"Ukrainian Approach on Guidelines for Assessment of Radiological Impacts for Sites with Multiple Existing and/or New Storage/Disposal Facilities and Decision-Making Criteria"[1]

*O. Tokarevskyi**, O. Mykolaichuk*, Z. Alekseeva**, S. Kondratyev**, E. Nikolaiev***

* State Nuclear Regulatory Inspectorate of Ukraine, 9/11 Arsenalna St., Kyiv, 01011, Ukraine
** State Scientific and Technical Center for Nuclear and Radiation Safety, 35-37 V.Stusa St., 03142, Kyiv, Ukraine

Abstract: In Ukraine, it is envisaged to construct a set of radioactive waste management facilities, including facilities for waste treatment, long-term storage and disposal, on the Vector site in the Chernobyl exclusion zone. It is planned to transfer practically all radioactive waste (radwaste) of Ukraine to the Vector site, including that from the existing radwaste disposal sites (RWDS), which were constructed in the 1960s in the former USSR at Radon enterprises. This paper describes the state of development of Guidelines for assessment of radiological impacts of the Vector and Radon sites on the public and environment. The Guidelines also establish decision-making criteria for the removal of radwaste from the Radon RWDS and the placement of radwaste into storage or disposal facilities on the Vector site.

1 INTRODUCTION

In Ukraine, it is envisaged to construct a set of radioactive waste management facilities, including facilities for waste treatment, long-term storage and disposal, on the Vector site in the Chernobyl exclusion zone.

It is planned to transfer practically all Ukrainian radwaste (either conditioned or to be treated) to the Vector site, including that from the existing radwaste disposal sites (hereinafter – RWDS), which were constructed in the 1960s in the former USSR.

In Ukraine, RWDS are located at six sites of state interregional specialised enterprises of the Radon Corporation (hereinafter – Radon enterprises).

The legislation of Ukraine [1] envisages re-equipment and conversion of the Radon enterprises aimed at temporary container storage of radwaste. The conversion measures include waste retrieval from RWDS of the Radon enterprises and further transfer of this waste to the Vector site.

In the framework of INSC Project UK/TS/39, the State Nuclear Regulatory Inspectorate of Ukraine (hereinafter – SNRIU), with the involvement of the State Scientific and Technical Centre for Nuclear and Radiation Safety (hereinafter – SSTC NRS) and the support of RISKAUDIT IRSN/GRS International, is developing Guidelines for assessment of radiological impacts for the Vector and Radon sites and identification of decision-making criteria. A part of this work is funded by the EU. The development of these Guidelines is on-going and discussions between Ukrainian experts and EU experts are not completed. According to the results of these assessments, decisions can be made, in particular, as regards:

- immediate or delayed removal of radwaste from RWDS of Radon enterprises or leaving radwaste in RWDS;
- placement of radwaste into long-term storage or disposal facilities at the Vector site.

[1] Disclaimer. The opinion expressed in this publication is the sole responsibility of the authors and can in no way be taken to reflect the views of the European Commission

The Ukrainian approach on principal provisions of the Guidelines for safety assessment of the Vector and Radon sites and for decision-making criteria is stated below.

The Guidelines are based on requirements of the Ukrainian legislation [1-4] and provisions of IAEA documents as regards safety of facilities for long-term storage or disposal of radwaste. In addition, the Guidelines take into account the peculiarities related to location of the Vector site in the contaminated Chernobyl exclusion zone, as well as to the history of creation and operation of RWDS at Radon sites.

2 GUIDELINE FOR ASSESSMENT OF THE RADIOLOGICAL IMPACT ON THE PUBLIC AND ENVIRONMENT OF THE VECTOR SITE WITH MULTIPLE FACILITIES FOR RADIOACTIVE WASTE TREATMENT, STORAGE AND DISPOSAL

The Guideline sets forth approaches to assessment of radiological impacts of the Vector site, application of regulatory requirements to limit exposure of people to radiation, as well as detailed requirements for assessment of impacts for the Vector site, taking into account peculiarities of its location in the contaminated exclusion zone (including requirements for site characterisation, determination of potential exit points and pathways of radioactivity release, selection of critical groups of the public, development of scenarios and assessments of radiological impacts).

2.1 **Approach to assessment of radiological impacts of the Vector site**

Specific construction activities at the Vector site should be carried out to ensure with confidence that, if all facilities for radwaste management (treatment, storage or disposal) are built and operated at the Vector site, an appropriate level of environmental and human protection will be ensured during the entire planned period of potential radwaste hazard according to the regulatory requirements of Ukraine in force and IAEA recommendations, e.g. with respect to the Environmental Impact Assessment (EIA) in transboundary context (Espoo Convention).

To ensure this, the Operator has to carry out:

- regular assessments of radiological impacts of the radwaste management facilities existing and planned to be constructed at the Vector site (hereinafter – impacts of the Vector site) on the public and environment;
- detailed safety analysis of specific facilities at the Vector site, taking into account assessments of the overall impact of the Vector site.

The Operator should assess impacts of the Vector site according to the approach described below.

Initial conservative assessment of the overall impact of the Vector site should be based on the following data:

- available input characteristic of the Vector site;
- types, amounts and main characteristics of radwaste from all suppliers;
- preliminary classification of radwaste into that acceptable for disposal or long-term storage;
- conceptual decisions on engineering safety barriers for specific facilities;
- arrangement of facilities according to the general layout of the Vector site;
- planned periods for construction, operation and decommissioning/closure of facilities.

According to results of the initial assessment, the Operator determines:

- potential suitability of the Vector site for placement of all planned amounts of radwaste into the long-term storage and disposal facilities;
- restrictions for placement of certain radwaste for storage or disposal (limitations of activities of specific radionuclides);
- correction of distribution of dose limitation quotas among different facilities;
- optimisation of the strategy for construction of facilities and transfer of radwaste to the Vector site.

In detailed safety analysis, the Operator assesses impacts of individual facilities, using dose limitation quotas adjusted according to the initial general assessment as an assessment criterion.

Assessments of the overall impact of the Vector site are revised (with less conservatism) on a regular basis, taking into account operational experience, new essential data on the Vector site, essential change of waste acceptance criteria, commissioning of new facilities and closure of facilities.

Based on the revised assessments of the overall impact of the Vector site, the above-mentioned aspects are revised and corrected.

The impact for three periods of existence of the Vector site should be considered:

Period I. At the Vector site, there are operational and/or decommissioned facilities intended for treatment, and/or storage, and/or disposal of radwaste. Period I will end in approximately 200 years, taking into account planned successive construction of radwaste storage facilities, long-term storage of radwaste in these facilities for up to 100 years, as well as further decommissioning of facilities at the Vector site. Construction, commissioning, operation, closure and decommissioning of different facilities may take place at the same time. Period I ends after placement of all radwaste for disposal and final closure of the last disposal facility.

Period II. At the Vector site, there are only closed disposal facilities, for which active institutional control is carried out. Period II will end in approximately 400 years after the beginning of Period I, taking into account that operation and closure of disposal facilities will continue for about 100 years and, according to regulatory documents of Ukraine, radwaste in the disposal facilities must reach levels for exemption (limited or complete) from regulatory control not later that 300 years after closure.

Period III. At the Vector site, there are only disposal facilities with radwaste with limited exemption from regulatory control; for a certain period of time, passive control is carried out, and the reduced exclusion zone including the Vector site with restricted access still remains (i.e. during the period of its existence, no population lives within its boundaries, and only limited activities are carried out, including nature conservation measures). Barriers of the disposal facilities gradually degrade within this restricted access area.

The territory of the exclusion zone was intensively contaminated with long-lived radionuclides, and free access to it is prohibited. Radiation monitoring is conducted in the exclusion zone. Residence of population is prohibited.

Conceptual documents on development of the exclusion zone envisage gradual reduction of its area, though there are no specific programmes or plans.
It is assumed that a contaminated restricted access area will exist for a long time around the Vector site.

Finally, the population may reside outside the Vector site after the exclusion zone ceases to exist (if it occurs) and later directly at the Vector site.

The impacts of the Vector site on the following categories of the public should be considered:
The critical group of the public:

- living outside the exclusion zone (impact decreases with time according to natural activity decay);
- theoretically living at the territory of the Vector site after the restricted access area ceases to exist and/or information on the site is lost.

Staff of adjacent facilities – staff working at facilities within the exclusion zone during Periods I and II that do not belong to the Vector site. As regards the Vector site, this staff is regarded as category B, which, according to NRBU-97 [5], is not directly involved in activities with ionising radiation sources (in this case, at the Vector site); however, because staff workplaces are located at industrial sites of facilities with radiation and nuclear technologies, this staff may receive additional exposure.

Staff of the Vector site – staff working at facilities of the Vector site during Periods I and II. As regards the Vector site, this staff is regarded as category A, which, according to NRBU-97 [5], is directly involved in activities with ionising radiation sources (in this case, at the Vector site).

2.2 **Regulatory requirements on restriction of exposure to people applied to the Vector site**

The main dose limits of routine exposure for Periods I–III and categories of the public are shown in Table 1.

Table 1. Dose limits for routine exposure due to radiological impact from the Vector site

Period	Dose limits, individual annual effective dose		
	Critical group of the public	Staff of adjacent facilities	Staff of Vector site[1)]
I	0.3 mSv – total for all facilities[2)] 0.08 mSv – for individual facilities for radwaste treatment and storage (Table 5.2 of NRBU-97 [5]) 0.04 mSv – for individual radwaste disposal facilities (Table 4.1 of NRBU-97/D-2000 [6])	2 mSv (Table 5.1 of NRBU-97 [5] for category B staff)	20 mSv (Table 5.2 of NRBU-97 [5] for category A staff)
II	0.3 mSv – total for all facilities (para. 2.15, SSR-5 [7]) 0.04 mSv – for individual radwaste disposal facilities (Table 4.1 of NRBU-97/D-2000 [6])	2 mSv (Table 5.1 of NRBU-97 [5] for category B staff)	20 mSv (Table 5.2 of NRBU-97 [5] for category A staff)
III	0.3 mSv – total for all facilities (para. 2.15, SSR-5 [7]) 0.01 mSv – for individual facilities with disposed radwaste exempt from regulatory control (Table 4.1 of NRBU-97/D-2000 [6])	-	-

1) for category A staff, other regulated values stated in Table 5.2 of NRBU-97 [5] must not be exceeded either

2) dose limit 0.3 mSv/year is not governed by existing regulations of Ukraine and IAEA documents. It is recommended to use this limit or show that, for the critical group of the public, dose limit of 1 mSv/year is not exceeded (Table 5.1 of NRBU-97 [5]), taking into account radiological impacts from the Vector site, Buryakivka disposal site and contamination of the exclusion zone. It is supposed that the dose for the public resulting from radiological impacts of the Buryakivka site and exclusion zone will not exceeded 0.7 mSv/year.

The main dose limits of potential exposure for Periods I–III and categories of the public are shown in Table 2.

Table 2 Dose limits of potential exposure due to radiological impact from the Vector site

Period	Dose limits D – annual effective dose of potential exposure P – probability of critical event		
	Critical group of the public	Staff of adjacent facilities	Staff of Vector site[2)]
I	D ≤ 50 mSv, P ≤ 1×10^{-2}/year		D ≤ 100 mSv, P ≤ 1×10^{-2}/year
II	D > 50 mSv[1)], P ≤ 2×10^{-5}/ year		D > 100 mSv, P ≤ 2×10^{-4}/year
III	D ≤ 1 mSv[3)], P ≤ 10^{-2}/year	-	-

1) probability of events that may lead, within a short period of time, to lethal exposure doses must not exceed 5×10^{-7}/year
2) other regulated values from Table 2.2 of NRBU-97/D-2000 [6] must not be exceeded either
3) D ≤ 50 mSv for making a decision on principal possibility of radwaste disposal based on calculations of potential exposure doses according to conservative scenarios of NRBU-97/D-2000 [6] at the beginning of Period III

The ALARA principle should be applied to activities related to radwaste treatment, long-term storage and disposal at facilities of the Vector site.

2.3 **Vector site radiological impact assessment**

2.3.1 Assessment of impacts of the Vector site for Period I (operation, decommissioning, closure)

For Period I, liquid and gaseous radioactive releases/discharges from all facilities to the environment should be considered.

For Period I, annual effective routine exposure doses should be assessed:
- for the critical group of the public living at the boundary of the restricted access area (or at the discharge exit point);
- for the staff (according to Table 1) of adjacent facilities with conservative assumption that the staff is permanently working at facilities near the boundary of the Vector site.

The total exposure doses should be assessed by summing up doses from individual facilities, taking into account distribution of their life stages with time.

Potential impacts of the Vector site should be assessed considering initiating events that may lead to critical events at all (majority) of facilities at the Vector site. The following extreme natural events should be considered: design-basis earthquakes (DBE), extreme wind, tornado of class F 3.0.

For each extreme event and each individual facility, the following should be assessed conservatively:
- possible damage/destruction of safety barriers and associated emergency release from each facility at different stages of its lifecycle;
- total emergency release at the Vector site taking into account distribution of the facilities' life stages with time;

– maximum effective potential exposure doses for the population residing at the boundaries of the exclusion zone and staff of adjacent facilities located at the boundaries of the Vector site.

Taking into account that the probability of a critical event caused by DBE and extreme wind is more than $2 \cdot 10^{-5}$/year, the estimated potential exposure doses for the public and staff of adjacent facilities must not exceed 50 mSv (see Table 2).

Taking into account that the Vector site is located in the exclusion zone, organisational and technical measures should be undertaken at facilities (roads, etc.) adjacent to the Vector site to:

– reduce the hazard of explosion so that, in case of explosion, the impact of shock waves on facilities of the Vector site is less that impacts from extreme wind;
– prevent damage of facilities at the Vector site due to onsite fires, flammable vapour clouds, release of toxic chemicals.

For ChNPP site, there is a requirement to implement organisational and technical measures to exclude (minimise) aircraft routes above the exclusion zone so that the probability of unintended aircraft crash onto the ChNPP site does not exceed $1 \cdot 10^{-7}$ per year. This requirement is also applicable to the Vector site.

For Period I, it is necessary to analyse impacts on staff working at the Vector site and demonstrate that the reference level (RL) for the annual effective dose equal to 14 mSv and, separately, RL for internal and external exposure are not exceeded.

Based on non-exceeding of RL for exposure dose for staff, basic RL for radiation situation at the territory of the Vector site and radwaste management facilities should be preliminary defined.

2.3.2 Assessment of impacts of the Vector site for Periods II and III (impact of disposal facilities after closure)

To determine impacts of radwaste disposal facilities at the Vector site, preliminary assessment of long-term safety for Periods II and III after closure of all disposal facilities is carried out. The goal of such an assessment is to make sure that safety of radwaste disposal facilities will be principally ensured over a long-term period in future. In turn, this requires analysis of principal barriers of the disposal systems and determination of potential evolution of the disposal systems and environment with time. The location of the disposal facilities in the exclusion zone and expected period of its reduction and existence for limitation of access to the Vector site should be taken into account.

Analysis of impacts from radwaste disposed of at the Vector site is based on the ISAM methodology [8] and is an iterative process, consisting of a series of interconnected steps.

1. Analysis of features, events and processes (FEPs), which may initiate release of radionuclides from radwaste and their transfer through geosphere and biosphere to the public or which may affect the rate of release and transfer of radionuclides.
2. Determination of the most critical (in terms of consequences) combinations of FEPs that should be assessed in the context of impacts on functioning of the disposal facilities.
3. Identification of potentially important scenarios that require sequential assessment.
4. For each scenario, development, justification and verification of models, analysis of available initial databases and computer codes for assessment of disposal systems and simulation of their behaviour.
5. Calculations of consequences of important scenarios according to the models developed.
6. Uncertainty analysis of the calculation results and determination of parameters and assumptions that have the maximum impact on the final results of the assessment.
7. Comparison of the results with appropriate criteria.

Based on the list of selected FEPs for each type of disposal facilities at the Vector site, the following is determined:

- Normal evolution scenarios (NES) – include only those FEPs that are always present or will probably occur after closure of the disposal facility (e.g. gradual degradation of containers, gradual leaching of radionuclides, etc.). This type of scenarios must base on a general description of the site and disposal facilities and include, in particular, phenomena such as groundwater flow, sorption, release of radionuclides due to leaching. NES, according to the definitions of routine and potential exposure by NRBU-97/D-2000 [6], must be considered as those that lead to routine exposure. In NES with high probability, according to NRBU-97/D-2000 [6], all FEPs with a frequency higher than once every 100 years must be considered.
- Alternative scenarios – include less probable FEPs, e.g. natural events that lead to enhanced degradation of barriers of the disposal facility and inadvertent human intrusion. Alternative scenarios originate from NEW, where one or several less probable FEPs are included. Alternative scenarios must be considered as those that lead to potential exposure.

For Periods II and III, transfer of radionuclides in the geosphere by ground and surface waters should be taken into account.

For Period II, integrity of the upper cover of the disposal facilities has to be maintained (potential degradations, necessitating repairing, have nevertheless to be taken into account and their impact evaluated). This excludes the possibility for release of solid radioactive materials to the surface and subsequent spreading with atmospheric air.

For Period III, release of solid radioactive materials to the surface of the Vector site (e.g. as a result of erosion, activities of flora/fauna or in case of human intrusion) and related exposure pathways are possible. The following should be taken into account to consider transfer of radioactive contamination with air and calculate distances of possible impact: wind speed, probability of tornado on site.

Conservative assessments are carried out on the basis of simplified models.

For detailed analysis of release pathways, more realistic assessments are carried out using sophisticated numerical models, taking into account the main peculiarities of the term sources and geosphere.

During Period III, the exclusion zone surrounding the Vector site will still exist or, depending on the evolution of the contaminated territories, will be reduced to a restricted area under passive control. In any case, human intrusion should be excluded. Nevertheless, during this period, the barriers will degrade, which can have consequences on ground water discharge at the exit point for the critical group of the public and on people working occasionally at the Vector site.

After completion of passive control, the possibility for unrestricted human access to the Vector site without any limitations for land use (geotechnical activities – drilling of boreholes, road construction, permanent settlement on the disposal facility site) is taken into account.

Critical groups of the public are to be defined and justified taking into consideration the relevant components of the “assessment context” (site features, inventory, assessment endpoints, timeframes, etc.) to determine the radiological significance of potential future release of radionuclides.

Specific modes of release or particular radionuclides within the source term that may require consideration of specific exposure pathways should be taken into account.

For Periods II–III, critical groups of the public that may potentially receive the maximum dose by the identified pathways of radionuclide release should be considered.

For justification of such selection, it is recommended to take into account the results of IAEA coordination research project BIOMASS ("BIOsphere Modelling and Assessment" – IAEA, Report on BIOMASS "Reference Biosphere" for solid radioactive waste", 2003 [9]). To define critical groups, it is recommended to base on habits and behaviour of people that are typical for the location area of the disposal facility (e.g., type of water use).

3 GUIDELINE FOR SAFETY REASSESSMENT OF THE EXISTING DISPOSAL FACILITIES AND DECISION-MAKING CRITERIA CONCERNING SUBSEQUENT MEASURES ON THESE FACILITIES

The Guideline states approaches to safety reassessment of existing RWDS, application of safety principles and criteria to RWDS, as well as detailed requirements for safety reassessment of RWDS in each area (assessments: characterisation and condition of engineering barriers of RWDS, radiological impacts on the public, measures for control, monitoring and maintenance of RWDS safety, removal of radwaste from RWDS), taking into account peculiarities of RWDS, in particular, insufficiency of reliable data on characteristics and condition of radwaste in RWDS and RWDS engineering barriers.

3.1 **Approach to safety reassessment for existing RWDS**

The safety analysis report (hereinafter – SAR) for all radwaste management activities at each Radon enterprise is developed by the Operator and is submitted to SNRIU according to the requirements of legislation in force. In SAR, safety assessment for existing RWDS is generalised (due to the lack of initial data, absence of special research results, etc.) and is mainly based on data on control of RWDS condition and environmental monitoring.

For making justified decisions on the duration and sequence of radwaste retrieval from RWDS, safety reassessments for RWDS located on sites of each Radon enterprise should be carried out. Safety reassessments of existing RWDS should be carried out by detailing the SAR concerning radwaste management at Radon enterprises as regards activities related to existing RWDS.

Safety reassessment of existing RWDS is intended to:

- ascertain whether the adequate level of safety is achieved at existing RWDS and whether RWDS comply with the safety principles and criteria defined by Ukrainian regulations in force and IAEA documents;
- identify possible measures for increasing the safety level of RWDS (e.g. reinforcement of protective properties of the RWDS cap, increase in scope of control, etc.);
- define possible options and appropriate measures for radwaste removal from RWDS and further management of this radwaste;
- make decisions on the duration, sequence and options of radwaste removal from RWDS (e.g. immediate removal of all or certain radwaste from RWDS, removal of all radwaste from RWDS after a certain period of time) or, in exceptional cases, justification of inexpediency of radwaste removal.

3.2 **Application of safety principles and criteria to RWDS of Radon enterprises**

3.2.1 Application of requirements for safety goals and principles in force to the RWDS

The safety goals and principles defined in Ukrainian legislation in force are much different from those used at the time of RWDS construction. The most important distinctions and,

respectively, necessity and possibility for use of safety goals and principles for RWDS according to legislation in force are given below.

The safety goals related to protection of human health and environment, as well as radwaste isolation, must be applied to RWDS to the fullest extent.

The safety of RWDS must be maintained for a certain period of time so that radiological safety criteria defined in regulatory documents in force be met, and then radwaste must be retrieved from RWDS. Radwaste may remain only in those RWDS where adequate safety level may be ensured without maintenance by future generations.

The defence-in-depth principle cannot be applied to the full extent to existing RWDS, because the system of engineering and natural barriers still exists. However, as compensatory measures prior to radwaste removal from RWDS, the following should be ensured to the full extent: strengthening and maintenance of the reliable cap of RWDS, monitoring of the RWDS barriers and environment.

3.2.2 Application of radiological criteria in force to disposal of radwaste in RWDS

Criteria for radiological protection of the public established at the time of RWDS construction are much different from those established in regulatory documents in force.

Nevertheless, radiological safety criteria defined by the Radiation Safety Standards of Ukraine in force, which represent dose limits of routine and potential exposure, must be used to the fullest extent. If radiological safety criteria in force are not complied with, radwaste must be immediately removed from the disposal facility, or measures to increase the safety level of RWDS must be immediately implemented.

For the time before exemption from the regulatory control:
- quota for annual effective dose for routine exposure of the public is 0.04 mSv/year for individual RWDS according to Table 4.1 of NRBU-97/D-2000 [6];
- reference probabilities of critical events and doses of potential exposure of the public, taking into account all RWDS at the site of Radon enterprises, are defined according to para. 2.7 of NRBU-97/D-2000 [6].

If these radiological safety criteria are not complied with, radwaste must be immediately removed from the disposal facility, or measures to increase the safety level of RWDS must be immediately implemented.

For the period after exemption of RWDS from the regulatory control (NRBU-97/D-2000 [6]):
- dose of routine exposure from individual RWDS is 0.01 mSv/year;
- dose of potential exposure of the public, taking into account all RWDS on the site of Radon enterprises, is 1 mSv/year.

If these radiological criteria are complied with according to the estimates, radwaste need not be removed from RWDS.

Radwaste must be removed from RWDS if at least one of the following conditions is fulfilled:
a) dose of routine exposure from individual RWDS is higher than 0.01 mSv/year;
b) dose of potential exposure of the public is higher than 50 mSv/year.

If, according to the estimates, the dose of routine exposure does not exceed 0.01 mSv/year and the dose of potential exposure is within the range 1–50 mSv/year, it is allowed to consider different options of radwaste removal from RWDS or increase RWDS safety level (partial removal of radwaste, strengthening of engineering barriers, etc.).

3.2.3 Application of existing requirements for the site and engineering barriers for radwaste disposal to RWDS

Requirements of the Ukrainian legislation in force regarding sites for radwaste disposal in subsurface facilities are more extensive and systemised compared to those that were in force previously. However, it is not expected that the existing sites of Radon enterprises can be inacceptable for location of RWDS according to the exclusion criteria defined in regulation NP 306.4.149-2008 [10].

Requirements for the barriers of the disposal facilities in the regulatory documents in force (NP 306.4.149-2008 [10], RD 306.4.098-2004 [11]) are more detailed and systemised compared to those that were in force previously and are aimed at ensuring, in particular, protection of future generations. It is expected that existing engineering barriers of RWDS of Radon enterprises do not fully comply with the regulatory requirements in force. First of all, it is expected that engineering barriers of RWDS cannot ensure reliable isolation/confinement of radwaste over the entire period of its potential hazard.

Taking into account that RWDS still exist, requirements of the regulatory documents in force relating to the sites and engineering barriers can be applied partially to RWDS.
If the Radon site is characterised by any condition from the exclusion criteria listed in NP 306.4.149-2008, radwaste must be removed from RWDS.

If the Radon site is characterised by one or several unfavourable conditions for location of a subsurface radwaste disposal facility listed in NP 306.4.149-2008 [10], options are considered for delayed removal of radwaste and/or possible measures for increase of RWDS safety level (partial removal of radwaste, strengthening of engineering barriers, etc.) to compensate for the effect of unfavourable conditions on safety of the disposal system as a whole.

If characteristics of the Radon site comply with the requirements for location of a radwaste disposal facility, radwaste and RWDS engineering barriers are assessed, exposure doses for the critical group of the public are calculated, and compliance with radiological criteria is checked to make a decision on the safety level of RWDS.
If RWDS engineering barriers do not ensure isolation/confinement of radwaste at the moment, radwaste must be immediately removed from RWDS.

If RWDS engineering barriers ensure isolation/confinement of radwaste for a certain period of time but are not capable of ensuring safety for design natural events with a probability not less than 10^{-2}/year, options for radwaste removal or possible measures for increase of RWDS safety level are considered as regards resistance to impacts of natural events.

If RWDS engineering barriers ensure isolation/confinement of radwaste, including that for design natural events, the necessity for waste removal during this period or possibility to leave it in RWDS is determined on the basis of assessments of radiological impacts in case of extreme natural events.

3.2.4 Application of existing waste acceptance criteria for disposal to RWDS

Requirements for waste acceptance criteria (WAC) for disposal in the existing regulatory documents are more systemised compared to those that were in force previously and are aimed at ensuring safety of future generations.

The regulatory documents in force hardly establish specific numerical values for WAC. It is recommended to determine these values according to results of safety analysis of the disposal system, in particular, according to the results of long-term assessments of radiological impacts on people and the environment and comparison of these impacts with established radiological criteria. At the same time, the regulatory documents that were in force previously defined a set of numerical criteria. At the moment, it is not known what

assessments or other factors were used for development of these criteria. It is obvious that criteria for long-term radiological impacts were not taken into account, because they were not defined in the regulatory documents.

As follows from the above-mentioned, it is expected that radwaste disposed of in RWDS of Radon enterprises does not fully comply with the existing regulatory requirements. The following principal inconsistencies are expected:

a) specific/total activities of long-lived radionuclides may exceed limits, resulting from long-term safety assessment of RWDS;
b) radwaste form/packages disposed of in RWDS are not capable of functioning as the first barrier for a long time and will not ensure reliable confinement of radwaste for a period of time sufficient for decrease of radwaste activity;
c) radwaste may contain chemically active substances and/or substances incompatible with barriers of RWDS that may lead to enhanced degradation of RWDS engineering barriers.

Taking into account that some existing RWDS are already closed, as well as there are decisions on conversion of Radon enterprises and step-by-step removal of radwaste, requirements of existing regulatory documents concerning WAC are not applied directly to RWDS.

At the same time, in the framework of assessment of radwaste isolation/confinement by RWDS engineering barriers for a certain period of time, radwaste characteristics should be considered, which, according to current regulatory documents, should be used for establishing limitations for radwaste placement in the disposal facility. The following are the most important:

1) Presence of chemically active substances and/or substances incompatible with barriers of RWDS, that may lead to significant degradation of engineering barriers, as well as highly explosive and self-igniting substances. In this case, radwaste is immediately removed from RWDS.
2) Presence of radionuclides (especially long-lived) in radwaste in such amounts that exceed radiological criteria and can potentially lead to radiological impacts on people. In this case, radwaste is removed from RWDS within a certain period of time, depending on reliability of engineering barriers.
3) If radwaste does not contain chemically active substances and/or substances incompatible with barriers of RWDS, as well as radionuclides in the amounts stated in 1) and 2), this radwaste can be left in RWDS provided that compliance of RWDS with other safety requirements is demonstrated.

3.3 **General contents and algorithm for RWDS safety reassessment**

Safety reassessment of RWDS is carried out in the following areas:

- characterisation of RWDS site;
- characterisation and condition of radwaste in RWDS;
- characterisation and condition of RWDS engineering barriers;
- assessment of radiological impacts for the public;
- measures for control of RWDS, environmental monitoring and maintenance of the RWDS safety level;
- assessment of radwaste removal from RWDS and further management.

Safety reassessment is carried out iteratively in the following sequence:

- Stage 1. Reassessment to determine necessity for immediate removal of radwaste from RWDS and making respective decisions.
- Stage 2. Reassessment to determine necessity for delayed removal of radwaste from RWDS and making respective decisions.
- Stage 3. Reassessment to determine expediency of radwaste removal from RWDS or radwaste leaving in RWDS and making respective decisions.

A general algorithm of safety reassessment is the as follows.

Stage 1 of RWDS safety reassessment

If the results of Stage 1 indicate the necessity for immediate removal of radwaste, Stage 2 is not performed.

According to the results of reassessment by Stage 1, conceptual decisions for immediate removal and further management of this radwaste are justified.

If there is no need for immediate removal of radwaste from RWDS, safety reassessment by Stage 2 is carried out.

Stage 2 of RWDS safety reassessment

If the results of Stage 1 indicate the necessity for delayed removal of radwaste, Stage 3 is not performed.

According to the results of reassessment by Stage 2, permissible periods for storage of radwaste in RWDS under existing conditions are determined, and need for corrective measures to increase safety level of RWDS for the period up to removal of radwaste from RWDS is considered.
According to the results of reassessment by Stage 2, conceptual decisions are justified for immediate removal of radwaste during the period of its temporary storage or at the end of this period and for further management of this radwaste.

If there is no need for delayed removal of radwaste from RWDS, safety reassessment by Stage 3 is carried out.

Stage 3 of RWDS safety reassessment

If Stage 2 has not indicated principal need for radwaste removal from RWDS, the following assessment is carried out:
- for the option of radwaste removal from RWDS: measures required for radwaste removal during a certain period and further radwaste management;
- for the option of leaving radwaste in RWDS: measures required to ensure RWDS safety for the period of active institutional control.

It is necessary to carry out a comparative analysis of these measures to make a decision on the expediency of radwaste removal from RWDS within a certain period of time or radwaste leaving in RWDS.

If the decision on the expediency of radwaste removal from RWDS is made, conceptual decisions for radwaste removal within a certain period of time and further management of this removed radwaste are justified.

If the decision to leave radwaste in RWDS is made, safety reassessment of RWDS according to the safety requirements for radwaste disposal in subsurface facilities is carried out, and conceptual decisions for maintenance of RWDS safety are justified.

During performance of each subsequent stage, safety reassessment of the previous stage is used. The scope of reassessment in individual areas increases.

Reassessment at Stage 1 to determine the necessity for immediate removal of radwaste from RWDS and making respective decisions

Necessity for immediate removal of radwaste from RWDS is defined if RWDS does not comply with the requirements of regulatory documents as regards the following:

- radwaste contains chemically active substances and/or substances incompatible with material of engineering barriers, as well as highly explosive and self-igniting substances;
- engineering barriers in their current state do not ensure isolation/confinement of radwaste.

Accordingly, at Stage 1, the following is reassessed first of all:
- characteristics and condition of radwaste in RWDS;
- characteristics and condition of RWDS engineering barriers.

The scope of reassessment must be sufficient to reveal the above-mentioned inconsistencies.

If any of the above-mentioned inconsistencies is revealed, analysis is carried out by individual areas in the scope required for development and justification of conceptual decisions for immediate radwaste removal from RWDS and further management.

Reassessment at Stage 2 to determine the necessity for delayed removal of radwaste from RWDS and making respective decisions

The necessity for delayed removal of radwaste from RWDS is defined if RWDS does not comply with the requirements of the regulatory documents as regards the following:
- Radon site is characterised by any of the exclusion criteria for siting of subsurface disposal facilities stated in NP 306.4.149-2008 [10];
- safety level for the entire period of radwaste potential hazard is not ensured by passive systems taking into account the defence-in-depth principle;
- at the moment, engineering systems of RWDS ensure isolation/confinement of radwaste, but they are not capable of performing these functions reliably is case of design natural events with a probability not less than 10^{-2} per year;
- criteria for limitation of radiological impacts on people and the environment are not complied with for the period after release from regulatory control.

Accordingly, at Stage 2, the following is reassessed first of all:
–characterisation of RWDS site;
–characterisation and condition of radwaste in RWDS;
–characterisation and condition of RWDS engineering barriers jointly with natural barriers;
–assessment of radiological impacts for the public.

The scope of reassessment must be sufficient to reveal the above-mentioned inconsistencies.

If any of the above-mentioned inconsistencies is revealed, analysis is carried out by individual areas in the scope required for determination of a permissible period for storage of radwaste in RWDS, as well as development and justification of conceptual decisions for removal of radwaste from RWDS during this period or upon its completion and radwaste further management. A permissible period for radwaste storage must not exceed the duration of active control (100 years).

Reassessment at Stage 3 to determine the expediency of radwaste removal from RWDS or leaving radwaste in RWDS and making respective decisions

The expediency of radwaste removal from RWDS within a certain period of time or radwaste leaving in RWDS is determined taking into account comparison of the following factors (for radwaste removal and further management, or for active institutional control and maintenance of RWDS in a safe state):
1) estimated collective doses for staff carrying out respective activities;
2) estimated resources;
3) suitability of radwaste disposal site and controlled area for use for other purposes;

4) social factors related to habitation of the public at the territory adjacent to the radwaste disposal site.

Factors 3) and 4) give essential preference to the option of radwaste removal because, in this case, radwaste is removed for disposal from the RWDS and Radon site to the Vector site that will not be used for other purposes, and there is no population at the adjacent territory.

Therefore, the option to leave radwaste in RWDS of Radon enterprises may become preferable only due to factors 1) and 2), i.e. a decision about the expediency to leave radwaste in RWDS may be made only if estimated resources and/or collective doses for staff during radwaste removal and further management will significantly exceed those for the option to leave radwaste in RWDS.

In case of justification of radwaste removal from RWDS, analysis is carried out by individual areas in the scope required for development and justification of conceptual decisions for removal of radwaste from RWDS within a certain period of time and further radwaste management.

In case of justification of the option to leave radwaste in RWDS, analysis is carried out by individual areas in the scope required for justification of long-term safety of radwaste disposal in RWDS.

LIST OF REFERENCES

[1] Law of Ukraine "About the State Goal-Oriented Ecological Program for Radioactive Waste Management"

[2] Law of Ukraine “On Human Protection against Ionizing Radiation ”

[3] Law of Ukraine “On Radioactive Waste Management ”

[4] "Strategy for Radioactive Waste Management", approved by the order of the Cabinet of Ministers of Ukraine dated 19.08.2009 No.990-p

[5] “Radiation Safety Standards of Ukraine, NRBU-97”

[6] “Radiation Safety Standards of Ukraine, Supplement: Radiation Protection against Ionizing Radiation Sources” (NRBU-97/D-2000)

[7] "Disposal of Radioactive Waste Specific Safety Requirements”, IAEA Safety Standards Series SSR-5, 2011

[8] ISAM – Safety Assessment Methodologies for Near Surface Disposal Facilities. IAEA, Vienna, 2004

[9] “BIOsphere Modelling and Assessment” – IAEA, Report on BIOMASS “Reference Biosphere” for solid radioactive waste”, 2003

[10] NP 306.4.149-2008 "Requirements for site selection for the facility for disposal of radioactive waste";

[11] RD 306.4.098-2004 "Recommendations on establishment of acceptance criteria for disposal of conditioned radioactive waste in subsurface facilities";