Present state of the art in the development of a geological radioactive waste repository in Ukraine

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Abstract:
The prospects and advantages of the Chernobyl Exclusion zone (ChEZ) for geological repository allocation are considered. The initial data for analysis are: governmental policy, strategy and current practice of spent fuel, high-level and long-lived waste management as well as geological, hydrogeological, economical and social-demographic conditions of ChEZ. The conclusion about suitability of ChEZ geological and hydrogeological conditions for geological repository allocation has been made. High promise of borehole-type repository is shown.

1 INTRODUCTION

It is internationally accepted that geological disposal is an ethically and environmentally sound long-lived waste management solution [1], for which considerable practical experience has been developed. Variant of waste disposal in specially made mine workings is the most extensively studied. Possibility of waste disposal in super deep boreholes is under investigation as well [2].

Approximately 50% of electricity in Ukraine is generated by NPP [3]. Large volumes of spent fuel (SF) and long-lived intermediate level waste (LL-ILW) have been accumulated in the country. More than 90% of its volume is located within the ChEZ borders. The subject of waste isolation has received insufficient consideration in Ukraine. This causes threat for sustainable development of nuclear power system and national safety and lays burden to future generations.

In presentation consideration is given to geological, economic, social-demographic and technological factors determining much promise of allocation of radioactive wastes geological repository in ChEZ.

2 HLW AND LLW MANAGEMENT IN UKRAINE

At present 15 water-cooled water-moderated power reactors (WWER-440 and WWER-1000) at total electric power of 13.8GW are in operation in Ukraine. 3 power reactors of RBMK-1000 type (Chernobyl NPP) were stopped. 1 reactor of RBMK-1000 type was ruined in 1986 (‘Shelter” Object –SO).

National policy in the field of nuclear power application and radioactive waste (RAW) management was determined by legislative acts [4,5]. This policy can be characterized by the following features:

- RAW producers have no license for RAW disposal;
- Expenses associated with RAW disposal are born by RAW producers;
- All long-lived waste[1] must be disposed in a deep geological repository (DGR);
- Conclusion of LLW repository allocation, designing and construction pertains to terms of reference of the Supreme Soviet of Ukraine;
- Local authorities take part in making a decision about nuclear object siting.

As defined in [7], in Ukraine the category of the long-lived waste include:

- Vitrified high-level waste;
- High-level waste from nuclear power reactor operation and demounting;
- Fuel-containing materials resulted from the Chernobyl NPP (ChNPP) accident

The strategy of WWER-1000 spent fuel management known as "deferred decision" is realized in Ukraine [8]. Decision on further processing or disposal of spent fuel in deep geological repositories will be taken later (after 2010). The Ukrainian Government made a resolution to store spent nuclear fuel generated by WWER reactors of the Ukrainian NPP's in dry interim storage facilities (ISF) within the territory of Ukraine over the next 50-100 years. At present Ukraine has no intention to reprocess SF from reactors of RBMK-1000 type. In future the reprocessing of SF from WWER-1000 may become economically inexpedient. Therefore, a great probability exists that indicated SF types will be ascribed to radioactive waste.

Current national practice of spent fuel, high level and long-lived waste management consists in the following [9]:

- WWER spent fuel is cooled in reactor ponds for no less than 5 years and then transported to Russia for reprocessing;
- vitrified high level waste is stored in Russia;
- RBMK-1000 spent fuel is stored in reactor decay pools and site pool storage facility for spent fuel at the ChNPP;
- A dry ISF for WWER-1000 spent fuel is being commissioned at Zaporizhzhya NPP. The same type of storage facility for RBMK-1000 spent fuel is being under construction within the 30-km zone of ChNPP;
- Long-lived RAW resulted from the accident at the ChNPP 4th Unit have been stored in the Shelter Object and points of radioactive waste disposal. Storage conditions don't meet the requirements of Ukrainian legislation.

It should be mentioned that a critical situation has arisen concerning high level and long-lived waste isolation: by quantity of HLW and LLW per 1GW of NPP capacity Ukraine passes ahead of many other countries due to significant amounts of RAW of Chernobyl's origin. At the same time Ukraine does not have its home program of HLW and LLW disposal. Such a situation brings the threat to sustainable development of nuclear power system. Moreover, delay in solution of problem of HLW and LLW isolation implies shift of economical burdens on future generations.

Principle lines of activities on creation of RAW geological repository in Ukraine are determined in [7}. Siting in Ukraine is performed with the use of IAEA guidance [10]. In Ukraine national methodical guidance was elaborated as well [11]. Besides, at present time

[1] As defined in [6], in Ukraine category of long-lived waste covers radioactive waste whose level of exemption from regulatory control can be achieved in no less than 300 years after its disposal.

Draft Concept of Programme on geological disposal of high-level and long-lived waste is being approved by authorities [12].

Under above-mentioned guidance, the following factors should be considered in siting a RAW geological repository:

- Geological factors determining repository long-term safety;
- Economical and social-demographic factors exerting influence on political and administrative decision-making process as well as on HLW and LLW disposal costs;
- Technical factors (repository safety conception, repository design type, repository siting and construction terms, etc.) serving as a basis for site requirements elaboration, exert influence on selecting policy and allow an optimization of costs for repository construction.

3 THE CHEZ PROSPECTS FOR GEOLOGICAL REPOSITORY ALLOCATION

3.1 Geological and hydrogeological conditions of ChEZ

The works on siting the geological repository in Ukraine were started in 1993. During 1993-1996 the availability of geological formations and regions over the whole Ukraine territory for RAW isolation was assessed [13]. In 1997-2000 regional study of granitoid formations in the borders of Korostenskiy pluton and ChEZ was performed [14]. The purpose of study – to assess availability of given territory for RAW isolation in geological repository of mine type. In 2001-2002 in the framework of STCU Project [15] the scientific grounds were made concerning possibility of creation of borehole-type geological repository in this region.

By results of studies two most promising sites for further studies were determined, namely Veresnia and Tovstyi Lis sites. Veresnia site is located outside the ChEZ, close to its south-western border. Crystalline rocks are presented by rapakivi-like biotite-hornblend, fine-, medium- and coarse-ovoid granites. Tovstyi Lis site is located within ChEZ borders at the distance of 15-25km west of Chernobyl NPP. The territory is contaminated by radionuclides. Within the site the granite-porphyry intrusion is revealed, occupying an area of 130km^2. Its bottom lies at the depth of 4.0-4.5km. Intrusion is characterised by low rate of tectonic dislocation. In general, geological structure of Veresnia site is less complicated as compared to Tovstyi Lis site.

The two sites have some common features. They are as follows:

- Occurrence of overlapping sedimentary cover composed by terrigenous and carbonate rocks. Thickness of sedimentary deposits within the Versenia site and Tovstyi Lis site varies in the range of 150-250m and 300-450m, respectively.
- Decrease of crystalline rock fracturing with depth. The volume of open fractures achieves its maximum value at a depth greater than 700m below crystalline rocks surface.
- Occurrence of several aquifers separated by confining beds in sedimentary cover and crystalline rocks weathering zone.
- Location within watershed area. It determines predominantly downward groundwater flow in the zone of intensive and considerable water exchange down to the depth of 1000-1500m. At the same time, the upward groundwater flow discharging into the rivers prevails in river valleys.

- Stagnant water exchange character at a depth greater than 1500-2000m as well as increase of total groundwater salinity with depth.
- Absence of discharge area for deep groundwater.

Therefore, good prospects of geological medium within ChEZ for allocation of geological repository is indicated by the following factors:

- Low permeability of crystalline rocks;
- Low intensity of water exchange between aquifers;
- Small effect of lower hydrodynamic zones on the upper ones;
- High sorptive capacity of sedimentary rocks in geological structure.

By now, integrated field geophysical studies at the Veresnia site have been performed that made it possible to confirm good prospects of given territory for repository development and determine most promising area for further detailed investigation.

3.2 Economical and social-demographic conditions of ChEZ

ChEZ economical and social-demographic conditions are determined by its specific status as a radio-contaminated territory. They are characterised by the following features [9]:

- Any industrial activity in ChEZ has been prohibited by Ukraine legislation;
- Within ChEZ borders the works are conducted associated with construction and exploitation of objects designed for RAW management, environment radiation monitoring, water protection and forest conservancy measurements, maintaining shutdown of 1-3 Power Units of Chernobyl NPP and transformation of "Shelter" Object into ecologically safe system.
- The resident population was evacuated from ChEZ. A part of territory is kept unsettled because of high radio-contamination levels and will remain out of economical activity for a long time.
  - Well-developed road network as well as public, trade and medical services infrastructure is available in ChEZ.

Thus, current economical and social-demographic conditions of ChEZ are favourable for allocation of RAW geological repository because of the following factors:

- Availability of highly skilled and professionally trained labour force;
- Availability of complete infrastructure for labour force supply;
- Low land cost;
- Absence of potential troubles associated with gaining the permission from local authorities to allocate radiation-dangerous objects;
- Vicinity of basic suppliers of HLW and LLW (see, section 1).

4 TECHNICAL FACTORS

Selecting appropriate type of geological repository design may exert significant effect on the total costs and realisation terms of national Program of HLW and HLW disposal. It may also promote maximum use of favourable features of territory with allocated repository.

Results of comparison between mine and borehole types of geological repositories are given in Table 1. The results were compared using technical characteristics from Swedish projects of geological repositories KBS-3 [16, 17] and VDH [17].

Analysis of data presented in the Table indicates that borehole-type of repository has many points in its favour, namely:

- lesser cost;
- lesser time spent on repository construction;
- greater versatility in respect of spending capital costs and schedule of individual boreholes commissioning, that correspondingly provides optimisation of interim SF storage expenditures;
- lesser vulnerability in case of inadvertent human intrusion;
- higher values of volume use factor and, consequently – lesser effect on the environment;

However, borehole-type method of HLW and LLW disposal has a number of shortcomings:

- complexity in providing a means for damaged canisters retrieval;
- complexity of large-sized RAW preparation for packing (e.g., RAW produced as a result of nuclear reactors shutdown)

Table 1. Comparative characteristics of mine and borehole type of geological repository.

Attribute	Mine type KBS-3	Borehole type VDH
Technical description		
Type of the radioactive waste	SF, LL-ILW	SF
Capacity, t U	9000	9000
Number of canisters	4500	13500*
Area of surface (underground) facilities, km^2	0.3 (2,8 – 3,5)	1,0 – 1,5* (1,0 – 1,5)*
Volume of excavated rocks, $\times 10^6$?^{3}	1,3	0,084*
Use factor of volume DGR	0,013*	0,14*
Long-term safety		
Availability of example of safety assessment	Yes, for different types of rocks	No
Difficulty of long-term safety justification	High	Moderate
Relative vulnerability caused by human intrusion	1	0,001
Importance of engineering barriers for safety	High	Low
Difficulty of retrievability	Moderate	Very high
Time		
Duration of site selection and confirmation, year	15 – 25	5 – 7
Duration of capital investments, year	6 – 10	As required

Attribute	Mine type KBS-3	Borehole type VDH
Required canister life-time, year	More then 100000	Several hundred
Cost		
Repository construction, $\times 10^6$ Euro	1850*	160*
Operations needed for encapsulation and deposition of SF, $\times 10^6$ Euro	1100*	1500 – 2000*
Total, $\times 10^6$ Euro	Approx. 3000	Approx. 2000
Share of packing and infrastructure costs, %	Approx. 30*	More then 90*

* - calculated by authors based on [16-18]

5 DISCUSSION

Despite all preferences (as to construction cost and terms) of borehole-type geological repository, its inherent shortcomings (limited canister dimensions) will not enable disposal of all types of long-lived radioactive wastes produced in Ukraine in such repository. This is pertinent both to long-lived wastes contained in Shelter Object and ChEZ repositories and to those wastes arising from nuclear reactors dismantling. However, it is quite possible that future investigations will justify safety of disposal of certain waste types in the near surface repositories. Perhaps, this is much easier to realize for repositories located in ChEZ.

Based on generalisation of conclusions made in the previous sections, the strategy for handling problem of HLW and LL-ILW waste disposal in Ukraine may be proposed. The essence of strategy consists in separation of above stated waste groups by creating: 1) geological repository of borehole-type for disposal of vitrified HLW and SF; 2) mine geological repository for disposal of HLW and LLW produced by Ukrainian NPP and those stored in SO and ChEZ repositories. Given separation of RAW groups takes into account the fact that SF and HLW problem pendency more actively influences national safety in short-term perspective.

Borehole-type repository can be constructed in much shorter terms as compared to mine-type, which provides conditions for sustainable development of nuclear power in Ukraine. This enables decreasing of total expenses of RAW disposal, whereas capital expenditures are extended in time because boreholes can be put into operation as required.

In order to decrease costs of mine repository construction it is of great importance to study and ground possibility of diminishing volume of HLW and LLW subjected to deep geological disposal. Similar work should be performed with respect to RAW in the Shelter Object as well as to those accumulated in the RAW storage facilities within ChEZ.

Strategy potential will be realised to the maximum for the case of repository allocation within ChEZ territory.

6 CONCLUSIONS

The main conclusions are as follows:

- Unsolved problem of HLW and LLW disposal in Ukraine is a threat to sustainable nuclear power development and national security;
- geological repository development is the resolution of problem;
- application of geological repository for HLW and LLW disposal makes possible time optimisation and cut down work costs;
- in ChEZ there are optimal (geological, economical and social) conditions for geological repository development.

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