Safety Issues in Construction of Facilities for Long-Term Storage of Radioactive Waste at Vector Site

*O.Tokarevskyi**, N.Rybalka*, Z.Alekseeva**, S.Kondratiev***

* State Nuclear Regulatory Inspectorate of Ukraine, 9/11 Arsenalna St., 01011, Kyiv, Ukraine

** State Scientific and Technical Center for Nuclear and Radiation Safety, 35-37 V.Stusa St., 03142, Kyiv, Ukraine

Abstract:

In Ukraine, it is planned to create a number of near-surface facilities for disposal of short-lived RW and long-term (up to 100 years) storage of long-lived RW at the Vector site in the Chernobyl exclusion zone. The expected streams of long-lived RW are analyzed in the paper. According to the analysis of RW streams, in particular, issues are considered on development of RW acceptance criteria, admissible radiological impacts during preparation of RW for long-term storage, reliability of barriers (RW packages, modules and structures, etc.) during long-term storage of RW.

INTRODUCTION

The Vector site is located in the Chernobyl exclusion zone. It is planned to supply almost all Ukrainian waste (conditioned or for treatment), including RW from Chernobyl NPP (ChNPP), exclusion zone, Ukrainian NPPs, and specialized "Radon" plants to the Vector site.

56 repositories of two types (SRW -1 and SRW -2) with a total capacity of 500,000 m^3 of SRW are planned to be constructed at the Vector site for disposal of Chernobyl RW. A near-surface disposal facility (Lot 3) for 50,000 m^3 of processed low- and intermediate-level RW (LLW and ILW) of ChNPP has also been constructed there (Lot 3 is a part of the ChNPP RW processing plant including Lot 1, Lot 2, and Lot 3). Further it is planned to build additional facilities for disposal of RW from NPP decommissioning and Shelter transformation into an environmentally safe system.

It is also planned to build facilities for long-term storage of: spent ionizing radiation sources (SIRS), long-lived ILW and HLW, as well as vitrified RW from processing of spent nuclear fuel (SNF) from Ukrainian NPPs.

In general, it is expected to accept RW of the following origin at the Vector site: Chernobyl ≈ 1,500,000 m^3, ChNPP (including the Shelter) ≈ 650,000 m^3, NPPs in operation ≈ 200,000 m^3, «Radon» facilities ≈ 5000 m^3.

At present, construction of one SRW -1 and one SRW -2 is almost completed. Lot 3 has been commissioned with restrictions, namely: RW disposal in two sections (out of 22).

A centralized SIRS long-term storage facility is under construction. The design of RW long-term storage facilities has also been started, including one facility for storage of long-lived ILW, one facility for HLW and one facility for vitrified high-level RW from processing of SNF.

The legislation of Ukraine limits RW disposal in the near-surface facilities by exposure dose criteria for critical groups of the population that are set for different periods of disposal facilities life time , in particular, in 300 years after their closure when the disposed RW should be released (fully or partially) from regulatory control. Accordingly, these dose criteria limit both specific and total activities of RW which can be disposed in the near-surface facilities.

Such restrictions of specific and total RW activity are determined by scenarios of radiological impact on the population and depend on the properties of engineering and natural barriers of the disposal system.

At present, the analysis of long-term safety for the near-surface RW disposal facilities which are under construction and those to be constructed has been performed only on the basis of conservative scenarios. Realistic scenarios are not developed, in particular, due to insufficient study of the site geosphere. Accordingly, at present there are no realistic estimates based on which RW should be attributed to short-lived and disposed in the near-surface repositories on the Vector site or to long-lived and placed into facilities for long-term storage followed by disposal in stable geological formations. Only rough estimation of long-lived RW volumes may be performed (from 11,500 to 15,000 m^3 of HLW and 130,000 m^3 of ILW), and the total activity is estimated as 10^{18} - 10^{19} Bq.

The strategic documents on RW treatment envisage construction of a national geological repository in Ukraine. But as for today, activities within this area are on the pre-conceptual level and realistic deadlines for creation of the geological repository are not defined. Under these conditions, it is planned to store long-lived RW for a long period of time (100 years) in facilities for long-term storage at the Vector site.

The main volumes and activities of long-lived RW will be generated primarily during ChNPP decommissioning and transformation of the Shelter and later during decommissioning of other NPPs in Ukraine (that are currently operated with possible lifetime extension). For decommissioning of ChNPP and other Ukrainian NPPs, there is an accepted option of deferred dismantling with 30-50 years on hold. During transformation of the Shelter, gradual retrieval of RW will be performed under the New Safe Confinement, the lifetime of which is 100 years.

Another task is long-term storage of SIRS of different types accumulated and stored at the "Radon" site.

The regulatory requirements for the safe storage of long-lived ILW and HLW are established in the national document "Requirements and Rules for Long-Term Storage of Long-Lived and High-Level Radioactive Waste till Their Disposal in Deep Geological Formations" [1] and other regulatory documents.

1 CONCEPT OF DISPOSAL FACILITIES

One of the principles set out in [1] requires taking into account the interdependence between all stages of RW management, from waste generation to disposal in deep geological formations inclusive, during implementation of activities related to long-term storage of long-lived RW.

According to the abovementioned, processing and supply of conditioned long-lived RW to the Vector site will be implemented step by step (perhaps during 100 years), till creation of a geological repository.

Taking this into account, it is appropriate that the concept of long-lived RW disposal facilities considers their step-by-step construction and expansion in accordance with the expected supply of conditioned long-lived RW. At the same time, periods for long-lived RW storage for the next stages of expansion of disposal facilities may be reduced, taking into account the need to construct a geologic repository. Such a concept can influence design decisions regarding disposal facilities (for example, decisions on layout, taking into account the possible expansion of areas, facilities, communications, configuration of systems for management of RW packages).

Detailed forecast on supply of conditioned RW for the whole period is impossible due to a number of uncertainties, but it is possible to make a robust forecast on RW supply from various RW producers (volumes, total activities, particularly important characteristics). This may be enough to develop an overall conceptual design and for step-by-step construction of facilities for storage of RW with optimized design decisions on storage areas, buildings and infrastructure.

The Regulatory Authority of Ukraine (SNRIU) recommends using the specified conceptual approach during design of the first facilities for storage of long-lived RW at the Vector site, which is now started.

As an example, treatment with degraded and damaged packages of RW may be considered. According to [1], the facility design should envisage equipment for treatment of such packages, in particular, to eliminate possible effects of depressurization of RW packages. The documents with requirements for the design of the first facilities did not consider this requirement (except for the facility for vitrified HLW). As an option to solve this issue, an area for treatment of certain types of packages that have been damaged or degraded can be created for the system of facilities.

Another open question is relationship of long-term storage of long-lived RW with subsequent disposal in a geological repository. Today, this issue is not resolved properly, as Ukraine does not have a concept of the geological repository design. Development of this concept should be accelerated in accordance with the regulatory document “General Safety Provisions for Radioactive Waste Disposal in Geological Repositories” [2].

The legislation of Ukraine provides disposal of long-lived RW in geological repositories which are located in deep stable geological formations at depths of hundred meters (and deeper) from the surface [3, 4]. RW are not divided into classes that can be disposed at middle depths (from tens to hundred meters) and those that should be disposed in deep geological formations (more than few hundred meters), as it is accepted in the international classification of RW [5].

It should be noted that due to the presence of transuranic elements in Chernobyl RW (which is the main scope of RW in Ukraine), a large number of ILW are related to long-lived ones. But such ILW, taking into account the current global practices, may also be disposed at middle depths [5, 6]. Recommendations for revision of Ukrainian legislation on this issue are developed on the basis of Project U4.01/08-C “Improvement of Radioactive Waste Classification System in Ukraine” [6].

2 LIMITATION OF RADIOLOGICAL IMPACTS

Radiation Safety Regulations of Ukraine [4, 7] determine the quota of current radiation dose limit for specific RW treatment facilities, including annual population exposure dose limit of 0.08 mSv/year for a single RW storage facility and 0.04 mSv/ year for a specific RW disposal facility during its operation.

However, special limits of dose from all site facilities have not been established (dose limit from all industrial sources of radiation is 1 mSv/year). In [8] it is recommended to establish for the Vector site a criterion on total annual dose for the public of 0.3 mSv/year for limitation of routine exposure due to radiation impact from all facilities of Vector site during their operation.

Since the Vector site is located in the exclusion zone, it is necessary to consider a separate group of people, namely staff working in the exclusion zone at facilities adjacent to the Vector site. For the staff of adjacent facilities, it is recommended [8] to use the current radiation dose limit of 2 mSv/year (for category B staff [7]).

Taking into account the large number of facilities that can be operated simultaneously at the Vector site (see Introduction), due to application of quotas on current radiation dose limits

(0.08 mSv/year and 0.04 mSv/year), and criterion of 0.3 mSv/year for the public can be exceeded. Accordingly, the regulatory body recommends to perform an integrated assessment of impacts of all facilities and to determine (correct) quotas for each separate facility on the basis of it [8].

In addition, possibly the most critical for the design of facilities will be a criterion for limiting of radiological impacts on the personnel of adjacent facilities (2 mSv/year), which can operate near the Vector site (adjacent facility - centralized repository for storage of SNF – is planned to be built next to the Vector site).

Regulatory document [4] determines radiation and hygiene regulations on potential exposure in the form of limitation of critical event probability (P) depending on the potential exposure dose (D) which is possible as a consequence of a critical event. In particular, for the critical events that can lead to high potential exposure doses D, it is established: for the public (and staff of adjacent facilities) at D > 50 mSv/year, $P \leq 2 \cdot 10^{-5}$/year (when lethal dose for short period of time $P \leq 2 \cdot 10^{-7}$/year) and for the staff of the Vector site at D > 100 mSv/year, $P \leq 2 \cdot 10^{-4}$/year.

Integrated assessments of potential exposure, taking into account the total activity of long-lived RW which can be simultaneously stored in facilities at the Vector site, should be also carried out for scenarios with simultaneous effects on the whole system of facilities (e.g. extreme natural events - earthquake, tornado, etc.). These estimates can be used to select the criteria of engineering barriers strength (for example, for non-exceeding of potential exposure dose of the staff of the adjacent facilities of 50 mSv/year, it will be required to prevent destruction of engineering barriers under effects of external events with probabilities of $2 \cdot 10^{-5}$/year).

3 RELIABILITY OF ENGINEERING BARRIERS OF FACILITIES

Engineering barriers of facilities should ensure reliable isolation of long-lived RW during long-term storage with a possibility of further retrieval of RW packages in order to dispose them [1].

The following conditions should be considered to meet this requirement:

- lifetime of engineering barriers up to 100 years;
- strength of engineering barriers under impacts caused by possible natural and man-made events.

Containers which ensure RW isolation and/or buildings for container storage may be considered as the main engineering barriers in long-term storage of long-lived RW.

Designs of RW disposal facilities at the Vector site use reinforced concrete containers KTZ-3.0 which perform barrier function (with certain degradation) during 300 years. If such containers are used for storage of long-lived RW during 100 years (as it was envisaged in documents with requirements for design of the first ILW and HLW storage facilities), it would be necessary to confirm their acceptability for reliable isolation of RW during this period, taking into account possible physical and chemical processes inside the containers with RW and possible impacts on the strength during storage.

Primary packages with vitrified RW supplied from the Russian Federation after processing of SNF of Ukrainian NPPs are envisaged to be placed in containers made of stainless steel with its tightening by means of welding. Such a package may ensure sufficient durability of RW isolation, but provided that stainless steel is compatible with materials of primary packages which will be supplied by the Russian Federation.

Taking into account that a large amount of long-lived RW and SIRS are planned to be placed at the Vector site for long-term storage (see Introduction), engineering barriers should obviously be resistant to extreme external impacts. Earthquake and tornado are natural events which may lead to major impacts on engineering barriers of all or several storage facilities. Safe shutdown earthquake (SSE) with probability of 10^{-4}/year is an earthquake of 6 magnitudes according to MSK scale. Maximum possible tornadoes which may occur within the Vector site region are of F3.0 class. It is not a problem to ensure resistance of containers with RW, modules and/or building for container storage to these impacts.

Aircraft crash and explosion are the most hazardous man-made events.

A new protective building is under construction at Chernobyl NPP (New Safe Confinement – NSC) above the existing Shelter, where a number of fuel-containing materials with total activity of $\approx 5 \cdot 10^{17}$Bq are located. Resistance of NSC will be ensured during SSE and tornado, but it is impossible to ensure resistance of such a large building as NSC in case of an aircraft crash. That is why measures should be implemented on prohibition of flights above ChNPP area. The Vector site is located within 11 km distance from ChNPP and the same approach on prohibition of flights may be applied to this site.

It is not planned to create industrial enterprises with potentially explosive technologies within the exclusion zone. Volumes of simultaneous transportation of potentially explosive substances should be limited (this is also implemented at ChNPP site).

In such a way, it may be possible and necessary to ensure resistance of engineering barriers of the storage facility in case of extreme natural events and to ensure minimization of hazards of man-made events using organizational measures.

CONCLUSIONS

It is necessary to develop a conceptual framework and design basis with systemic analysis of safety issues at the beginning of development of facilities for long-term storage (up to 100 years) of long-lived intermediate- and high-level RW at the Vector site in Chernobyl exclusion zone together with the use of the integrated approach.

References

1. NP 306.4.143-2008. "Requirements and Rules for Long-Term Storage of Long-Lived and High-Level Radioactive Waste Till Their Disposal in Deep Geological Formations", approved by SNRIU Ordinance No. 169 dated 7 December 2007 and registered by the Ministry of Justice of Ukraine No. 149/14840 dated 27 February 2008.

2.NP 306.4.133-2007**.** "General Safety Provisions for Radioactive Waste Disposal in Geological Repositories", accepted by SNRIU Ordinance No. 81 dated 29 May 2007 and registered by the Ministry of Justice of Ukraine No. 605/13872 dated 11 June 2007.

3. Low of Ukraine "On Radioactive Waste Management", 1995.

4. NRBU-97/D-2000 DGN 6.6.1-6.5.061-2000. Regulations of Radiation Safety of Ukraine. Addition: Radiation Protection from Sources of Potential Exposure. State Safety Regulations

5. Classification of Radioactive Waste, Safety Guide, No. GSG-1, Vienna, IAEA, 2009

6. INSC Project – U4.01/08-C. Improvement of the Radioactive Waste Classification System in Ukraine of RW Classification into the Regular Structure of Ukraine. Task 7. Report: Support on Introduction of the New Classification System to the Regulatory Framework of Ukraine, November 2012.

7.NRBU-97 DGN 6.1.-6.5.001-98. Regulations for Radiation Safety of Ukraine. State Safety Regulations.

8. INSC Project UK/TS/39 Subtask 1a. Guideline for the Assessment of the Radiological Impact of the Vector Site with Multiple Facilities for Radioactive Waste Processing, Storage, And Disposal, December, 2012.