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

Vector Site

- The Vector site is located in the Chernobyl exclusion zone
- It is planned to supply to this site almost all Ukrainian waste (both conditioned and that require treatment):
  - Chernobyl Exclusion Zone ≈ 1,500,000 m^3
  - ChNPP (including the Shelter Object) ≈ 650,000 m^3
  - NPPs in operation ≈ 200,000 m^3
  - «Radon» facilities ≈ 5000 m^3

Storage and Disposal Facilities

- Long-term storage facilities:
  - disused sealed radiation sources (SRS)
  - long-lived ILW
  - HLW
  - vitrified RW from processing of spent nuclear fuel (SNF) from Ukrainian NPPs
- Disposal facilities:
  - 56 repositories for disposal of Chernobyl RW. Further it is planned to build facilities for disposal of RW from NPP decommissioning and from the Shelter

RW for Storage

- Dose criteria limit both specific and total activities of RW which can be disposed in the near-surface facilities. At present, there are only conservative estimates based on which RW should be attributed to short-lived and disposed of in the near-surface facilities or to long-lived and placed into storage facilities
- Only rough estimation of volumes of long-lived RW may be performed (according to very approximate estimate, 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

Status of Construction

- A centralized facility for long-term storage of disused SRS is under construction
- The designing of RW long-term storage facilities has 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 regulatory requirements for safe storage of long-lived ILW and HLW are established in the document "Requirements and Rules for Long-Term Storage of Long-Lived and High-Level Radioactive Waste till Their Disposal in Deep Geological Formations" and other regulatory documents

Supply of long-lived RW

- It is planned to store long-lived RW for 100 years in the storage facilities at Vector site. Processing and supply of conditioned long-lived RW will be carried out step by step
- Long-lived RW will be generated primarily during ChNPP decommissioning and transformation of the Shelter and later during decommissioning of other NPPs. For decommissioning, there is an accepted option of deferred dismantling with 30-50 years holdup. Gradual retrieval of RW from the Shelter will be performed under the New Safe Confinement (100 years)
- Start of supply of disused SRS of different types, accumulated and stored at the "Radon" site, may begin after commissioning of the storage facility and obtaining license for operation. Part of disused SRS may be supplied much later, because of difficulties of their removal from sites of their actual storage

Step-by-Step Concept

- The concept of long-lived RW storage facilities should consider their step-by-step construction and extension in accordance with the expected supply of conditioned RW
- Due to a number of uncertainties, it is possible to make only a robust forecast on RW supply (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

RW Storage and Geological Repository

- Interconnection of long-lived RW storage with subsequent disposal in a geological repository is important. Development of the concept for geological repository in Ukraine should be enhanced in accordance with the regulations “General Safety Provisions for Radioactive Waste Disposal in Geological Repositories”
- The legislation of Ukraine provides disposal of long-lived RW in deep geological repositories. RW are not divided into classes (to be disposed at middle or big depths). Recommendations for revision of Ukrainian legislation on this issue are developed in the framework of Project U4.01/08-C “Improvement of Radioactive Waste Classification System in Ukraine”
- Due to the presence of transuranic elements in Chernobyl RW, a large number of ILW are related to long-lived ones. In principle, such ILW may be disposed at middle depths

Current Exposure – Dose Limits

- Regulations of Ukraine determine the quota of current exposure dose limit for specific RW facilities, including population exposure dose quota of 0.08 mSv/year for a single RW storage facility
- Special dose limits from all facilities at the site have not been established (dose limit from all industrial sources is 1 mSv/year). It is recommended to establish for the Vector site a criterion on total current exposure dose for the public of 0.3 mSv/year
- It is necessary to consider staff working in the exclusion zone at facilities adjacent to the Vector site. It is recommended to use the current exposure dose limit of 2 mSv/year
- It is recommended to perform an integrated assessment of impacts of all facilities and to determine (correct) quotas for each separate facility on the basis of it

Potential Exposure – Dose Limits

- Limitation of critical event probability (P) depending on the potential exposure dose (D). For the critical events with high potential exposure doses D, it is established in regulations:
  - for the public (and staff of adjacent facilities) at $D > 50$ mSv/year, $P \leq 2 \cdot 10^{-5}$/year (for lethal dose for short period of time $P \leq 2 \cdot 10^{-7}$/year)
  - 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, should be carried out for scenarios with simultaneous impacts on the whole system of facilities (e.g. earthquake, tornado, etc.). These estimates can be used to select the criteria for strength of engineering barriers (e.g., 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 with $P \leq 2 \cdot 10^{-5}$/year)

Engineering Barriers - Requirements

- 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:
  - 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 of long-lived RW storage

Engineering Barriers - Containers

- Disposal facilities are designed for 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 requirements for design of the first storage facilities), their acceptability for reliable isolation of RW should be confirmed, taking into account possible impacts on the containers 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 stainless steel containers with its tightening by welding. Such a package may ensure sufficient durability of RW isolation provided that stainless steel is compatible with materials of primary packages

Resistance to External Natural Impacts

- Taking into account that a large amount of long-lived RW and SRS are planned to be placed at the Vector site for long-term storage, engineering barriers should be resistant to extreme external impacts
- Earthquake and tornado may lead to major impacts on engineering barriers of all or several storage facilities:
  - Maximum design earthquake (MDE) with probability of 10^{-4}/year is an earthquake of 6 points according to MSK scale
  - Maximum possible tornadoes which may occur on the Vector site are of F3.0 class (probability of 10^{-6}/year)
- It is possible to ensure resistance of containers with RW, modules and/or building for container storage to these impacts

Resistance to Aircraft Crash and Explosion

- New Safe Confinement – NSC is under construction above the existing Shelter, where the fuel-containing materials with total activity of ≈$5 \cdot 10^{17}$Bq are located. Resistance of NSC will be ensured for MDE and tornado, but it is impossible to ensure resistance of such a large building as NSC in case of an aircraft crash. Measures should be implemented on prohibition of flights above ChNPP area. Vector site is located within 11 km from ChNPP, and the same approach 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)

Conclusions

It is necessary to develop a conceptual framework and design basis with system 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 on base of the integrated approach.

Thank you!