene; restriction and control of access to the places and areas contaminated with radioactive substances; including restriction of the consumption of food products which are potentially contaminated with radioactive substances.

The longer-term protective actions applied in the course of weeks, months or years after the occurrence of a nuclear or radiological emergency include: temporary relocation or permanent resettlement; restriction of the consumption of food and feed contaminated with radioactive substances; decontamination of places and areas and of property contaminated with radioactive substances, as well as restriction of their use; recovery operations to normalize living conditions in the areas affected by the accident.

Urgent protective actions are considered always justified after the potential exposure of each individual may result in an immediate hazard to his or her health. Hence, urgent protective actions are taken whenever it is expected that in the course of less than two days the absorbed doses could exceed in each individual the levels shown in the following table, according to Ordinance on Emergency Planning and Emergency Preparedness in Case of Nuclear and Radiological Emergencies, adopted by Council of Ministers Decree No. 313 of 22 November 2011 and promulgated in the *State Gazette* No. 94 of 29 November 2011.

TABLE 6.1-2. INTERVENTION LEVELS BASED ON PROJECTED ABSORBED DOSE FOR 48 HOURS IN AN EXPOSURE DUE TO A NUCLEAR OR RADIOLOGICAL EMERGENCY [GY]

Exposed organ or tissue	Projected absorbed dose in less than 48 hours [Gy]
Whole body (bone marrow)	1
Lungs	6
Skin	3
Thyroid gland	5
Lens of the eye	2
Gonads	3
Foetus [1] (for pregnant women)	0.1

[1] *The possibility of direct detriment to the foetus by potential doses exceeding approximately 0.1 Gy must be taken into consideration when the current intervention level for urgent actions is justified and optimized*

A decision on the introduction of protective actions is made largely on the basis of the guide values applied, which reflect the current status of knowledge and the internationally acquired experience of when a particular protective action can be expected to do more good than harm. On the basis of case-specific data, using optimized radiation protection, these intervention-related reference levels are determined in emergency plans for each radiation activity or source of ionizing radiation which are likely to cause a radiological emergency.

Data specific to the determination of intervention levels refer, for example, to data characterizing the habitation and infrastructure in the vicinity of the source of ionizing radiation and conditioning the expected collective effective doses and the feasibility of the protective actions, especially the presence of specific groups of residents, the transport situation etc.

In making a decision on taking protective actions upon the occurrence of a radiological emergency, consideration should be given above all as to whether the current situation does not differ substantially from the conditions which applied when the levels were determined. With the present frequency of occurrence of a radiological emergency and an emergency after another accident such as the accidental release of hazardous chemicals or after a natural disaster, consideration should also be given to whether the introduction of a "radiological" protective action will not result in an increase of the detriment from those other accidents or disaster, and then on a larger scale than the contribution to a reduction of the exposure.

An intervention is not undertaken when:

- the annual effective dose for the population is less than or equal to 1 mSv, excluding the dose received from the natural background radiation of the area;
- the annual effective dose for the population is less than or equal to 5 mSv, under special circumstances – only in case the annual effective does will not exceed 1 mSv during the next five consecutive years.

In case the annual effective dose for the population is:

1. greater than the minimum intervention level but less than 10 mSv (boundary intervention level), apart from radiation level monitoring of the environment, farm produce and of the dose received by the population from external and internal exposure, measures are applied to limit the dose and to protect the population depending on the specific situation and circumstances;
2. equal to or greater than 10 mSv, but less than 20 mSv, including the dose received from the natural background radiation of the area, an intervention is undertaken to limit public exposure; the type and scope of the protective actions are determined with consideration for the radiation impact on the population indicated by the value of the collective effective dose for a period of 70 years; for persons settling in the limited habitation zone, detailed information on the possible health hazards of the radiation impact is provided to the Minister of Health;
3. greater than 20 mSv and less than or equal to 50 mSv, settling is not allowed and the permanent habitation of children and persons of reproductive age in the zone is prohibited; radiation level monitoring is conducted of the persons and the environmental media, and measures for radiological and medical protection of persons are applied;
4. greater than 50 mSv, permanent habitation is prohibited; agricultural activity is performed and the environmental resources are used after the issuance of express acts of the Council of Ministers; the personnel is subjected to radiation level monitoring and dosimetric checks, and measures for protection of the personnel are applied.

6.1.3 ACCIDENT EVALUATION METHODS

The methodology of evaluation consists of the following steps: identification of the source and subsequent calculation of the spread and environmental impact of the radioactive material.

6.1.3.1 Nuclide vector of the source

The term *nuclide vector of the source* means the quantity, isotopic composition and distribution in time of the radioactive substances which have escaped from the containment (the protective shell) into the environment.

The nuclide vector of the source is one of the most significant factors (along with the current meteorological conditions, the season, the demographics in the environs of the source etc.) determining the potential radiological effects of such an accident at the nuclear power plant. The composition of the nuclide vector of the source heavily depends on the specific design solutions, e.g. on the leak-tightness of the containment and its spatial location, on the chemical and physical form of the radionuclides (especially on their volatility and half-life), on the deposition and coagulation of the individual aerosols, on the operation of the systems trapping the fission products from the containment atmosphere, on the capacity and efficiency of the filtering systems, on the progression in time of the accident itself.

Each radiological emergency scenario analysed has a specific nuclide vector of the source whose parameters are derived from the extent of damage to the technological systems, the core inventory and the condition of the separate barriers.

The universally accepted conservative approach to safety analysis requires that the source be determined in such a way as the radiological effects corresponding to that source would be worse by a sufficient margin than the effects which, with an allowance for a certain uncertainty, would result from the later safety analyses for a specific reactor for the NNU. That is why the assumption of the radiological effects for the purposes of the environmental impact assessment may be more general, considering that it is made with a sufficient margin and that such an assessment for the specific project solution will be made in the Preliminary Safety Report.

6.1.3.2 Qualitative determination

The results of international studies of accidents, in which the proportion of individual radionuclides in the radiological effects has been evaluated, demonstrate the need to take into consideration the following main groups of fission products:

- radioactive noble gases (mainly Xe-133 with half-life of 5.2 days): a source of external human exposure from radioactive substances spread by the cloud; it should be said, however, that from the point of view of the long-term radiological effects of the accident this exposure is not that significant;
- iodine (mostly I-131 with half-life of 8.0 days): its exposure route is inhalation, it is deposited mostly in the thyroid gland, and its share is significant from the point of view of the short-term and medium-term effects of the accident, unless the deposition in the thyroid gland is blocked through timely stable iodine administration;

- caesium (mainly Cs-137 with half-life of 30 years): in a long term aspect, as a rule this is the principal source of external and internal exposure of persons affected by the accident as a result of contamination of the ground surface and other elements of the environment (water, flora) and, ultimately, as a result of contamination of particular foods in the food chain;
- the other fission products (above all Te, Sr, Ru, La, Ce, Ba) and actinides in smaller quantities are negligible in design basis accidents, and in the more serious accidents are less relevant than caesium but, nevertheless, mainly during the first post-accident year their share in the exposure of persons and elements of the environment and food chains must be taken into consideration.

It follows from the above that a comprehensive assessment of the immediate threat to humans in the vicinity of the nuclear facility requires that representatives of all groups of nuclides be included in the nuclide vector of the source, such as: Xe-133, I-131, Cs-137, Te-131m, Sr-90, Ru-103, La-140, Ce-141 and Ba-140. The calculations made on the basis of this nuclide vector of the source will enable an assessment of the radiological effects of potential accidents for the source and area concerned.

A simplified nuclide vector of the source, limited to I-131, Cs-137 and, possibly, Sr-90, as representative radionuclides, is suitable to characterize the environmental risk from the point of view of the long-term environmental load, and more specifically in case of a design basis accident.

In this case, the nuclide vector of the source is based on derivation of fission products and activation products of nuclear reactions in a fuel with UO_2, enriched with U-235, which is used as an energy source in all PWR type reactors under consideration. The presence and proportions of the various significant radionuclides are, therefore, determined by the objective laws of physics and do not depend on the particular design of the reactor or on its suppliers. That is why it is possible to determine a group of radionuclides whose presence in the nuclide vector of the source will be determining for the results of the safety analysis and to select from them such representatives that the simplified source composed of them could assess with sufficient accuracy the radiological effects of the whole inventory of radionuclides which has escaped into the environment at the accident.

The liberation of decay products from the molten fuel in a severe accident depends above all on their chemical and physical form. Generally, it is presumed that at the high temperature of the molten fuel, it liberates in the containment up to 75 – 100% radioactive noble gases (RNG), iodine and caesium (in design basis accidents, these are just tenths of a percentage point to whole percentage points). The rate of liberation of the rest of the radionuclides from the fuel in the containment is in the order of tenths of a percentage point to tens of percentage points. In a serious accident and with the integrity of the containment intact, only a fraction of the activity of the fuel decay products are liberated, depending on a number of factors (technical, structural).

6.1.3.3 QUANTITATIVE DETERMINATION

The total quantity of radioactive substances which could escape into the environment depends on the physical properties of the separate barriers and their current status at the moment of the event.

The quantitative determination of the nuclide vector of the source proceeds from the prerequisite of preserved containment integrity, with an allowance for escapes through admissible design leakiness and the so-called bypass containments. This prerequisite is justified by the fact that in all units under consideration the containment is equipped with special systems so as to prevent a loss of its integrity even in severe accidents caused by any of the relevant phenomena. Damaged core cooling and heat removal from the containment are ensured in such a way that the containment remains intact while the accident is in progress and for a long time after that.

Even though radionuclides can be liberated from the fuel into the containment atmosphere in the course of tens of hours, the calculation is based on the assumption that the entire quantity is liberated at once, immediately after the occurrence of the accident. Moreover, it is pessimistically assumed that the entire quantity of radionuclides is liberated from the containment into the environment at a constant rate in the course of 6 hours after the accident, even though in reality this liberation may continue for at least several days.

A nuclide vector of the source representing the long-term environmental impact, containing I-131 and Cs-137, was chosen for a design basis accident. This nuclide vector of the source is based on the European Utility Requirements (EUR) for LWR Nuclear Power Plants applicable to a third-generation nuclear power plant. According to EUR, the accident in question has a probability of occurrence approximating the value of 10^{-6}/year.

TABLE 6.1-3. NUCLIDE VECTOR OF THE SOURCE FOR DESIGN BASIS ACCIDENT

High-altitude emission		**Ground level emission**	
Radionuclide	TBq	Radionuclide	TBq
I-131	150	I-131	10
Cs-137	20	Cs-137	1.5

To generate the nuclide vector of the source for a severe accident, account is taken of the proportion of the inventory of radionuclides which has escaped from the damaged fuel in the containment according to the provisions of the U.S. Nuclear Regulatory Commission NUREG-1465.

The proportion of radionuclides which have escaped from the containment to the quantity of radionuclides present in the containment (determined according to the above method) has been arrived at using the requirements applied to the potential suppliers of the nuclear facility. The limit values for Xe-133, I-131 and Cs-137 have been determined on the basis of these requirements.

The values of the radionuclides liberated into the environment are proposed according to the method in question as follows:

Table 6.1-4. Table of the source element for a severe accident

Radionuclide	TBq
Xe-133	770,000
I-131	1,000
Cs-137	30

The values of the rest of the decay products have been recalculated from the limit values for Cs-137 in direct proportion to their relative concentration against Cs-137 in the containment atmosphere. The pertinence of this method has been tested through accessible descriptions of the source from comparable projects.

6.1.3.4 Calculation programme description

The projections of the radiological effects of severe accidents are set in the calculations made in a HAVAR-RP programme.

The following input parameters have been selected for calculation of the radiological effects of the emergency conditions:

Table 6.1-5. Table of the input parameters for calculation of the radiological effects in emergency conditions

Height of release	for design basis accident: 45 m, 100 m for severe accident: 45 m
Distribution of iodine forms	aerosol: 5 % organic: 5 % elementary: 90 %
Time of release	6 hours
Excessive heat rise of particles	Zero

Two selected meteorological conditions have been used for each of the calculations. The conditions have been selected in a way that the scenario modelled would produce the worst radiological results. The separate scenarios of the meteorological conditions vary above all in wind speed and weather category (possibly amount of precipitation). The weather category is according to the so-called Pasquill-Gifford atmospheric stability classification.

Table 6.1-6. Table of the separate scenarios of meteorological conditions

Scenario	1.	2.
Wind speed [m/s]	5	2
Atmospheric stability class	D	F
Amount of precipitation [mm/h]	10	0

The short-term (48 hours, 7 days, 30 days) individual exposure is the sum total of the contributions of the following impact pathways:

- external exposure from plume,
- inhalation (including from resuspension),
- external exposure from the radionuclides deposited on the ground.

In calculating the individual exposure dose for a period of one year, account is also taken of the internal exposure as a result of consumption of contaminated food products and water.

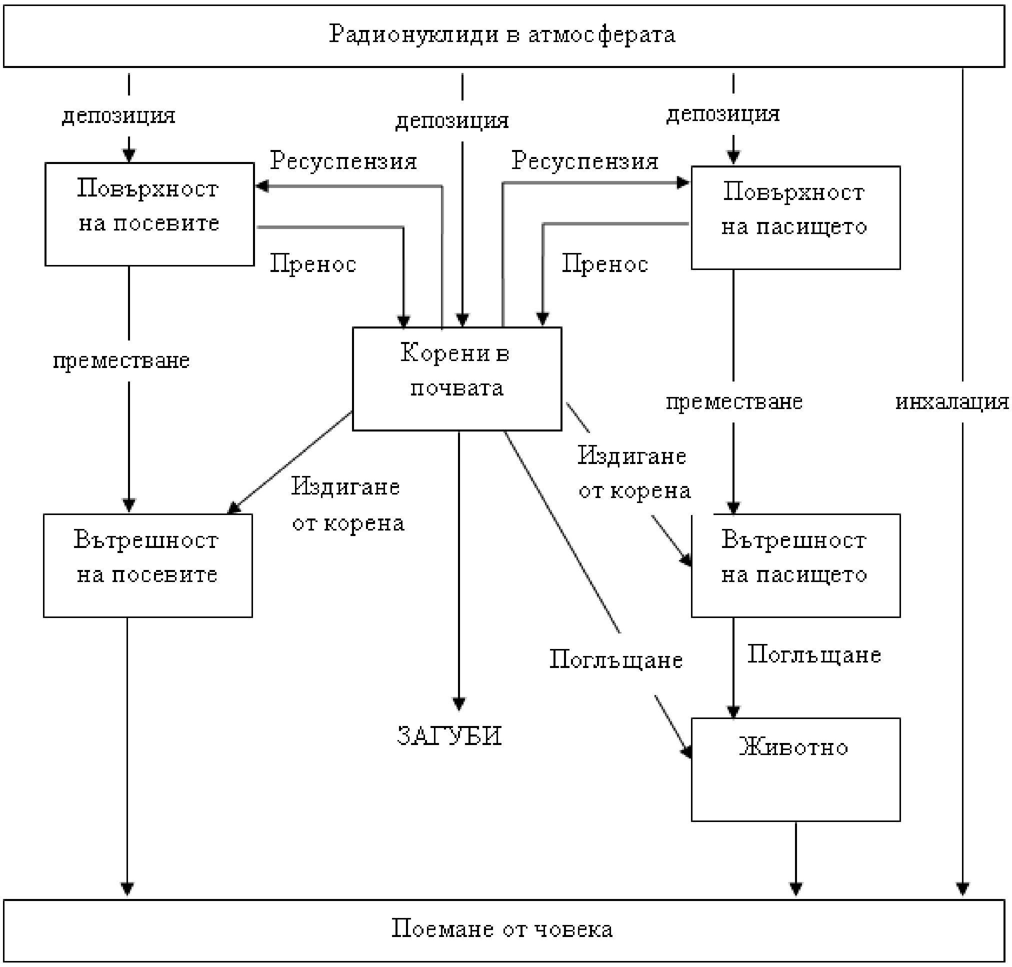


FIGURE 6.1-3: PRINCIPAL PROCESSES UPON TRANSFER OF RADIONUCLUIDES TO FOOD PRODUCTS

Radionuclides in atmosphere
deposition deposition deposition
Resuspension Resuspension
Crop surface Pasture surface
Transfer Transfer
translocation Roots in soil translocation inhalation
Root uptake Root uptake
Crop interior Pasture interior
Ingestion Ingestion
LOSSES Animal
Human intake

The transfer of radionuclides to food products is a complex of multiple processes and depends on the characteristics of the nuclides and the environment. **Figure 6.1-3** illustrates the most significant processes. The combined matrix of the values with the specific location of the population and agricultural production enables calculation of the collective doses.

More area-specific factors are determined in calculating the individual doses in the area of location of the Kozloduy NPP: information on the location of the individuals and on the points at which food products for human consumption are produced.

A radioactive-contaminated water body impacts humans by varied pathways which, however, can be grouped into external and internal exposure. The former requires direct human contact with the river (e.g. swimming, boat rowing etc.). The latter pathway (**Figure 6.1-4**) requires human consumption of food and water and intake of radionuclides by the human body down the food chains involving products originating directly from the water body or such products in the production of which water from the water body has been used (livestock watering, irrigation).

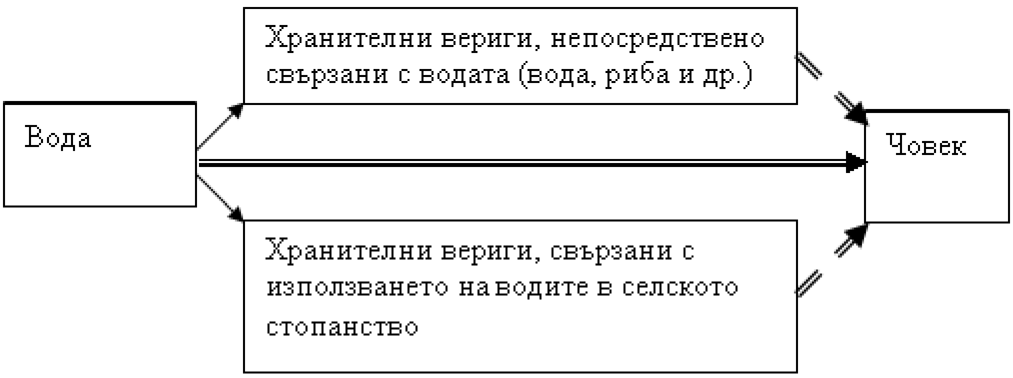


FIGURE 6.1-4: INTERNAL EXPOSURE

Food chains immediately related to water (water, fish etc.)
Water Human
Food chains involving use of water in agriculture

All these pathways have been examined. The physical movement and dispersion of water masses have been taken into consideration, along with the radioactive decay of radionuclides. The resulting concentration of radioactive substances in water and bottom sediments provides the input for calculation of the human intake through contact with the environment and ingestion and the subsequent individual and collective doses.

The results of internal exposure due to the annual intake through ingestion are expressed by values of 70-year radiation exposure to the effective doses for a child who is 1-2 years old at the moment of the accident (hereinafter “effective dose due to ingestion per year”). The same applies to calculating the “lifetime dose”, i.e. the sum total of doses from external exposure and the radiation exposures to the effective doses in a 70-year intake. In principle, the following factors influence the calculation of the results: decay time, the person's age, dry deposition velocity etc.

6.1.3.5 DESIGN BASIS ACCIDENT

Scenario 1 meteorological conditions have been selected for assessment of the impact of design basis accidents. Two different height levels of release have been selected. The high-altitude emission has been modelled for a height of 100 m, and the ground level emission for a height of 45 m.

The annual effective dose and the lifetime dose with digestion and without digestion in a design basis accident are presented by charts in **Figure 6.1-5** and **Figure 6.1-6.**

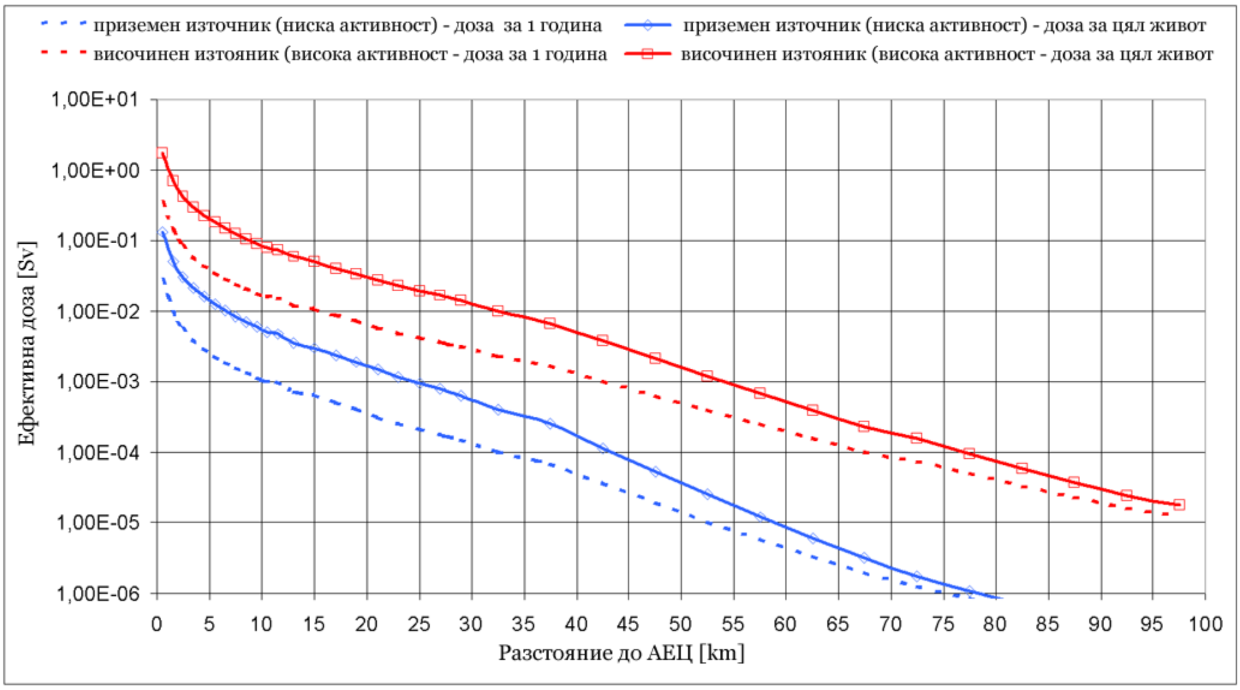


FIGURE 6.1-5: DESIGN BASIS ACCIDENT, EFFECTIVE DOSE FOR 1 YEAR [SV] AND LIFETIME DOSE, WITH INGESTION

ground level source (low activity): dose for 1 year *ground level source (low activity): lifetime dose*
elevated source (high activity): dose for 1 year *elevated source (high activity): lifetime dose*
Effective dose [Sv]
Distance to NPP [km]

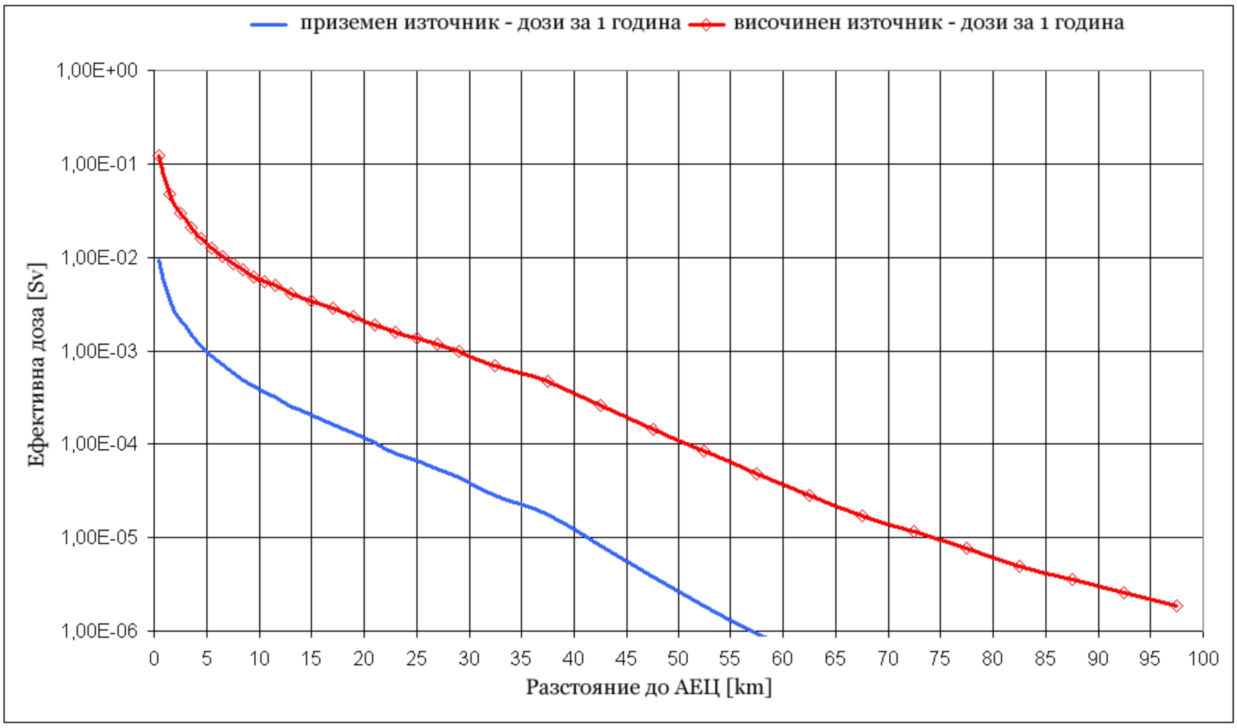


FIGURE 6.1-6: DESIGN BASIS ACCIDENT, EFFECTIVE DOSE FOR 1 YEAR [SV] AND LIFETIME DOSE, WITHOUT INGESTION

ground level source: dose for 1 year elevated source: dose for 1 year
Effective dose [Sv]
Distance to NPP [km]

6.1.3.6 SEVERE ACCIDENT

Both scenarios of meteorological conditions have been selected for modelling the effect of a severe accident, with long-term measures being modelled on the basis of scenario 1 involving precipitation which aggravates the short-range impact. The values of the effective doses of external exposure are presented in **Figure 6.1-7.**

Urgent protective actions can be expected in a severe accident. The maximum size of the potential evacuation zone is 1 km. The maximum size of the potential shelter zone is 8 km.

The shares of the separate exposure pathways in the lifetime dose are presented by charts in **Figure 6.1-8** and **Figure 6.1-9**. According to estimates, the contribution of ingestion to the total dose is approximately 71% at the boundary of the emergency planning zone at a distance of 12-14 km and up to 52% at a distance of 45-50 km.

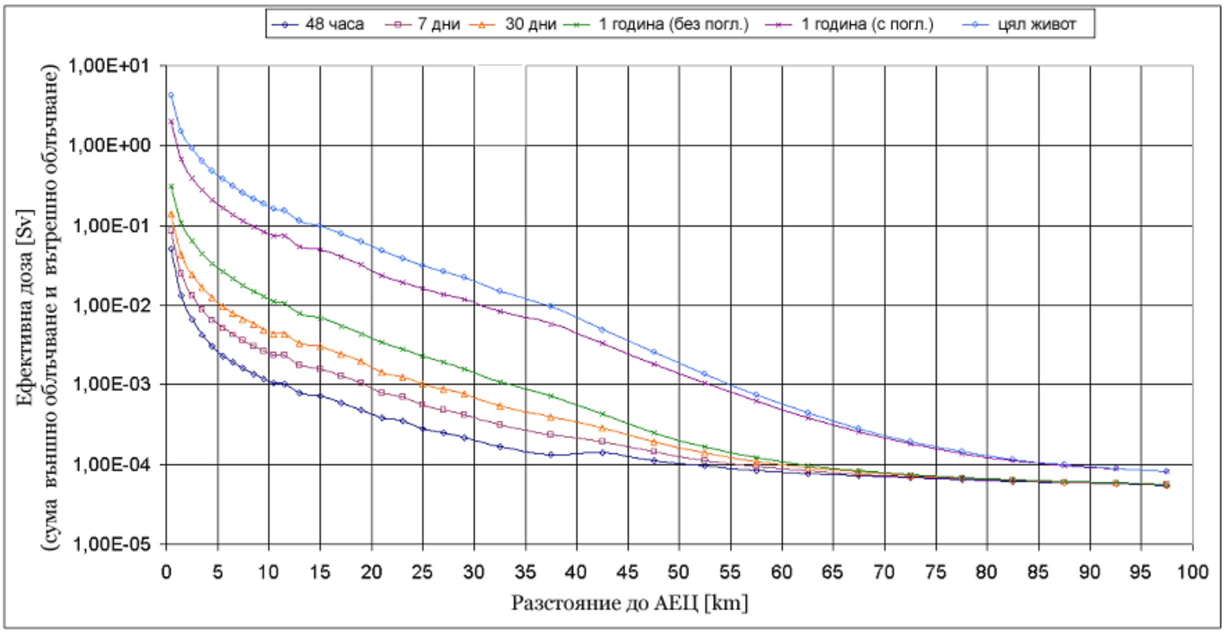


FIGURE 6.1-7: SEVERE ACCIDENT. SCENARIO 1. VALUES OF THE EFFECTIVE DOSES OF EXTERNAL EXPOSURE AND INTERNAL EXPOSURE [SV]

48 hours 7 days 30 days 1 year (without ingestion) lifetime
Effective doze [Sv]
(sum total of external exposure and internal exposure)
Distance to NPP [km]

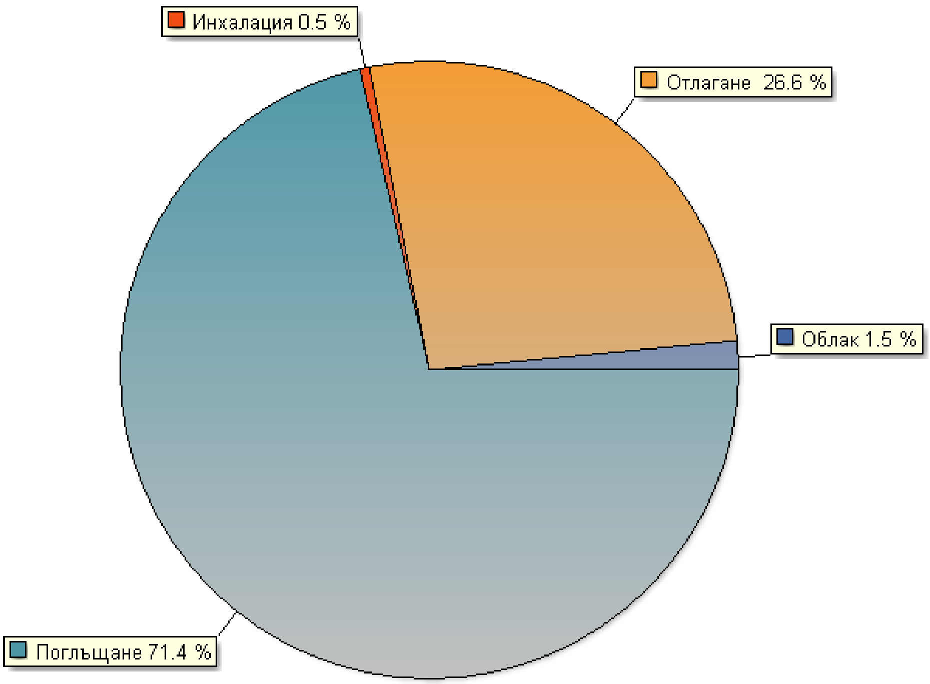


FIGURE 6.1-8: SHARE OF EXPOSURE PATHWAYS FOR THE DOSES [%] AT A DISTANCE OF 12-14 KM

Inhalation 0.5% Deposition 26.6% Cloud 1.5% Ingestion 71.4%

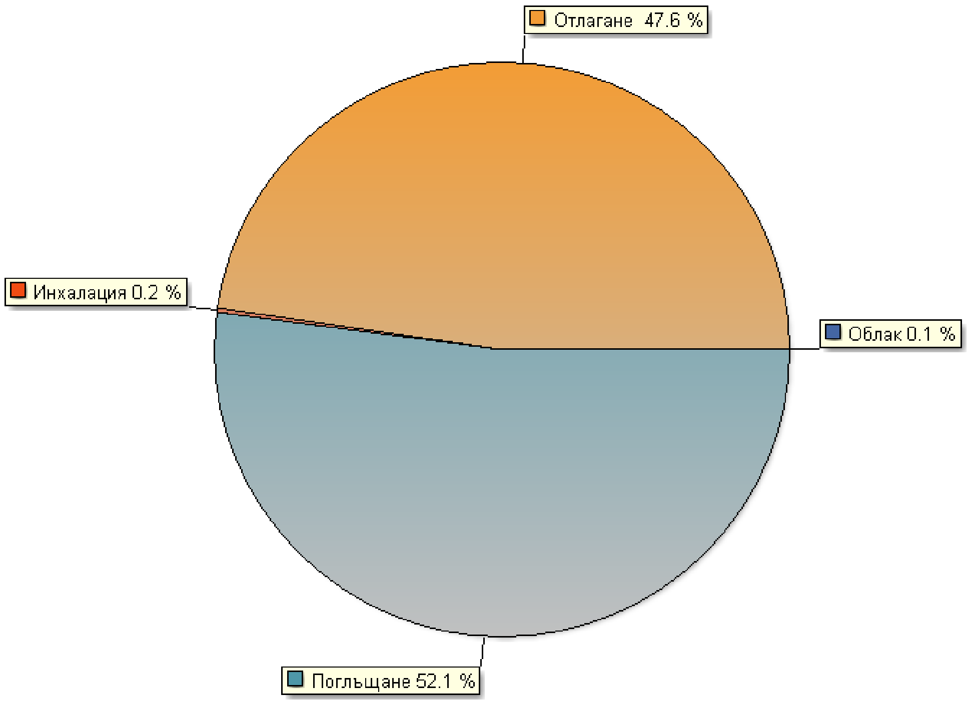


FIGURE 6.1-9: SHARE OF EXPOSURE PATHWAYS IN A DOSE [%] AT A DISTANCE OF 45-50 KM

Deposition 47.6% Inhalation 0.2% Cloud 0.1% Ingestion 52.1%

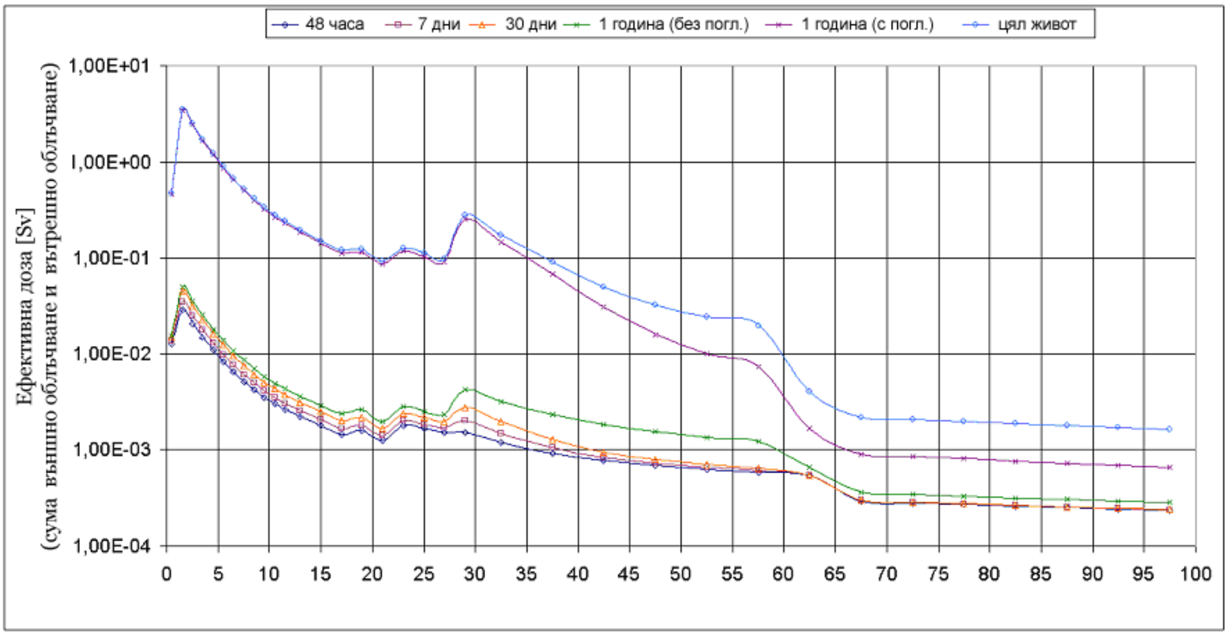


FIGURE 6.1-10: SEVERE ACCIDENT. SCENARIO 2. VALUES OF THE EFFECTIVE DOSES OF EXTERNAL EXPOSURE AND INTERNAL EXPOSURE [SV]

48 hours 7 days 30 days 1 year (without ingestion) lifetime
Effective doze [Sv]
(sum total of external exposure and internal exposure)

6.1.3.7 CONCLUSION

The analyses conducted invite the conclusion that the radiological results of the accidents analyzed demonstrate that the environmental risks are acceptable.

The results of the assessment of design basis accidents show that for a random hypothetical design accident, human exposure does not require the undertaking of any urgent protective actions whatsoever even in the habitable zone in the nearest vicinity to the NNU.

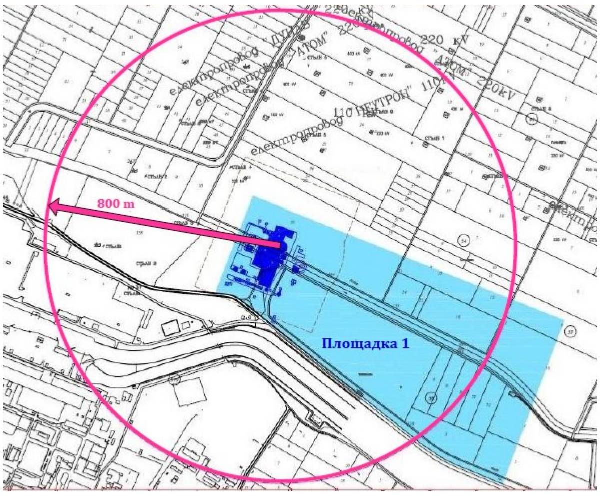
The models of radiological effects of severe accidents did not exceed the threshold values for undertaking urgent protective actions beyond the boundaries of the existing emergency planning zones of the Kozloduy NPP. As to follow-up protective actions, permanent resettlement is not expected even in the nearest populated zone around the NNU (the threshold value of the dose of 1 mSv will not be surpassed). In this case, the regulation of the distribution and consumption of farm produce within 30 km of the source depending on the direction of contamination should not be ruled out.

In conclusion, it should be summed up that in accordance with expectations, more than half of the total exposure will be incurred by the pathway of ingestion. Consequently, the imposition of a short-term restriction on the consumption of locally grown products would be crucial for a reduction of the dose received.

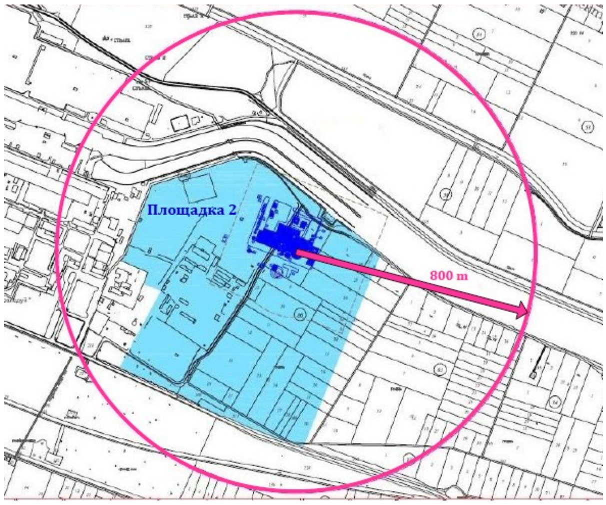
The actual scope and place of conduct of follow-up protective actions would depend on the movement and progression of the accident and the actual meteorological conditions, and in the cases of long-term measures, on a comprehensive monitoring of the area affected.

6.1.4 POSITION RELATIVE TO THE EXISTING EMERGENCY PLANNING ZONES

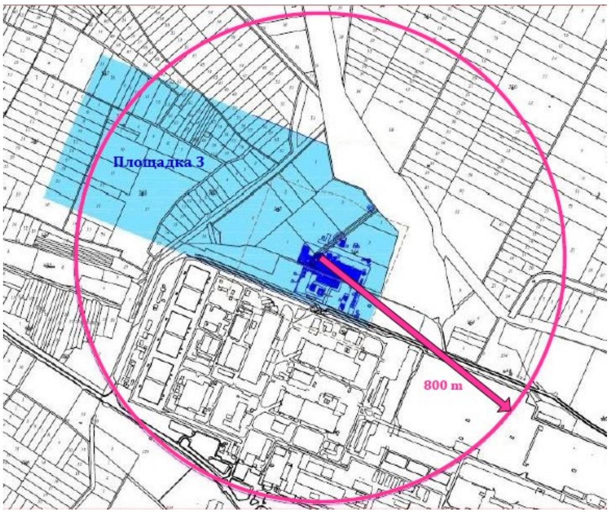
The investment intention for construction of a NNU at one of the alternative four sites envisages building of a unit of the PWR III or III+ generation type. According to the requirements of EUR, a circular area of 800 m in radius is established around the building in which reactors of this type are housed (the radius is even smaller for some reactor models) for the purposes of radiation protection: **Figure 6.1-11**. According to the requirements of the statutory instruments in the Republic of Bulgaria, this area corresponds to a precautionary action zone.



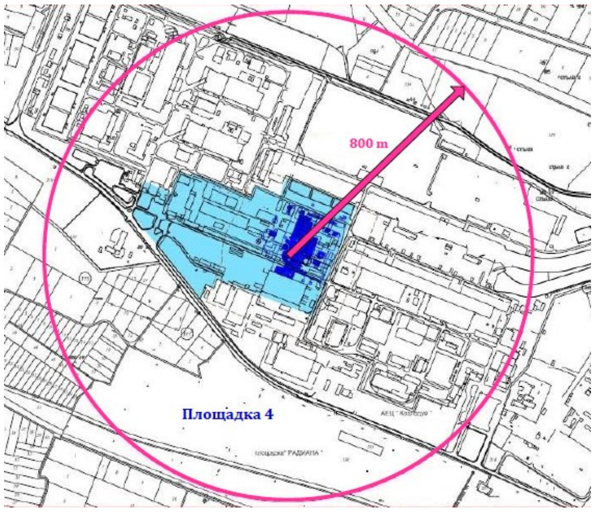
Site 1



Site 2



Site 3



Site 4

Figure 6.1-11: 800 m radiation protection areas for all alternative sites

6.1.4.1 Special-statutory areas

A REGULATION on the Conditions and Procedure for Establishing of Special-Statutory Areas around Nuclear Facilities and Installations with Sources of Ionizing Radiation (2004) establishes the conditions and procedure for defining the sizes, boundaries and regime of special-statutory areas around nuclear facilities and installations with sources of ionizing radiation. According to Article 2 (2), there are two special-statutory areas:

1. Radiation protection area;
2. Surveillance area (SA).

The boundaries of the radiation protection area and of the surveillance area are defined at the design stage of NNU taking into account: the risk category; the design calculations and analysis of potential releases of radioactive substances to the environment during normal operation and in an accident; the peculiarities of the spread of gaseous and aerosol releases into the atmosphere and the migration of radionuclides to the environmental media; the hydrological, hydro-geological and climate data; the existing and design boundaries of urbanized areas; the demographic and social characteristics, including the living conditions and conditions for public activities; the development prospects of the area and other factors relevant to establishing the areas. The methodology for defining the sizes of the special-statutory areas is endorsed by the Chairman of the Nuclear Regulatory Agency (NRA).

The outermost boundary of the **Radiation Protection Area** is defined in compliance with specified criteria (Article 4 of the Ordinance), such as:

1. The annual individual effective dose of public exposure during normal operation of the nuclear facility or an installation with a source of ionizing radiation must not exceed the dose limits statutorily prescribed in Article 26 (3) of the Act on the Safe Use of Nuclear Energy;
2. The annual individual effective dose in case of a design basis accident must not exceed 5 mSv outside the boundaries of the radiation protection area.

When a single site is used for more than one nuclear facility or installation with a source of ionizing radiation, the cumulative impact of all facilities or installations at the site must be taken into account.

The outermost boundaries of the **Surveillance Area** are defined in Article 5 of the Regulation.

The Radiation Protection Area is a special planning-protection area whose sizes and boundaries are defined by a specific detailed plan under Article 111 of the Spatial Development Act.

The Surveillance Area around a nuclear facility or an installation with a source of ionizing radiation is established by an order of the Chairman of the NRA depending on the factors of nuclear safety and radiation protection, taken into consideration in a developed technical design.

6.1.4.2 Emergency planning zones

The following emergency planning zones have been defined around the Kozloduy NPP site, according to Annex 3.1-1 to the Emergency Plan of Kozloduy NPP EAD, in order to ensure a prompt and adequate response upon the occurrence of an emergency in accordance with Risk Categories I, II and III and the limit dose criteria under the REGULATION on Emergency Planning and Emergency Preparedness of Nuclear and Radiological Emergencies (promulgated in the *State Gazette* No. 94 of 29 November 2011):

- **On-site Emergency Planning Zone – *Protected Zone* No. 1,** the site of Kozloduy NPP EAD;
- **Precautionary Action Zone (PAZ) – Zone No.2,** with a radius of 2 km and a geometric centre between the ventilation stacks of Units 5 and 6: the green circle in **Figure 6.1-12.**

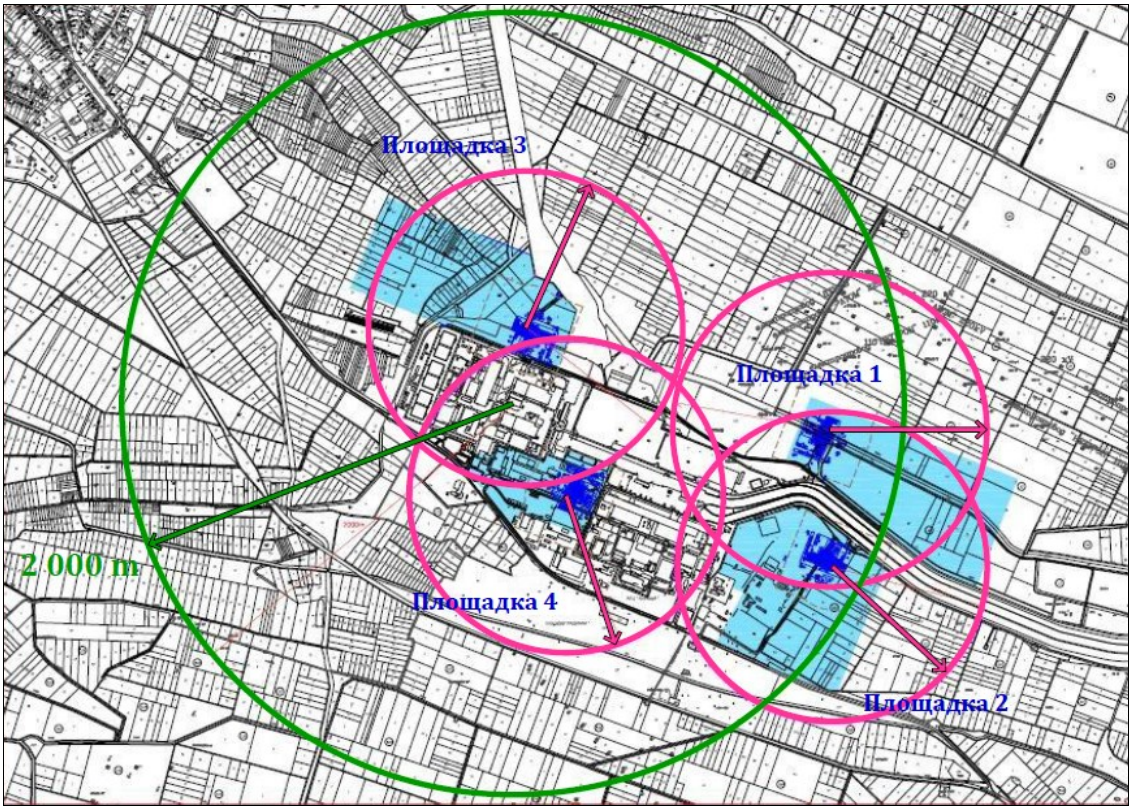


FIGURE 6.1-12: SAFETY ZONES FOR EACH ALTERNATIVE SITE AND EXISTING PAZ (2,000 M) AROUND UNITS 5 AND 6

Site 1 Site 2 Site 3 Site 4

The PAZ, defined in the emergency plan under the Regulation on Emergency Planning and Emergency Preparedness of Nuclear and Radiological Emergencies (2011), is coextensive with the **Radiation Protection Area,** defined as a special-statutory area under the Regulation on the Conditions and Procedure for Establishing of Special-Statutory Areas around Nuclear Facilities and Installations with Sources of Ionizing Radiation (2004), in which the annual individual effective dose in case of a design basis accident must not exceed 5 mSv.

At a later stage, after selection of a specific reactor model, the emergency planning will also have to take into consideration the results of the evaluation of the safety of the NNU and a new safety evaluation will have to be prepared for the entire Kozloduy NPP site , which will define the new **Radiation Protection Area** around Units 5 and 6 and the NNU implemented at one of the alternative sites.

The existing 2,000 m **PAZ** may be modified in respect of its surface area, being expanded by some 300 m eastward in case the NNU is implemented on Site 1 and 2 (**Figure 6.1-12**). The new boundaries can be defined after selection of a specific reactor model and after a detailed analysis.

The designs of a reactor model for the NNU must also be assessed against the requirements of EUR, taking account of several parameters: **Table 6.1-7.**

TABLE 6.1-7: VALUES ENVISAGED FOR OFF-SITE RELEASES IN SEVERE ACCIDENTS

No Emergency Protection Action beyond 800 m from the reactor upon releases from the containment	Emergency Protection Action: Actions involving public evacuation, based on projected doses up to seven days, which may be implemented during the emergency phase of an accident, e.g. during the period in which significant releases may occur. This period is usually shorter than 7 days. The sum total of soil and aerial releases during the whole period of releases must be checked against the reference values for each isotope: ^{131}I - 4000 TBq ^{137}Cs - 30 TBq ^{90}Sr - 400 TBq
No delayed action at any time beyond 3 km from the reactor	Delayed action: Actions involving temporary public relocation based on projected doses up to 30 days, caused by groundshine and aerosol resuspension, which may be implemented after the practical end of the release phase of an accident.
Non-application of long-term action beyond 800 m from the reactor	Long-term action: Actions involving public resettlement, based on projected doses up to 50 years caused by groundshine and aerosol resuspension. Doses due to ingestion are not considered in this definition.

→ **Urgent Protective Action Planning Zone (UPAPZ) – Zone No. 3**, with a provisional radius of 30 km.

The UPAPZ is not expected to be modified in connection with the construction of a NNU. In all cases, after selection of a specific reactor model, an analysis to this end will be conducted.

6.1.5 Radiation hazards during the IP preparation and implementation phase

Building and structural works during the preparation and implementation of the investment proposal are not of the nature of radiation activity.

6.1.6 Radiation hazards during the NNU decommissioning phase

Upon the decommissioning of the NNU, the nuclear fuel will first be moved to the reactor pool. The systems will be gradually cooled, depressurized, dried and decontaminated, which will limit the sources of the potential risk of radiation contamination. The activities carried out during decommissioning will take place with ensured nuclear safety, radiation protection, emergency preparedness and physical protection, on the basis of the then valid/current permits and applicable legislation. In this connection, the risk to the environment and to human health, compared to the preceding operation of the NNU, is expected to be considerably lower.

6.2 Assessment of the parameters of human induced impacts at the site of the plant

6.2.1 Aircraft impact

In respect of an aircraft impact, two main types of impact may be considered: incidental aircraft crash within the perimeter of the plant and premeditated steering of an aircraft to a particular facility at the site of the plant. The present assessment focuses on the identification of the parameters of an incidental aircraft crash at the site. With regard to the aircraft crash, three types of events have to be considered:

- ✓ Type 1 event: A crash at the site deriving from General Aviation[2] in the area of the site.
- ✓ Type 2 event: A crash at the site as a result of a take-off or landing operation at a nearby airport.
- ✓ Type 3 event: A crash at the site owing to air traffic in the main traffic corridors of regular Civil Aviation[3] and traffic in the military flight zones.

6.2.1.1 Aircraft crash: Type 1

For a Type 1 aircraft crash, the risk of crashes involving non-scheduled civil aviation in the area of the site is assessed. The probability of a light aviation aircraft crashing at a site of a given nuclear facility, considered as an area of 0.1 to 1.0 km^2, is evaluated for a region of

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[2] All types of air transport of passengers and cargo, as well as specialized air services, other than such operating to a schedule and on a fixed route. This type of aviation includes: flying ultralight and light aircraft, sports flying, pilot training and instructional flying, search and rescue flights and medical emergency service flights, aerial fire fighting, agricultural flying, business jet flying, test flights etc.

[3] All types of air transport of passengers and cargo which is operated to a schedule and on a fixed route by the relevant airlines

100-200 km in radius according to *External Human Induced Events in Site Evaluation for Nuclear Power Plants*, IAEA Safety Guide No. NS-G-3.1 (2001).

In the area of the Kozloduy NPP, this type of air traffic is generated mainly by agricultural aviation which consists of light aircraft / light aviation (aircraft with maximum take-off weight of less than 5,680 kg are classified as light aviation), which fly at a low altitude and are not subject to control by the Air Traffic Services Authority State Enterprise (unless they enter aircraft zones and air traffic corridors). Owing to this reason, sufficient reliable information on this type of traffic in the area of the Kozloduy NPP is not available.

Since the probability of a Type 1 aircraft crash will be practically the same for each of the potential sites, a more detailed examination of this impact is not necessary at this stage. On the basis of general considerations, it can be concluded that owing to the significantly lower take-off weight of aircraft of this type of aviation (compared to Type 3), the parameters of the impact on the facilities at the site (mechanical shock, vibration impact and fire) will be significantly lower.

6.2.1.2 AIRCRAFT CRASH: TYPE 2

According to *External Human Induced Events in Site Evaluation for Nuclear Power Plants*, IAEA Safety Standards Guide No. NS-G-3.1 (2001), the potential hazard posed by aircraft crash must be taken into account if:

1. airways or airport approaches pass within 4 km of the site;
2. airports are located within 10 km of the site;
3. large airports are located within 16 km of the site and the number of flight (landing and take-off) operations is greater than $500d^2$, where d is the distance in kilometres to the airport;
4. where large airports are located at a distance greater than 16 km, the hazard should be considered if the number of flight operations is greater than $1000d^2$;
5. in case of air space usage within 30 km of the plant for military training flights.

There are no large civil airports within 30 km of the Kozloduy NPP. The airport nearest to the site is the airport in Craiova, which is located at 68 km from the plant. To warrant consideration, the airport must have 4,624,000 yearly flight operations, which is 10^4 more than its actual traffic (3,394 operations for 2010). The largest airport near the sites under consideration is Sofia Airport, with 44,171 flight operations in 2012. Owing to the great distance to the plant, it, too, cannot generate a hazard of a Type 2 aircraft crash for the sites under consideration.

6.2.1.3 AIRCRAFT CRASH: TYPE 3

The hazard of an airport crash at the site depends on the intensity of air traffic (the number of flights) in the area around the site and the frequency of aircraft accidents (number of accidents per number of flights). Statistics of the civil aviation flights within 30 km and 100 km of the Kozloduy NPP have been compiled for the purposes of the present study.

For 2012, the air traffic amounted to 43,696 flights within 30 km of the Kozloduy NPP and to 252,361 flights within 100 km (compared to 548,482 flights for the entire air space of Bulgaria)[4]. According to the forecasts of Eurocontrol for the 2010-2030 period, air traffic over Bulgaria is expected to grow by an average annual 4% (on the basis of four scenarios with different hypotheses about the development of the global economy), and by 2030 the traffic is expected to be between double and treble its level in 2010. Therefore, for a 60 year operating experience of the new nuclear unit it can be presumed that the growth of air traffic over Bulgaria for the 2030-2070 period within 30 km of the site will approximate 4.8 million aircraft (an average 80,000 annually). Accordingly, approximately 28 million aircraft are expected to pass within 100 km of the site, or an average of 460,000 per year.

According to data of the Statistical Summary of Commercial Jet Airplane Accidents, World Wide Operations, 1959-2011, the frequency of fatal aircraft crashes is 0.39 per 1 million flights, with 11% of all accidents occurring in-flight, i.e. it can be assumed that the frequency of in-flight air crashes is $4x10^{-8}$. The annual probability of an aircraft crash on any of the sites under consideration can be calculated using the following formula:

$$P(y) = N(y).f(y).\left(\frac{A_s}{A_z}\right),$$

where *P(y)* is the annual probability of an aircraft crash at the site, *N(y)* is the yearly number of flights within the distance concerned, *f(y)* is the frequency of in-flight accidents, A_S is the surface area of the site concerned, A_Z is the surface area of the zone for which the flight statistics have been compiled. The annual probability of an aircraft crash at one of the sites under consideration (on an area of 0.5 km^2) obtained in this way is $5.66x10^{-7}$ based on traffic data within 30 km of the site and $2.53x10^{-7}$ based on traffic data within 100 km of the site.

According to *External Human Induced Events, Site Evaluation for Nuclear Power Plants*, IAEA Safety Guide No. NS-G-3.1 (2001), some States have decided to design all nuclear facilities against aircraft crash impact in case the probability of such an event calculated for an area of 1-4 km^2 is equal to or greater than 10^{-6}. Employing this criterion, the values obtained for the annual probability of an aircraft crash will be in the range of $1.13x10^{-6}$ to $4.52x10^{-6}$ based on traffic data within 30 km of the site and $5.86x10^{-7}$ to $2.34x10^{-6}$ based on traffic data within 100 km of the site.

National legislation does not define minimum values for a Screening Probability Level (SPL) of an aircraft crash type of impact which, when exceeded, should warrant giving consideration to the design bases for the nuclear facility.

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[4] Information on flights in the air space over Bulgaria. 2012. Air Traffic Services Authority State Enterprise. Sofia

According to the REGULATION on Ensuring the Safety of Nuclear Power Plants (2004), sources of human induced hazards may not be neglected if their frequency of occurrence is greater than or equal to $1x10^{-6}$. The IAEA documents[5] mentions a tentative value for SPL of 10^{-7} per reactor-year.

Consequently, due to the low probability, an aircraft crash impact is not expected.

6.2.2 LEAK OF HAZARDOUS FLUIDS AND GASES

The leak of hazardous (explosive, flammable, corrosive and toxic) fluids and gases near the site is another event which may lead to problems with the safety of the new nuclear unit. Particular attention should be given to the following types of substances:

- Flammable gases and vapours, which can form explosive clouds and can enter ventilation system intakes and explode in a particular nuclear facility or facility responsible for safety;
- Toxic gases, which can threaten human life and hence impair some of the safety functions;
- Corrosive and radioactive gases and liquids, which can threaten human life and hence impair some of the safety functions.

According to the IAEA documents, consideration must be given to all possible sources of hazardous fluids and gases for which the SDV (screening distance value) is less than 8-10 km. Within 10 km of the potential sites for a new nuclear unit, the principal potential sources of hazardous gases are:

- → Facilities at the Kozloduy NPP site
- → UGS Chiren – Kozloduy – Oryahovo Gas Pipeline (planned)
- → South Stream Gas Pipeline (planned)
- → Nabucco Gas Pipeline (planned)

6.2.3 FACILITIES AT THE KOZLODUY NPP SITE

A document entitled “Analysis of the possibility of occurrence of industrial accidents outside the buildings of the generating units within the perimeter of the Kozloduy NPP” analysed the substances used at the NPP, their quantity and manner of storage and transportation in order to elaborate several scenarios for the “progression, scale, scope and possible effects of accidents involving the most hazardous chemical substances” used and stored at the site. Regarding the release of hazardous fluids and gas, the following emergencies can be singled out:

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[5] *External Human Induced Events in Site Evaluation for Nuclear Power Plants*, IAEA Safety Standards Series No. NS-G-3.1 (2001)

- Gas release as a result of an accident involving the stationary tank for nitric acid at the Chemical Cleanup Facility to Electroproduction-1;
- Gas release as a result of an accident involving a hydrazine hydrate drum during its transportation;
- Gas pollution of the environment with toxic products upon the interaction of inter-reacting substances;
- Release of hazardous fluids within the perimeter of the NPP.

The cited hazards of occurrence of emergencies have a low degree of probability and, therefore, no impact is expected.

6.2.4 NABUCCO AND SOUTH STREAM GAS PIPELINES

The analysis made of the incidents which have occurred in underground gas pipelines, as well as of the structure and location of the gas pipeline[6], [7], owing to the high pressure in the pipe the gas cloud formed will rapidly ascend. This process will continue until its complete atmospheric dispersion. The time of existence of this cloud will not exceed 250 -330 s. **In no situation can the gas reach the ground surface and linger on it and, therefore, an impact is not expected.**

6.2.5 EXPLOSIONS

6.2.5.1 FACILITIES AT THE KOZLODUY NPP SITE

Of the facilities considered in the report **Analysis of the possibility of occurrence of industrial accidents outside the buildings of the generating units within the perimeter of the Kozloduy NPP EAD,** 2007, the hydrazine hydrate storage facility and Storage Facility No. 106 are potential sources of explosions.

6.2.5.2 EXPLOSION IN THE HYDRAZINE HYDRATE STORAGE FACILITY

It has been established that an explosion in the hydrazine hydrate storage facility is impossible because the ignition temperature of hydrazine hydrate is 59°C, i.e. considerably above the temperature at which the product is stored. This means that if hydrazine hydrate spills, a combustible medium above its surface cannot form and, consequently, an explosion of the vapours is impossible.

No impact is expected.

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[6] Risk assessment of the Nabucco Gas Pipeline in the area of the Kozloduy NPP. Final Report. November 2012. Risk Engineering AD

[7] Simulation through mathematical modeling of emergency events along the route of the South Stream Gas Pipeline – Bulgarian sector in the area of the Kozloduy NPP, 03-06/01-SSB-MODEL/KzNPP PJSC YUZHNIIGIPROGAZ and GASTEC BG AD, 2012

6.2.5.3 Explosion in Storage Facility No. 106

A large number of combustible liquids are kept in Storage Facility No. 106. An analysis of the possibility of explosion of the vapours of these liquids shows that a breach of the integrity of an ethyl alcohol canister would have the most serious consequences. The capacity of these canisters in the storage facility is 38 litres. The projection of the effects of such an incident will be made proceeding from the following assumptions:

- Mishandling of the packagings has led to a total breach of the integrity of one of the ethyl alcohol canisters;
- The alcohol has spilled on the floor of the storage facility, and the spill is not contained by the walls (the spill occupies the largest possible surface);
- The unobstructed evaporation of the alcohol has been in progress for up to 1 hour;
- The air within the storage facility is motionless and the ventilation vents are closed;
- An accidental source of ignition ignites the explosive medium formed.

The calculations in the document show that the overpressure which will occur in the storage facility upon the combustion of 21.41 kg of alcohol vapours (28 litres of ethyl alcohol) is 18 kPa, which can be expected to produce the following effects:

- The glass components of the storage facility will be shattered;
- The doors and windows will be dislodged;
- The plastering will be damaged;
- The shock wave will lead to a breach of the integrity of other containers of hazardous substances: incompatible substances may be mixed and the accident may be aggravated, and toxic substances and products of the reactions between substances may spill out of the storage facility.

If the fire protection rules for availability of means to suppress fires of combustible materials or other hazardous substances are observed, the impact will be local, confined to the site of the storage facility, temporary, short-term and reversible.

6.2.5.4 Explosion in an on-site filling station

According to the analyses made in a report entitled **Studies and activities for enhancement of security at the Kozloduy NPP siteby Energoproekt, Sofia, 1992,** the impact on safety is assessed and organizational measures are proposed to avert and reduce the effects of an explosion in a filling station owned by the Kozloduy NPP and located within the perimeter of Truck Shed No. 2: the total quantity of the automotive petrol stored at the filling station must not exceed 3 tonnes.

Acting on this recommendation, the impact of a potential explosion of automotive petrol in the on-site filling station of the NPP on neighbouring installations and facilities within the perimeter of the Kozloduy NPP has been analyzed and assessed[8], with the results showing that if automotive petrol explodes the existing nuclear facilities and elements of the safety systems will not be affected. Therefore, the same applies to the NNU as well. **The impact will be local, confined to the site of the filling station, short-term and reversible.**

6.2.6 OFF-SITE FLOODING

The sources of potential off-site flooding are the maximum possible natural water levels of the River Danube, a rupture of the dam walls of the Iron Gates hydropower project, an accident at the Shishmanov Val Dam, slope water from the Marishkin Dol locality, water from the Marichin Valog tributary valley, and persistent torrential rains at the site of the plant.

The analyses conducted in the report entitled EUROPEAN UNION "STRESS TESTS", 2010, National Progress Report of Bulgaria" confirms that the requirements of the Regulation on Ensuring the Safety of Nuclear Power Plants have been met. The report determines the maximum elevation of flooding and its duration, the possibility of the river being blocked by ice is explored, and the possibility of a maximum elevation of flooding combining with other adverse phenomena is evaluated. The analysis of the results confirms that the Kozloduy NPP site is flood-proof.

6.2.7 EXTREME WINDS AND TORNADOES

The dominant winds in the area of the Kozloduy NPP are westerly, followed in frequency by easterly and northwesterly winds. At a probability P=1% (once in 100 years), the maximum wind speed in Kozloduy and Oryahovo is 37-42 m/s, respectively. Westerly winds prevail, with a wind frequency of 34.9-35.5% at speeds of 4.2-5.6 m/s.

At a probability P = 0.01% (probability of once in 10,000 years), the estimated wind speed is 45 m/s, which is considered extreme.

In an analysis conducted in 2009, the National Institute of Meteorology and Hydrology of the Bulgarian Academy of Sciences established the following characteristics of 16 tornadoes observed in the 1986-2009 period and evaluated for an area of 178 km in radius around the Kozloduy NPP: maximum speed 332 km/h (92.2 m/s); rotating speed 263 km/h (73.1 m/s); forward speed 69 km/h (19.2 m/s); radius corresponding to the maximum rotating speed of the air column: 45.7 m/s. The probability of occurrence of a tornado with the above characteristics in a 12,500 km^2 area around the Kozloduy NPP is 6.3×10^{-7} for one year and of a tornado with a speed exceeding 332 km/h, 1.26×10^{-8} for one year.

The probability of a tornado occurring over a tract of an area of 100,000 km^2 in the course of one year is estimated at $5.05\text{x}10^{-6}$.

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[8] Analysis and assessment of the impact of a potential explosion of automotive petrol in the on-site filling station of the NPP on neighbouring installations and facilities within the perimeter of the Kozloduy NPP, September 2008

Therefore, an impact is not expected because the future design of a NNU will take into account these impacts on building structures and facilities ensuring nuclear and radiological safety.

6.2.8 FIRE HAZARD

6.2.8.1 FACILITIES AT THE KOZLODUY NPP SITE

Considerable quantities of flammable liquids are stored within the perimeter of the NPP. Under certain conditions, these liquids could spill out of the tanks, ignite and lead to the occurrence of fires intricate in their progression. Such fires can occur above all at the oil station, where considerable quantities of diesel fuel and oils are stored. The document entitled **Analysis of the possibility of occurrence of industrial accidents outside the buildings of the generating units within the perimeter of the Kozloduy NPP, 2007**, analyzed the largest possible fire within the perimeter of the NPP: a fire of diesel fuel which has leaked from a tank of a capacity of 2 000 m^3 at the oil station. The analysis envisages the worst possible emergency: the integrity of one of the tanks is breached and the entire quantity of diesel fuel spills into the bunding, the diesel fuel ignites and the combustion spreads to the entire surface of the spill.

On the basis of the results obtained, the projection of the impact of the fire of diesel fuel at the oil station on neighbouring installations invites the following conclusions:

- The fire will pose a hazard only to the oil station: the heat flow will most probably cause a melting and ignition of the waterproofing of the station's roof and damage to the outer surface of the walls;

The fire does not pose a hazard to the rest of the neighbouring installations. The falling heat flow is of such density that it cannot inflict any damage to the neighbouring installations.

Impact is not expected.

6.2.8.2 NABUCCO AND SOUTH STREAM GAS PIPELINES

Two accidents are possible:

1. **Fireball:** in the first seconds after the rupture of the gas pipeline, a dense gas cloud will form above the place of the accident, in whose interior the gas concentration will be above the upper concentration limit of ignition. In this state, such gas cloud is non-combustible. Combustion is possible only on the fringe of the cloud, where the combustible gas comes into contact with air. If a source of ignition occurs on the fringe of the cloud at that moment, combustion will start on the surface of the gas cloud. The heat liberated in the process of combustion will heat the gas in the interior of the cloud, will expand that cloud and will reduce its density. Being considerably lighter than air, this gas cloud will start to ascend while continuing to burn. This phenomenon is called fireball-type combustion.

In its worst case scenario, the fireball-type combustion, actuated by the rupture of the gas pipeline, does not pose a hazard to the structures which will be positioned at the potential sites of the NNU. The density of the heat flow is lower than the critical density which could cause ignition of combustible materials and structures.

2. **Torch combustion of natural gas:** upon a local loss of integrity of pressure vessels and pipelines, a jet of escaping gas forms of a size depending on the quantity of the gas escaping through the breach. When gases lighter than air escape, the jet is directed straight upward.

   The situation of physical explosion (disruption) of the gas pipeline followed by a fire at the place of the accident and spread of the fire does not pose a hazard to the potential sites of the NNU.

6.2.8.3 UGS Chiren – Kozloduy – Oryahovo Gas Pipeline

Considering the smaller diameter of the pipe in this sector and the larger distance to the alternative sites of the NNU, an impact is not expected.

6.2.9 Non-radiation hazards during the construction phase

The hazards described above are inapplicable to the construction phase. The usual hazards in the performance of building and structural works, respectively, can be eliminated by the usual means for this type of activities.

6.2.10 Non-radiation hazards during the NNU operation phase

In connection with the operation of the NNU, certain emergency situations related to a leak of polluted waste water (in case of damage to the sewerage sealing or malfunction of the treatment facilities and installations), a leak of substances stored (chemical, combustive materials, lubricants, detergents and the like) from the tanks or pipelines upon their transportation, should not be excluded. There is also a risk of fire incidents.

The cited risks of occurrence of emergency situations have a low degree of probability. That is why no specific preventive or remedial measures are required other than such that are customary or prescribed by the relevant building, safety, transport or other regulations. Accordingly, the technological discipline is supposed to be observed in performing the relevant activities. Means intended to eliminate potential leaks of combustive material or other hazardous substances will be available in the area of the chosen site of the NNU and in its adjoining installations.

The effects of the emergency events can be eliminated by customary means. The follow-up measures depend on the scenario of the event concerned. If the measures taken are prompt and effective, there is no risk of an environmental impact.

The operation of the NNU after the extension of the NPP does not pose a risk of occurrence of emergency events which could have significant adverse effects on the environment and the population.

6.2.11 NON-RADIATION HAZARDS DURING THE NNU DECOMMISSIONING PHASE

The hazards during the phase of decommissioning of the NNU will not exceed the risks during the phase of preparation and implementation of the IP and in this case it should not be expected that applying any measures other than the customary ones would be necessary.