ENVIRONMENT IMPACT ASSESSMENT REPORT ON

INVESTMENT PROPOSAL

CONSTRUCTION OF NATIONAL DISPOSAL FACILITY FOR LOW AND INTERMEDIATE LEVEL RADIOACTIVE WASTE – NDF

PART V

CHARACTERISTICS OF THE RISKS TO THE ENVIRONMENT, TO POPULATION IN THE REGION AND TO THE WORKERS ON THE SITE IN CASE OF POTENTIAL ACCIDENTS AND INCIDENTS

Sofia, January 2015

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5 CHARACTERISTICS OF THE RISKS TO THE ENVIRONMENT, TO THE POPULATION IN THE REGION AND TO THE WORKERS ON THE SITE IN CASE OF POTENTIAL ACCIDENTS AND INCIDENTS

The type of radioactive waste, which is subject to disposal at the NDF, is of 2a category according to the *Regulation for safe management of radioactive waste.* According to the definition of **2a category** the maximum specific activity for long-lived radionuclides per package is less than or equal to 4.0E+06 Bq/kg, provided that the maximum average limits for the long-lived radionuclides in the disposal cells should not exceed 4.0E+05 Bq/kg.

The investment proposal **does not envisage treatment and disposal of spent nuclear fuel** (SNF) from the operation of the of Kozloduy NPP units or of other NPPs, nor of other types of RAW which fall outside the **2a category**.

The RAW pre-treatment, treatment and conditioning are carried out in the **RAW Processing Workshop (RAWPW),** located on the Kozloduy NPP site.

The main RAWPW systems are:

- “Solid RAW” line – used for sorting and processing with the aim of reducing its volume and preparing it for further conditioning and packaging in the reinforced concrete containers (RCC). Solid RAW pre-compaction into 210 litre drums by means of a 50-ton press is performed as well as a compaction of the drums with a 910-ton super-compactor.
- “Liquid RAW” line - designed for treatment and conditioning of liquid RAW by evaporating it by means of a two-stage evaporator and subsequent cementation. The "RAW packaging line" is an integral part of the "Liquid RAW" line.

The basic assembly unit for producing the packages for the conditioned RAW is a reinforced concrete container (RCC), which is licensed for transportation and storage of solid RAW of **2a category**, whose external dimensions are 1.95x1.95x1.95 m and its useful volume is 5 m^3. The container is manufactured and tested according to the terms of the permit issued by the NRA.

The packages for the conditioned RAW are temporarily stored in the Storage Facility for Conditioned RAW (SFCRAW), and outside the SFCRAW on site No.1 and site No.2 of the Varovo stopanstvo facility as they are subject to disposal without further treatment.

The protective reinforced concrete containers (RCC) act as sealed sources of gamma ionizing radiation only, since the package will prevent the emission of alpha and beta particles out of it. The walls of the containers provide biological protection and they are designed in such a way that the equivalent dose rate of gamma radiation from one package of RAW should not exceed 2 mSv/h at any point of its outer surface and reaches a maximum level of 0.1 mSv/h at a distance of 1 m from the surface. Since with the increase of the distance from the source of ionizing radiation – RCC , the gamma dose rate decreases by the square of the distance to the source, the rate measured at a distance of 10 m will be 100 times lower, therefore, it will be virtually indistinguishable from the natural background radiation levels typical for the region.

The subsequent disposal of the packages into the facility cells by their closure and covering with multilayer engineering barrier (including the preliminary constructed loess-cement cushion under them) will completely eliminate the possibility of radioactive contamination of water, soil, air, geological environment and biodiversity elements in the region as a result of penetration of gamma radiation into them. The servicing systems of the disposal facility will also contribute to it, especially the infiltration control network and the deep drainage system, which are described in the annotation. The fact that the process of RAW storage in the NDF, as a technology, does not involve the possibility of release of gas emissions into the atmospheric air should be taken into consideration.

The NDF is practically designed as a system of multiple barriers that will ensure the safe isolation of the radioactive waste from the environment over a period of time as long as the radionuclides contained in the waste represent a hazard. These barriers operate consecutively, so that a failure of one or more barriers or their degradation over time is compensated by the retention capacity of the rest of the barriers.

5.1 LEGAL REQUIREMENTS AND DEFINITIONS OF ACCIDENTS AND INCIDENTS

The Regulation of the conditions and procedure for notification of the Nuclear Regulatory Agency about events in nuclear facilities and sites with sources of ionising radiation, in force since 2004, last amended SG 7/21.01.2011, establishes the terms and procedure for compulsory notification of the Bulgarian Nuclear Regulatory Agency (NRA) by the licensee or the permit holder about deviations, incidents or accidents, referred to hereafter as “events”, in nuclear facilities and sites with sources of ionising radiation. According to art.4 the events in nuclear facilities and sites with sources of ionising radiation, which are subject to notification pursuant to the regulation, shall be classified into the following categories:

- Deviations from normal operation;
- Incidents;
- Accidents.

The following definitions[1] are used to help understand the logic applied during the conduction of safety analysis for a nuclear facility:

- **Incident** means a technical event or anomaly which, although not directly or immediately affecting nuclear safety or radiation protection, can lead to a subsequent re-evaluation of the provisions for nuclear safety or radiation protection. They do not have a significant impact in case of proper management of the NDF’s operation since they don't turn into accidents and no contamination with radioactive substances is expected nor any exposure of its personnel to ionizing radiation above the established exposure limits.
- **Accident conditions** are deviations from normal operation more severe than anticipated operational occurrences, including design basis and beyond design basis accidents.
- **Design basis accident** represents emergency conditions for which the facility has been designed in accordance with established criteria to the design of the facility, so that damage in the package or another barrier should not lead to the discharge of radioactive substances into the environment beyond the specified limits. (These are accidents, envisaged in the design, under which the NDF should withstand without any loss of systems, structures, and components. These events are characterized by a low probability of occurrence due to preventive and administrative measures, but they have potential radiological consequences, under which the dose (effective) limit for an individual member of the public is defined to be up to 1 mSv/a. - Regulation on basic norms of radiation protection (RBNRP-2012).
- **Beyond design basis accident** is an accident whose consequences are more severe than the design basis accident and for which no technical resources are provided in the design.

[1] According to the Regulation of the conditions and procedure for notification of the Nuclear Regulatory Agency about events in nuclear facilities and sites with sources of ionising radiation, in force since 2004, last amended SG 7/21.01.2011

- **Severe accident** is an accident which causes significant damage to the reinforced concrete containers (RCC) – the package of the conditioned RAW containing radioactive substances of 2a category.
- **Operation** means all activities carried out to achieve, in a safe manner, the purpose for which the nuclear facility or the facility with sources of ionizing radiation was constructed.
- **Deviations from normal operation** are deviations from the operation of the nuclear facility or of the facility with sources of ionizing radiation during which a violation of the defined limits and operational conditions occurs. Furthermore, other limits and conditions, defined by the design, including safety limits, can also be violated. In their case, the dose criteria for allowing the operation are observed and no radiological consequences are expected.
- **Critical population group** is a group of individuals that is sufficiently homogeneous in terms of radiation dose received from a certain source and of radiation exposure pathway, and the group is representative of the people who receive or will receive the highest effective doses or equivalent doses (as the case may be) from the defined source and radiation exposure pathway[2].

Regarding the accident hazards under the Regulation on Emergency Planning and Emergency Preparedness in Case of Nuclear and Radiological Emergency (Promulgated SG, 94/29.11.2011) the NDF is categorized below third category, but it is conservatively categorized as 3rd category nuclear facility based on the risk of emergency situations.

As a condition of the design permit of the NDF, an Interim Safety Analysis Report (ISAR)[3] was developed, where the possible design and beyond design basis accidents during operation and after the disposal facility's closure are analyzed in detail. An Emergency plan for the NDF is prepared to deal with accidents and the respective radiological consequences. In those cases when the criteria for the activation of the emergency plan are met, the potential radiological consequences are analyzed and criteria for intervention are put into effect to prevent exceedance of the permissible dose criteria.

The Regulation on Emergency Planning and Emergency Preparedness in Case of Nuclear and Radiological Emergency, in force since 2011, stipulates the criteria for intervention. According to Art.39:

(2) An intervention is not taken when:

1. annual effective dose for the population, less or equal to 1 mSv in which the dose received from the natural radiation background of the area *is not included*;

2. annual effective dose for the population, less or equal to 5 mSv *under special circumstances* – only in case if in the next 5 consequent years the annual effective dose will not exceed 1 mSv (= 1000µSv);

(3) In case of finding contaminations with radioactive substances as a result of previous emergency or activity's consequences when the annual effective dose for the population is greater than 5 mSv, protective measures are implemented or it is advised restriction of access. The intervention is implemented after justification when annual equivalent dose for the population is 100 mSv, including the doses received from all possible radiation impacts and from the natural radiation background of the area, in exception of cases for which the Minister of health has not defined that the implementation of the intervention is not justified.

[2] Regulation on Basic Norms of Radiation Protection, promulgated SG 76/ 05.10.2012 (RBNRP-2012).

[3] Interim Safety Analysis Report (ISAR), R5-NDF-ISA_Rev1, Consortium Westinghouse – DBE Technology – ENRESA. March 11, 2013

These requirements of this Regulation should be included, in writing, in the Emergency plan for the NDF and strictly abided by in case of eventually reached intervention levels.

The main criterion for acceptable consequences of design basis accidents is the individual effective dose per worker no higher than 20 mSv/a, and per member of the population at a distance > 100 m, the individual dose no higher than 1mSv/a.

According to these criteria the NDF's area of emergency protective measures (AEPM) is limited within the site area (within the limits of its fence) and the Surveillance zone around the NDF is less than 4 km.

5.2 RADIATION EXPOSURE RISKS ASSOCIATED WITH ACCIDENTS DURING THE NDF OPERATION AND CLOSURE

5.2.1 DURING THE NDF OPERATION

The NDF (**Figure 5.2-1**) is a nuclear facility, which operates over a long period of time by being engaged in various specific activities within a certain period of time. **Table 5.2-1** describes the time frame of the NDF's lifecycle and operation. Naturally, the accidents alter at the different stages of the NDF's lifecycle and they are of varying severity.

FIGURE 5.2-1 LAYOUT OF TRENCH TYPE NUCLEAR FACILITY

TABLE 5.2-1 TIME FRAME OF THE PRESUMABLE ACTIVITIES AFTER THE NDF IS PUT INTO OPERATION

ACTIVITY	TIME FRAME
Operation of the repository	60year (2015- 2075)
Active institutional control period, covering the final closure of the disposal facility and build up of the covering layer	50-100-year
Enforcement of measures for active control	50-100-year
Passive institutional control	< 200year
Lack of anycontrol - all records and knowledge are supposedly lost	> 300-year

During the operation stage the main manipulation activities are acceptance of the containers with radioactive waste and their transportation to the respective facility cell. The operation stage is completed by closing and covering the cells with lids and Earth's mass which has the corresponding structure as defined in the design.

Detailed safety analyzes are conducted to assess the safety of the NDF as well as of any other nuclear installation. During the analysis all properties, events, processes as well as the time scale of each period of the NDF's lifecycle are put under consideration. Such analysis was assigned and carried out by an international consortium which submitted a report (ISAR). In the ISAR, developed in 2014 by a consortium consisting of Westinghouse Electric Spain, DBE Technology and Enresa, all possible initial events leading to design or beyond design basis accidents are analyzed by applying the ISAM methodology of the IAEA and are divided into three categories:

- Natural events and phenomena;
- External ones, beyond the borders of the nuclear facility, caused by human activity;
- Internal events within the borders of the nuclear facility, caused by human activity (human error) or equipment failure.

A list is drawn up and all possible site-specific external events and phenomena are examined and divided into four main groups:

- Extreme climate conditions (7 types of impacts);
- Hydrological and hydrogeological events (3 types);
- Geological (related to the site and the region, 5 types);
- Geomorphology and topographic impacts on the site (3 types);

Every external event or phenomenon is analyzed in terms of its probability to be the cause of a design or beyond design basis accident. The basic natural or external events are:

5.2.1.1 SEISMIC RISK

The Radiana site is located on the stable part of the Moesian platform, which predetermines a low level of seismic activity at sub-regional scale. The maximum expected earthquake in the sub-region has a magnitude of Mmax = 5.0. The main sources of seismic risk are seismic zones located at a far distance from the site area. The most important of these is the Vrancha area (over 200 km) located in the neighboring Romania, which has generated earthquakes of magnitude of above M 7. The local seismic events are associated with the well-known eight seismogenic areas: Sofia, Marishka, Gornooryahovska, Kresna; earthquakes of magnitude of M <4 are recorded in these areas and they fall into the category of background seismicity.

In this regard, the disposal facility, its servicing installations (the infiltration control network and the deep drainage system, their servicing tanks, etc.) and its auxiliary buildings, facilities and installations will be designed, constructed, measured and secured in accordance with the seismic zoning of the Republic of Bulgaria, consistent with the Eurocode 8 requirements[4] and the standards for design and execution of construction works that are mandatory for design since January 2014 - adopted in accordance with Art.152 of **Ordinance No RD-02-20-2/2012 on Design of Buildings and Installations in Seismic Areas (SG.13/ 2012)**.

5.2.1.2 FLOODING

Potential sources of external flooding at the Radiana site could be the highest natural water levels of the Danube River and the water levels under the hypothesis of destruction of the 'Jelezni vrata' hydropower system.

[4] Draft of National Annexes to the European standards for design of construction works (Eurocodes) - http://www.mrrb.government.bg/?controller=articles&id=492

The landscape within the region of the Radiana site, the Kozloduy NPP and the town of Kozloduy resembles a ladder consisting of river terraces situated in descending order towards the Danube River - T_6, T_2, T_1 and T_0 - **Figure 5.2-2**. All of them have developed of the Paleo-Danube valley, which dates back around 800,000 years.

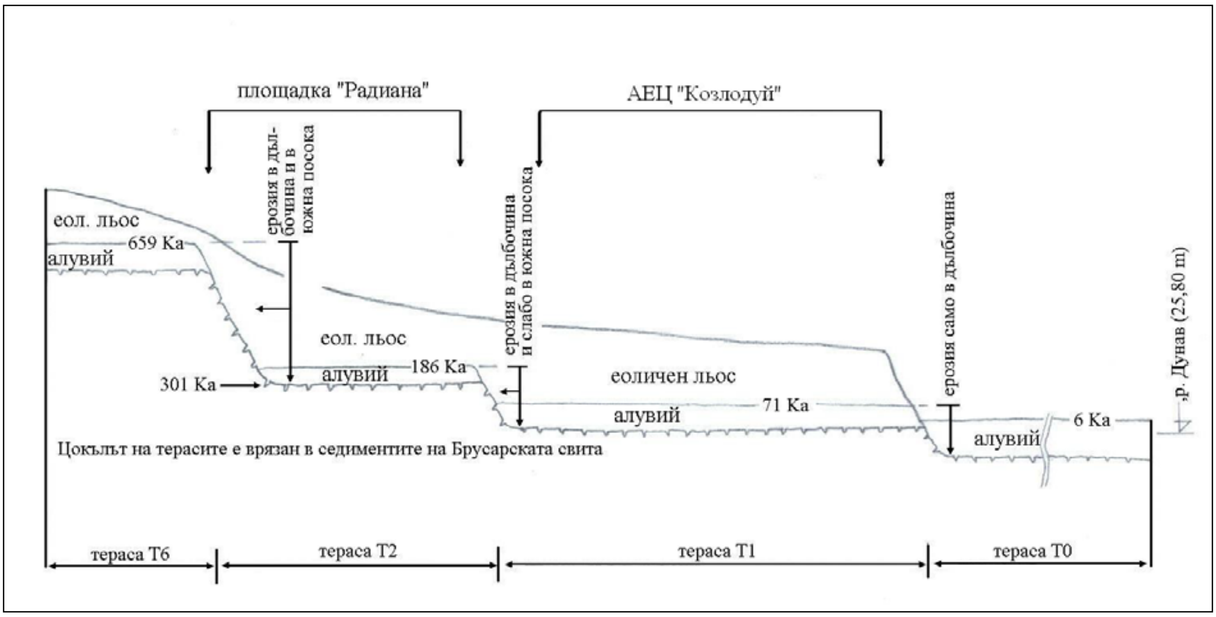

FIGURE 5.2-2 SCHEMATIC GEOLOGICAL AND GEOMORPHOLOGICAL PROFILE OF THE TERRACES OF THE DANUBE RIVER REGARDING THE RADIANA SITE AND THE KOZLODUY NPP SITE

In case of natural flow regime of the Danube River, the prognosticated maximum natural water levels[5] with probability of occurrence between 10^{-5} and 10^{-7} are **32.7 m** and in case of a combination of two events - occurrence of natural extreme water levels and wall collapse of the hydropower dam and reservoir system ’Jelezni vrata’ Dam I and II (an event with a very low probability of occurrence), the prognosticated maximum water levels are **33.42 m.** At these water levels the terrace T_0 is flooded by the river, which leads to groundwater level rise of terrace T_1. The groundwater level within the terrace T_2, where the Radiana site is located, will not change. Furthermore, the Radiana site is located above these flooded terraces (T_0 and T_1) at elevation of 50.00 m (between 20 and 100 m above the current level of the Danube River), therefore the risk of flooding does not exist.

<u>The main conclusion of the conducted analyzes is that</u> the flat part of the Radiana site, which is located on the second non-flooded terrace of the Danube River, is not a flood-threatened area for the entire period of existence of the surface disposal facility of the NDF even in case of catastrophic events such as the collapse of the dam wall of ’Jelezni vrata’. This conclusion is supported by the geological and geomorphological analyses, which confirm that the terrain on which the Radiana site is located, has not been flooded by Danube waters over the last 186,000 years.

<u>The risk for development of riverbank erosion</u> caused by the Danube River to the Radiana site is also analyzed on the basis of both historical data and data from the recent geological past, i.e. of the data from the geohistorical record stored in the Quaternary sediments, shaping the landscape within the area of the Radiana site, the Kozloduy NPP site and the town of Kozloduy. The performed analysis gives reason to the conclusion that the Radiana site is not threatened by the erosion caused by the Danube River. The river erosion activity affecting the second non-flooded terrace T_2 stopped

[5] Risk Engineering JSC REL-1000-ST-001-2, 2013

77,000 years ago and there is no reason to expect that it will resume again in the next few hundred years.

The conducted analyses in the report EUROPEAN "STRESS TESTS" FOR NUCLEAR POWER PLANTS, National Bulgarian Report, 2011[6], confirm the non-floodedness of the Kozloduy NPP, which applies to the Radiana site, on which the NDF will be constructed.

5.2.1.3 EXTREME WINDS AND WIND SPOUTS (TORNADOES)

The dominant winds over the region of the NDF are the western winds, followed in frequency by the eastern and northwestern ones. At a probability P=1% (once in 100 years) the highest wind speed in Kozloduy and Oryahovo is 37-42 m/s, respectively. The western winds prevail, with 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. The probability of occurrence of a tornado over a tract of land area 100,000 km^2 in any one year is estimated to be 5.05x10^{-6}. Hypothetical damages to the mobile roof during operation can be quickly fixed. Radiological consequences to the NDF due to extreme winds cannot be induced.

5.3 SCENARIO SELECTION METHODOLOGY ADOPTED BY THE ISAR

The task of the ISAR is to analyze and evaluate the safety during the operation of a nuclear facility. Ultimately, the applied algorithm to the NDF in the ISAR is the following:

1. Selection of accident-initiating events and probability assessment of the event, which damages the integrity of a particular barrier.
2. Analysis of the migration speed and/ or dissemination of radionuclides, which have been in the package.
3. Analysis of exposure pathways by which these radionuclides affect human health (exposure pathways, via which the dose rates per member of the public are generated)
4. Dose rate estimation for each pathway (exposure-to-dose models).
5. Comparison of the estimated individual effective dose to the permissible dose limit according to BSRP-2012.

The analysis and the well-founded methodological review are very important aspects of the scenarios selection process. The ISAR adheres to the systematic approach that is consistent with the IAEA methodology named ISAM. Under this approach, the scenarios selection is made according to certain criteria, such as critical moments, inclusion of all possible process developments, system sustainability, etc. A set of basic scenarios is used as a guide to determine the scenarios that are specific to the facility. The used basic scenarios are taken from a list included in the IAEA Safety Guide (IAEA-TECDOC-1347, Consideration of external events in the design of nuclear facilities other than nuclear power plants, with emphasis on earthquakes).

The methodology for assessment of the initiating events is based on the following criteria:

1. The initiating event frequency, assessed quantitatively by applying the following characteristics
   - Input data for the probability of occurrence of the event. An initiating event having a occurrence probability of 10^{-6} per year is directly eliminated;
   - Design methods for reducing or eliminating the risk associated with this initiating event;

[6] http://www.bnsa.bas.bg/bg/documents/conventions/reports/finalstresstests-kozloduy-bg.pdf

   - Established operational procedures for activities;

2. The radiological consequences of the initiating event are assessed qualitatively, by considering each of the following aspects:
   - Activity of the radiation source (nuclide vector) (“Source Term”);
   - Location of the people under threat;
   - Design preventative and mitigation techniques for reducing impacts.

The qualitative criteria for determining the initiating event as beginning of an accident or deviation are based on the significance of the expected radiological impacts which it will cause.

The following approach for the scenarios selection can be applied, taking into account that external radiation exposure and dispersion of radioactive waste particles represent the main risks associated with the radiological risk to human health:

- All initiating events, leading to an unwanted and unplanned individual effective dose being received by a worker or by a member of the public, are considered incidents if they do not result in release of radioactivity into the environment;
- All initiating events, leading to a proliferation of a very small amount of radioactive material, are considered incidents (abnormal situation), as they do not lead to significant radiological consequences;
- All initiating events, leading to the spread of a significant amount of radioactivity, are considered an accidental situation.

5.3.1.1 DESIGN BASIS ACCIDENTS

As explained above, the accident impacts are examined and analyzed in the developed ISAR, by taking into account the characteristics of a package of RAW and the specificity of the respective activities, which should be performed during operation. The accident scenarios for design basis accidents, which are postulated and analyzed in detail, are described in the following sections.

5.3.1.1.1 FALL OF A CONTAINER

A fall or drop of a container, which will have radiological consequences, is a technically possible accident unlikely to occur. The design envisages a number of technical and organizational measures to be taken to ensure a very low probability of occurrence, so that such a fall should be inadmissible during the NDF operation. The drop or fall of a container is analyzed at all possible stages until its placing in a cell and the event probability is determined for each stage. The ISAR contains a detailed analysis of this design basis accident performed on the basis of the maximum permissible concentration of various radionuclides in the package of RAW and the corresponding fall height (4 to 12 m).

The maximum consequences for a worker of the NDF personnel (Category A) are to receive an individual effective dose of 0.789 mSv/a, under the assumption of an average distance of about 30 m from the package (technologically and administratively justified). It should not be forgotten that such design basis accidents can be controlled over time and appropriate protective measures can be taken, which would actually lead to a significant reduction in this conservatively calculated individual dose. The potential radioactive surface contamination due to any type of design basis accident is entirely under control as well.

In case of this design basis accident, the individual effective dose per member of the critical population group, aged 17 years and above, based normally outside the site perimeter (at a distance of at least 150 m - the NDF fence), the individual effective dose is maximum conservatively calculated to be 0.062 mSv/a, which is even below the license criterion of 0.1 mSv/a during normal operation. The radiological impact on the population of the nearest settlement (at a distance of 2500 m) is considered practically non-existent.

In case of this design basis accident no intervention measures, given above, are necessary to be taken (Article 39 of the Regulation on Emergency Planning and Emergency Preparedness).

5.3.1.1.2 HUMAN INTERVENTION

The major terrorist act, which would lead to a destruction of the structures of the disposal facility, is an explosion or an explosion, followed by a large fire as a result of targeting the disposal facility with an aircraft having a large amount of fuel. A terrorist act by air is a very unlikely scenario, as the NDF is located within the Kozloduy NPP area and there is a protective shield (special security measures).

The structures of the disposal facility are of non-flammable materials. The disposed radioactive waste is cemented in a matrix, which is non-flammable as well, and the only expected consequences such as cracking and distortion of the matrix structure, could, on their part, lead to the necessity of processing and repackaging the treated waste.

Terrorist act performed by land is considered a more likely scenario. During the analysis of the radiological consequences a number of conservative assumptions are made that increase the volume of the exploded radioactive waste.

For example, the cube is conservatively assumed to be on the surface (for one reason or another, it is not located in the chamber) of the disposal facility, without any barriers around it to prevent the dispersion of radionuclides due to the explosion.

The detonation of explosive charges (EC), put in certain places and facilities on the territory of the disposal facility, is able to break through the walls of the package, in which case the radioactive substances discharge into the air, forming a cloud.

Depending on the weather conditions, influencing the transport of the radioactive cloud through the atmosphere, the potentially affected area will be determined as well as the maximum distance which the cloud will reach. In case of such transfer inhalation of fine radioactive particles, external exposure from the cloud itself and external exposure from the radioactive particles settled onto the ground surface are expected. The provisional assumption is that, in case of an explosion one quarter of the whole RCC will be destroyed and completely dispersed. In the ISAR this scenario is calculated by means of the program HotSpot - Module General Explosion. The wind rose for the region of the Radiana site for 2010 is used for the calculations allowing an assessment of a hypothetical explosion. The ICRP dose coefficients (BSRP -2004) relevant at the time of the research were used. In this research, the dose coefficients are used according to BSRP-2012.

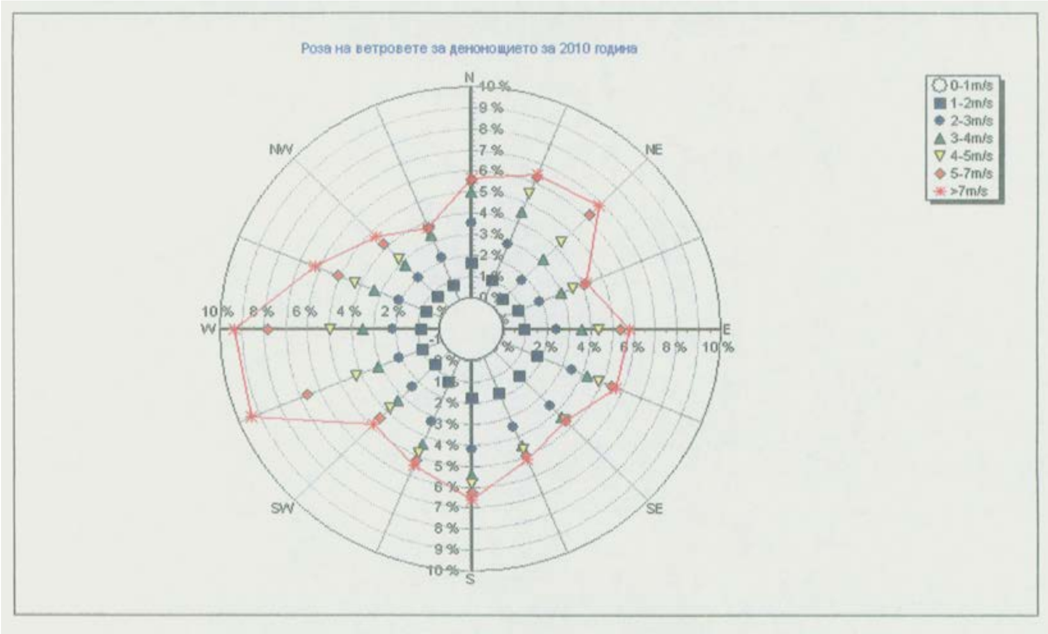

FIGURE 5.3-1 WIND ROSE FOR THE REGION FOR 2010

Calculations were made for three different wind speeds, and it becomes obvious that the higher the speed of wind, the larger the length of distribution (transport is more horizontal than vertical) of radioactive contamination, and the weaker the horizontal diffusion, i.e. lower concentrations of radionuclides at closer distances, due to the fast migration of the pollution plume.

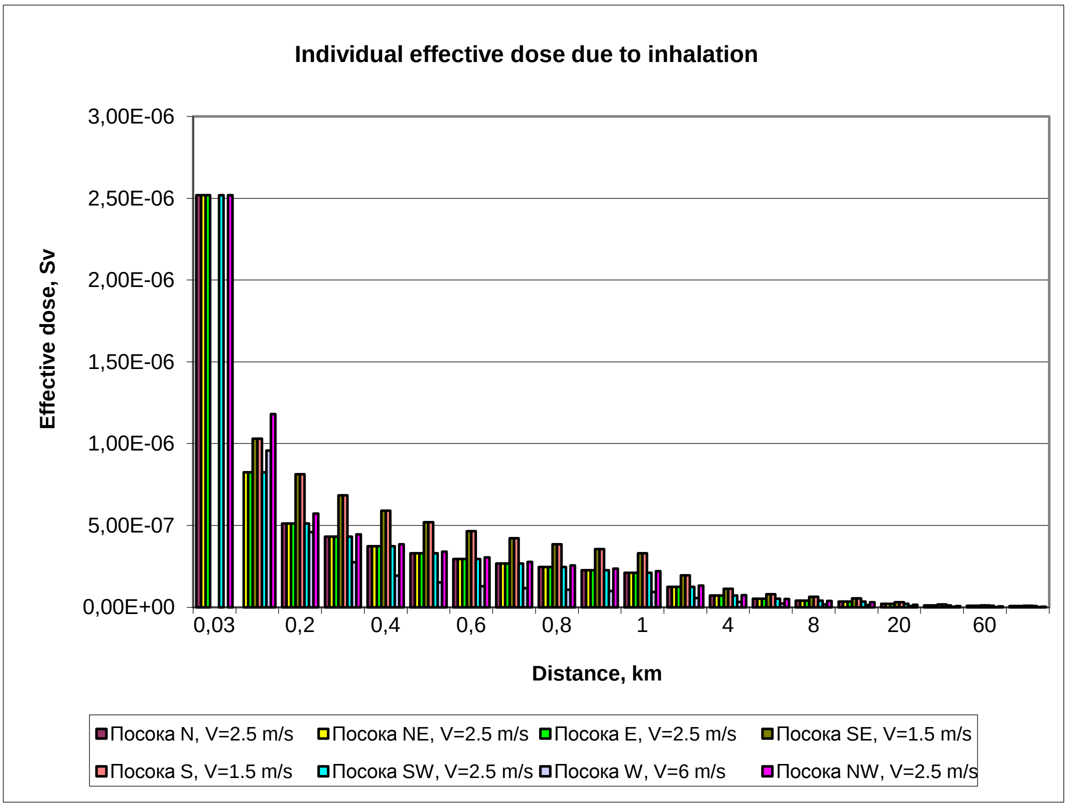

FIGURE 5.3-2 DISTRIBUTION OF THE INDIVIDUAL EFFECTIVE DOSE DEPENDING ON THE WIND SPEED AND ITS DIRECTION

As illustrated by the graph, the maximum values are within the range of $2.50x10^{-3}$ mSv and they are typical for a distance of **30 m**, namely:

- $2.52x10^{-3}$ – at wind speed – 2.5 m/s;
- $2.85x10^{-3}$ - at wind speed – 1.5 m/s;
- $1.81x10^{-3}$ - at wind speed – 6.0 m/s.

It can be clearly seen that the effective dose gets higher closer to the epicenter of the explosion and it gradually decreases when moving away from it. Wind characteristics influence and are important for the purposes of emergency planning if emergency measures need to be taken to protect public health.

The results indicate that the effective dose of the order of 10^{-3} mSv is prognosticated for the site boundaries and beyond them the effective doses decrease to $5.0x10^{-4}$ mSv. The impact at a distance of 2500 m (the nearest settlement) is assessed to be virtually zero.

The effective individual dose is mainly due to inhalation of radionuclides. **Even the dose criterion for normal operation, specified in the Permit HX-3593/04.05.2012, issued by the NRA for the design of the NDF is not exceeded.**

The cumulative radiological impact (in case of design basis accidents) from the NDF operation carried out on the Radiana site is within the range of the dose rate limits defined by the legislation both for the personnel of the NDF and for the population. **No immediate protective measures need to be undertaken if such accidents occur.**

5.3.1.2 BEYOND DESIGN BASIS ACCIDENTS

Beside the definition given above of such an accident, it can be summarized that these are events (accidents) which are not part of the design, but they are analyzed so that the project‘s feasibility as well as the ability of the facility to cope with the consequences of such an event can be comprehended and assessed. In the Permit HX-3593 from 04.05.2012 issued by the NRA for the design of a national disposal facility - NDF is written that in case of a beyond design basis accident, neither the application of a measure for permanent deportation or evacuation of the population, nor limiting the consumption of foods by the population should be imposed. The measures for hiding and protecting the respiratory organs and the skin should be limited in time (for a short time).

5.3.1.2.1 FALL OF A HEAVY AIRCRAFT

The fall of a heavy aircraft is considered the most severe postulated scenarios for a beyond design basis accident. (R5-NDF-CN-I-GGG-003 Rev 1 “Large Commercial Aircraft Impact Report”). This event is analyzed to demonstrate that it is not necessary to implement emergency measures for limiting and eradicating the consequences of a radiation accident outside the perimeter of the NDF. The analysis is conducted by applying engineering assessment and certain assumptions: the size of the aircraft; speed; quantity of fuel; angle of the fall and etc. The very low probability of the event (flight over the NDF area) is taken into consideration and the confined area exposed to a direct hit from an aircraft.

The methodology is based on an equation adopted by the American National Defense Research Committee (NDRC) and is approved by the U.S. Nuclear Regulatory Commission (the U.S. Nuclear Regulator). The structures that are targets of attack are: **two cells** with containers of RAW and the **Waste acceptance and buffer storage building**. The maximum number of containers, assumed to be broken and in flames, is 16. The total number of damaged containers is assumed to be up to 120.

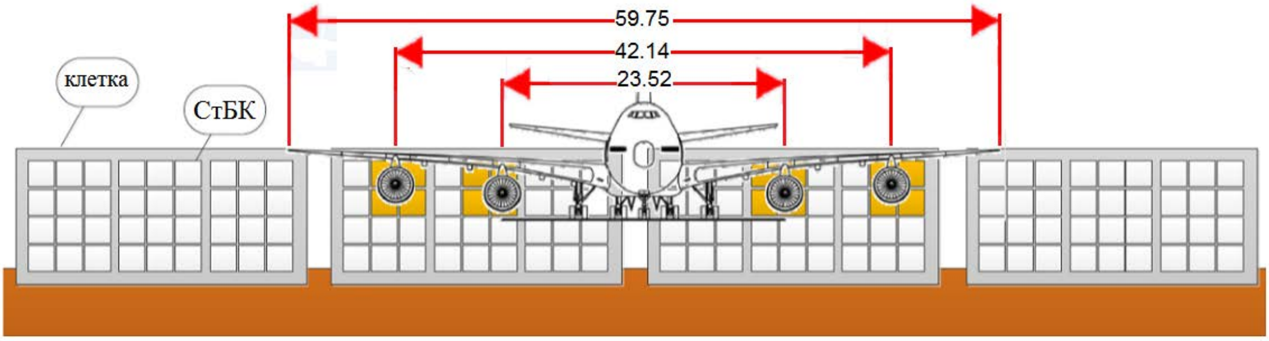

FIGURE5.3-3 FALL OF AN AIRCRAFT ONTO THE NDF

For the purposes of the assessment of the radiological consequences, imposed by the radionuclides dispersion, adverse atmospheric conditions are conservatively assumed - atmospheric stability class F and wind speed of 1 m/s, during which the absence of or the very low turbulence prevent the spread of pollutants in vertical direction and it transports them in horizontal direction. The doses to the population are estimated by age group and for each radionuclide contained in the container at a distance of 2.5 km from the Radiana site. The nearest population is based at this distance in the town of Kozloduy. The total activity of radionuclides in the cells is assumed to be $2.42x10^{14}$ Bq.

Under the assumption that 1/100 of this activity is entirely due to ^{239}Pu, an assessment of the individual dose rate is made. The maximum individual effective dose per individual of the population at a distance of 2500 meters is 0.0246 mSv. A critical group are people aged 17 years and above. At ten times the value of the activity from the source (too conservative assumption), the dose per person of the critical population group reaches 0.184 mSv/ a.

In order to calculate when the dose of 5 mSv will be exceeded and what its value will be at a distance of 2500 meters, an estimate is made under the super conservative assumption for maximum activity of the source of radiation - the whole activity of the nuclide vector is $3.9x10^{+13}$ Bq and it is entirely due to ^{239}Pu. The estimated individual effective dose per person of the critical population group aged 17 years and above is 1.78 mSv/a. The largest share of contribution to this dose (approximately 95.5%) comes from ^{239}Pu. This individual effective dose drops to 0.381 mSv/a for the rest population groups (under 17 years of age).

Under the above assumptions, the dose of 5 mSv/a is exceeded at a distance of over 150 meters, as the estimated dose in this case is 266 mSv/a.

Particular attention must be paid to the fact that the main component of these doses is the internal exposure due to inhalation and ingestion. These exposure pathways are easy to be eliminated after conducting a pollution assessment and taking the appropriate protective measures.

5.3.2 AFTER THE CLOSURE OF THE NDF

The NDF is designed to have a multi-barrier passive protection to prevent release of radionuclides to the environment throughout the whole institutional life of the disposal facility. The ISAR contains a very detailed analysis in Section 14 of the possible initiating events and the corresponding radiological consequences for the purpose of demonstrating the safety of the NDF upon occurrence of every one of them. The analyses are conducted under the assumption of maximum capacity of the disposal facility (the total sum of all radionuclides after closure).

The selection of the initiating events and the analysis are conducted in accordance with the IAEA methodology – ISAM (IAEA): "Application of Safety Assessment Methodologies for Near Surface Disposal Facilities (ASAM). Common Application Aspects. Working Group Position Paper - Engineered Barrier Performance (Draft version), IAEA, Vienna, 2005) by identifying, selecting and grouping the dozens of various accidents regarding the NDF into the following possible alternative scenarios in addition to the normal evolutionary scenario (NES).

- Evolutionary scenarios that take into account geological and climatic processes and events;
- Scenarios that take into account future human activity;
- Scenarios initiated by unexpected external events (explosions and accidents);

The normal evolutionary scenario (NES) summarizes the aspects mentioned above regarding the degradation of passive barriers and is the most realistic one. The alternative scenarios include possible changes, as compared to the NES, due to man's intrusion or natural phenomena.

The normal evolutionary scenario has number 1. Except it, the following scenarios are considered in detail:

A. Scenario 1 – NES – farm in a small settlement

B. Scenario 2 – Intrusion

Scenario 2.1 – A road construction

Scenario 2.2– Residence and agricultural use

C. Scenario 3– Damage to technical barriers and geological changes caused by an earthquake

D. Scenario 4– Climate changes

E. Scenario 5– Accidents

Scenario 5.1– Explosions of vehicles on the road

Scenario 5.2– A fall of a medium-sized aircraft

5.3.2.1 NORMAL EVOLUTIONARY SCENARIO (NES)

The normal evolutionary scenario is presented in the ISAR thoroughly and in every detail, since it is the most likely scenario compared to the alternative scenarios.

A long period of active and passive control follows the filling of the cells with containers and the closure of the NDF. During the NDF normal operation and after its closure the dose limit of 0.1 mSv/a shall not be exceeded for the critical population group. After the closure of the NDF the passive protective barriers remain operative for a long period of time. The entire defense system of the NDF "evolves" over this rather long period of time. Degradation of the passive barriers is expected to occur in about 50 years from now, degradation of the containers - in about 60 years and degradation of the concrete structures - in about 300 years.

The entire inventory of a filled disposal facility is reviewed, as the activity reduction of the disposed RAW is, on the one hand, due to the half-life period of the radionuclides contained in them, and on the other – due to the processes of leaching of the matrix after the infiltrating water reaches them.

The concentration of radionuclides, which as a result of their migration reach the point of discharge of the main aquifer, is analyzed in the assessment since it is the input data for modeling and developing the dosimetry models. For this purpose, the dilution of the concentration of the radionuclides, which have reached the aquifer, is conservatively taken into account. The simulation is based on a conceptual model of "the near-field" of the NDF, presented in **Figure 5.3-4**.

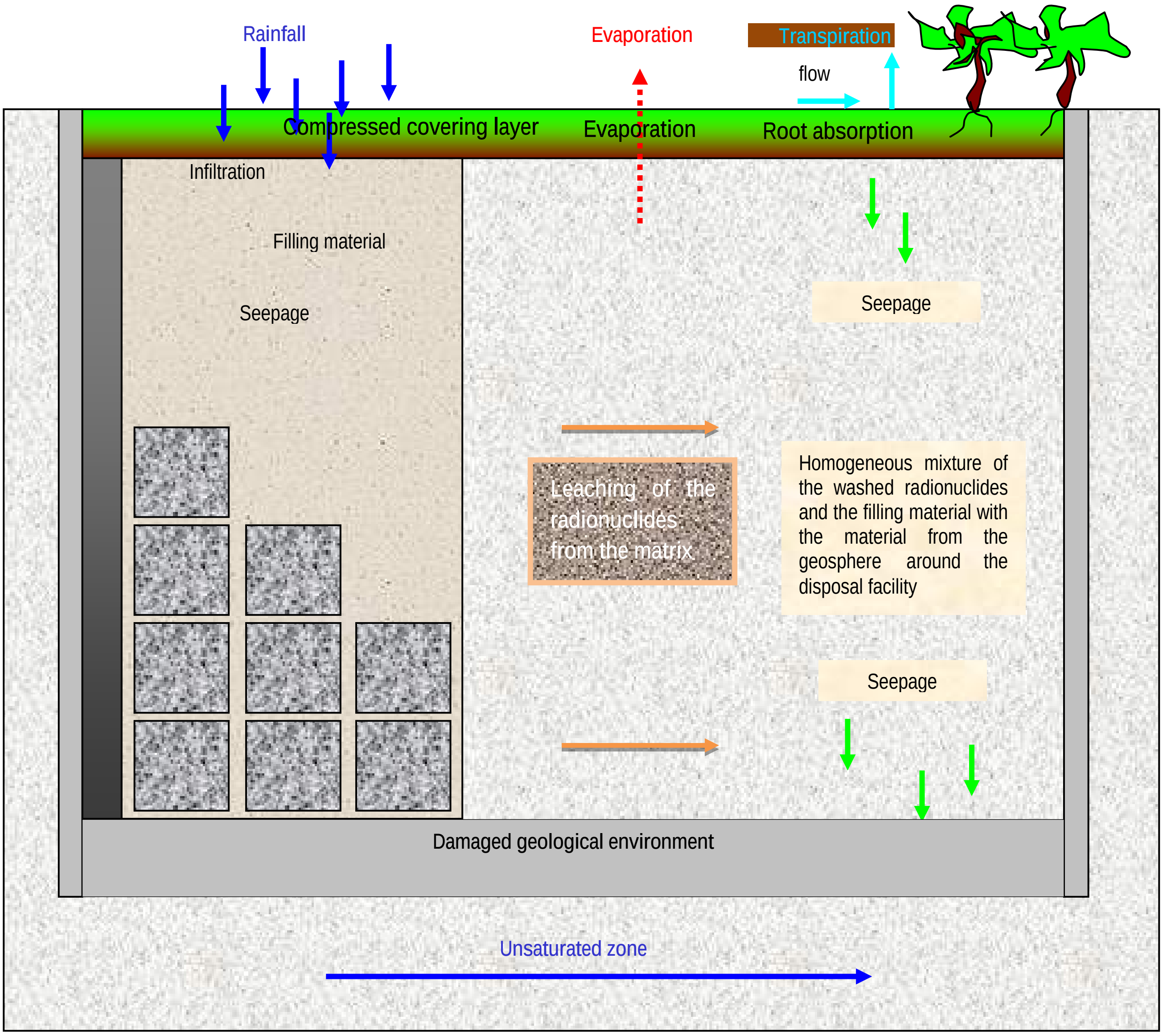

FIGURE 5.3-4 SCHEMATIC REPRESENTATION OF THE CONCEPTUAL MODEL OF NES AFTER THE CLOSURE OF THE NDF

For the purposes of the dosimetry models, the current demographic characteristics, habits and customs of the population of the nearby settlements around the Radiana site and data for consumption of observed products from the food chain are taken into account. Quite conservative assumptions have been made during the assessment of the radiological consequences of the NES, the more important of which are:

- A small settlement, which is located at a distance of 1000 meters from the NDF in the groundwater flow direction (the distance is determined on the basis of the particular landscape of the area and the opportunity for construction of residential buildings and infrastructure);
- The total water use and irrigation water use are satisfied by water from the aquifer that is connected with the disposal facility;
- The hypothetical consumption consists entirely of food produced in the region around the settlement;

- No allowance is made for lateral dispersion in the modelling of radionuclide transport in groundwater (maximum concentration towards the settlement);
- Climatic conditions as they are now;
- No flooding or excess quantities of surface water are expected;
- All radionuclides are considered highly soluble;
- The concrete structures are examined in detail in the ISAR in event of maximum water ingress.

The modelling indicates the extreme importance of the residual activity in 50 years from now as well as the velocity of leakage of radionuclides to the environment.

Table 5.3-1 represents the residual activity levels of the important radionuclides in 50 years from now.

TABLE 5.3-1 RESIDUAL ACTIVITY LEVELS OF VARIOUS RADIONUCLIDES IN THE 50TH YEAR

Radionuclide	Period, [a]	Residual activity, [Bq]
^{3}H	50	7.12E+9
^{14}C	50	2.64E+12
^{60}Co	50	2.08E+10
^{63}Ni	50	3.10E+12
^{90}Sr	50	1.93E+11
^{94}Nb	50	3.30E+9
^{99}Tc	50	1.71E+09
^{129}I	50	8.45E+7
^{134}Cs	50	9.96E+5
^{137}Cs	50	4.36E+13
^{239}Pu	50	4.35E+9
^{241}Am	50	1.20E+10

The software, which is used to simulate the long-time evolution of the NDF and to calculate the radiological consequences, is GoldSim, 11.0.2 of 22 November 2013 (www.goldsim.com).

A specific mathematical model is developed for each scenario. The contribution to the individual effective dose is estimated under each scenario and for each radionuclide contained in the container.

The ICRP dose conversion factors are used for all the estimates of dose rate in the research. (ICRP:"ICRP Database of Dose Coefficients: Workers and Members of the Public" and of ICRP (International Commission on Radiological Protection) CDROM, Ver.1, Elsevier Science Ltd.(1998). Data taken from “Beilage 160 a und b zum Bundesanzeiger vom 28. August 2001”.(http://www.bfs.de/de/bfs/recht/dosis.html)

A number of additional conservative assumptions are made in each developed mathematical migration model and in each dosimetry model. For example, the radioactive decay of the radionuclides until the closure of the NDF is not taken into account, a destruction of a barrier is assumed to occur as soon as possible to the moment of closure, etc.

5.3.2.2 ALTERNATIVE SCENARIOS FOR THE NDF AFTER CLOSURE

For the period after closure the radiological consequences under the above mentioned alternative scenarios are also considered.

Table 5.3-2 presents a summary of the maximum individual effective dose under the examined scenarios and the time necessary for its accumulation.

TABLE 5.3-2 THE MAXIMUM TOTAL ANNUAL EFFECTIVE DOSE BY SCENARIO TYPE

Scenario	Peak dose [μSv/a]	Time of peak dose - years
1. NES	0.803	6220
2.1. Settlement and agricultural use	42.1	300
2.2. Road construction	3.29	300
3. Earthquake	6.55	1520
4.1. Dry climate	0.900	8340
4.2. Humid climate	0.695	4590
5.1. Vehicle explosion on the road	Conservatively estimated at 5.2	
5.2. Fall of an aircraft	5.49	2400

Table 5.3-2 presents the potential annual doses that determine the radiological impact under the various scenarios. While the climate change scenarios are actually regarded as constituting alternative evolutions of the disposal facility, the rest of the alternative scenarios: earthquakes, a fall of an aircraft are considered a type of catastrophic scenarios. The limit of the radiological impact should be respectively 1 mSv/a, as under the human induced scenarios, which requirement is met under all scenarios.

Under the NES scenario the annual dose is 0.803 μSv/a, which is significantly below the limit of 100 μSv/a, as defined by the permit issued by the NRA for normal operation of NDF.

The alternative scenarios based on different weather conditions (at different ambient temperatures and precipitation quantity) take into account the altered conditions as compared to the normal ones concerning the NDF evolution and the annual limits within the range of 0.900 μSv/a - 0.695 μSv/a, which are also below the permissible annual limit of 1000 μSv/a for this type of facility.

The impact assessment of emergency scenarios, caused by human intervention, should be compared on the basis of the dose limit for the population of 1 mSv/a (= 1000 μSv/a), as defined in the BSRP-2012.

5.3.2.3 FAILURE OF THE INFILTRATION CONTROL SYSTEM

Apart from the scenarios presented above, a specific, scenario in development is studied under which a potential link between the waste and the biosphere is assumed to exist. If the infiltration control system is not maintained properly or is closed, the contaminated water from the cells can cause radiation impact by flowing directly into the biosphere, where it could be collected for consumption or in some other way. It is assumed that the water from this system is used as a source of drinking water (a conservative assumption of consumption of two liters per day of contaminated drinking water).

Due to its extremely low probability, it is not assumed as a likely alternative scenario, but as a worst-case scenario, when contaminated water from disposal cells can directly penetrate the biosphere. Different events need to occur simultaneously to make the radiological impact possible. Each of these events is analyzed and assessed as having a **very low probability of occurrence**:

- It is a much less plausible assumption that enough water could be collected together so that a regular consumption of 2 liters per day of water is justified;
- The permeability of the upper concrete slab must be significantly lower than the one of the bottom plate so that a significant amount of water could be collected which is discharged through the drain outlet;
- The pipeline system connecting the exits to the tunnel entrance is assumed to be still operational. At the end of the institutional control period this system is to be dismantled and the inspection galleries are to be closed with the aim of preventing leakages;
- Even if after 300 years passed the additional filling-up is not perfect, it is not expected that a significant quantity of water from the cells can work its way through the inspection tunnel exit. There is no collecting system or a suitable place for collection of the potential leak.
- The water should be diverted in some way to be used;
- No administrative control must be exerted anymore;
- All “memory "of the facility existence must be lost so that people start using the water from the tunnel as a regular source of drinking water.

There are two scenarios under which no backfill of the control galleries and lack of administrative control over the population's access could be assumed.

Under the **first scenario** it is assumed that **after the end** of the institutional control period the facility is abandoned without dismantling the pipeline system and filling-up the galleries. Then, for a short period of several decades infiltrated water from the cells could accumulate before the degradation of the pipeline system occurs and it loses its functionality. In this case only a small quantity of water may leak out of the entrance of the galleries and it is very unlikely to be collected for consumption. As the case may be, there will be a very small period of time when the pipeline system will be still functional and people will have forgotten the existence of the facility.

Under the **second scenario**, it is assumed that **during** the institutional control period the facility is left without filling-up the infiltration control system. Such a scenario (most serious violations of administrative control) can be triggered only by catastrophic events - war, major natural disaster. Even in this case, it is difficult to accept that people will use water from the pipeline system without knowing its origin moreover, within an area with a sufficient supply of water from other sources.

In case of abrupt cease of the active control and facility abandonment, it is assumed that at least another generation must come after the facility’s closure before local people start using water from this source for drinking purpose. This means that under this scenario the earliest time is about 20 years after the closure, and in this case, the maximum annual dose will be 165 μSv/a.

As a general conclusion, it can be said that the scenario, under which the consumption of drinking water from the water infiltration control system is assumed, cannot be considered a reasonable alternative scenario, that it cannot be implemented in practice and that it is included in the ISAR only as a specific case so that it serves as an assessment of the worst-case scenario compared to any realistic alternative scenario associated with direct radionuclides release into the biosphere **so that the need for proper shutdown of this control system could be demonstrated**.

Such more realistic scenarios can be a sporadic use of the collected water for consumption by tourists or for consumption by local animals that have used the water discharge from the entrance to the galleries for drinking.

At the end of institutional control period (300 years after the closure) the maximum dose, in this case and under the highly conservative assumptions mentioned above, will be 358 μSv/a, about 445 times the NES maximum dose, which is 0.803 μSv/a.

5.3.2.4 CONCLUSION

As a general conclusion, under all conservatively developed and analyzed scenarios after the closure of the NDF, the estimated individual effective dose is below 100 μSv/a except in the case of "a failure of the infiltration control system", under which it reaches 358 μSv/a based on all highly conservative assumptions.

5.4 IMPACTS DURING ACCIDENTS AND INCIDENTS

5.4.1 ATMOSPHERIC AIR

No impacts are expected in a non-radiation aspect due to anthropogenic accidents and incidents with the exception of a fall of an aircraft when there will be volley dust and gas emissions in case of outbreak of fire. The impacts due to accidents and incidents in a radiation aspect are assessed in sections 5.2. and 5.3.

5.4.2 WATER

No impacts are expected in a non-radiation aspect due to anthropogenic accidents and incidents with the exception of a fall of an aircraft when a break in the sewage wastewater system may occur, which would lead to impossibility of its use. The impacts due to accidents and incidents in a radiation aspect are assessed in sections 5.2. and 5.3.

5.4.3 SUBSOIL

No impacts are expected in a non-radiation aspect due to anthropogenic accidents and incidents with the exception of a fall of an aircraft when a local damage to the upper part of the geological base will be inflicted. The impacts due to accidents and incidents in a radiation aspect are assessed in sections 5.2. and 5.3.

5.4.4 LAND AND SOILS

The impacts from the NDF – subject of the investment proposal, during emergency situations are the most dangerous of all possible negative impacts on land and soil, as well as on the adjacent ecosystem. These impacts can be studied in several aspects – aboveground and underground ones, i.e. in the disposal facility itself and radiation and non-radiation ones. Although these impacts are very unlikely, the impact from some of them can be expected to spread to the neighbouring areas. These impacts in a non-radiation aspect can be caused by:

- ⇒ Fires caused by negligence or by malicious people on the surface of the disposal facility. Such fires are quickly extinguished but they consume hard work and money. They can affect the neighboring land as well as plant and animal habitats. This requires a very strict control not only of the workers from the disposal facility, but also an early control at the checkpoint resulting in non-admission of outsiders onto the site and around it. An emergency plan consisting of strict schedule of all activities aimed at extinguishing any outburst of fire needs to be developed. Such fires can be considered similar to those occurring in all the other industrial sites.
- ⇒ Intensive rainfall causing flooding and water overflow from the higher parts of the terrain toward the lower ones as well as groundwater level rise. These waters are erosional waters, which will carry mud and biological materials into the sewage system. They will pollute not only the soil around the site, but also the lands along the downstream to the catchment area. For this reason the more favorable outcome is after the completion of the excavation work during the construction period, the site to be cleaned up by removing soil masses, waste and chemicals, and every terrain, which is not site-specific, should be planted with grass so that the potential erosion of the terrain could be prevented.

⇒ Potential earthquake can also cause some damage to the land covering the surface of the disposal facility. They may take the form of cracking and upheaval of the land masses, development of landslide processes, and detachment of parts from non-fortified after the construction surfaces and distribution of these parts onto the adjacent lands.

⇒ Such drastic impacts on the NDF cells themselves due to emergency situations could not be expected as the cells are protected both from a possible radiation leak, and from the effects of tectonic movements. For this reason we do not envisage a radiation impact on the soils due to similar emergency situations.

A development of an emergency plan, consisting of strict schedule of all activities aimed at preventing any possible emergency situations related to the objective of the investment proposal, is a prerequisite for reducing the consequences of possible emergency situations. This plan must be coordinated with the relevant authorities responsible for preventing or reducing the effects of emergency situations. After its adoption it must be adhered to without question and the operation of the NDF - objective of the project investment, should be under the control of both the departmental control bodies of the disposal facility and by the persons responsible for taking measures in case of emergency situations. The impacts due to accidents and incidents in a radiation aspect are assessed in sections 5.2. and 5.3.

5.4.5 BIODIVERSITY

No serious and irreversible impacts on the biodiversity can be expected in case of anthropogenic accidents and incidents (terrorist attacks, technological accidents, etc.) within the region of the NDF as, on one hand, the potential anthropogenic accidents and incidents and respectively the potential impacts associated with them have a very low probability of occurrence, and, on the other hand, in case of their possible occurrence the impacts will be temporary and of short duration, in most cases reversible and highly spatially restricted (local impacts), since, in a negative aspect, mainly the vegetation and the wildlife in the artificially planted with grass and/ or rehabilitated areas after closure of the disposal facility will be affected; no rare and protected species will be planted in these areas. This conclusion can be drawn from the fact that, if any accidents and incidents with anthropogenic origin occur, there is a risk to the integrity of only a small part of the disposed RCC with RAW to be affected (and not the entire amount of containers located in the disposal facility), and measures for their removal and repackaging will be subsequently taken. Furthermore, it should be taken into consideration that the risk of radioactive contamination as a result of occurrence of incidents will constantly reduce over time as the activity of the disposed RAW will continuously decrease as a result of the half-life of the radionuclides contained in them.

The impacts in a non-radiation aspect in case of a fall of an aircraft will be temporary, of medium significance, reversible, due to the local damage to the terrain and the destruction of the nearby species.

With regard to non-anthropogenic accidents and incidents caused by natural disasters, the issue is already discussed in the sections of the EIA Report considering the characteristics of the potential impacts on the biodiversity, as well as above in the current section 5.4.

5.4.6 LANDSCAPE

No impacts are expected in a non-radiation aspect due to anthropogenic accidents and incidents with the exception of a fall of an aircraft which would cause a local damage to the landscape.

5.4.7 WASTE

No significant impacts are expected in a non-radiation aspect due to anthropogenic accidents and incidents, as the generated waste is not in relatively large quantities, including the hazardous waste included as well as its temporary storage on the site of the NDF, (more significant are the surplus amounts of earth masses, but they cannot cause significant negative impact on the environment and on the human health).

In a radiation aspect under design basis accidents certain quantities of RAW can be generated (during the destruction of a package) that can be treated again to enter the RAW safety management cycle.

5.4.8 HAZARDOUS SUBSTANCES

No significant impacts are expected in a non-radiation aspect from hazardous substances in case of anthropogenic accidents and incidents, since the utilized and temporarily stored on the site chemical substances and mixtures during the construction, operation and closure of the NDF are in relatively small quantities.

5.4.9 HARMFUL PHYSICAL FACTORS

No impacts are expected in a non-radiation aspect due to anthropogenic accidents and incidents with the exception of a fall of an aircraft when there will be volley noise emission, volley fire radiation and local vibrations.

5.4.10 HUMAN HEALTH

No impacts are expected in a non-radiation aspect due to anthropogenic accidents and incidents with the exception of a fall of an aircraft when the local impact can lead to potential human casualties. The impact in a radiation aspect is analyzed in section 5.2.

5.4.11 TANGIBLE CULTURAL HERITAGE

No impacts on tangible and movable cultural heritage are expected in case of potential accidents and incidents, since there is no such heritage located within the Radiana site.