

## Regional analysis of Ukraine's prospects for geological disposal of radioactive waste

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### SUMMARY

The purpose of this paper is to describe the preliminary results of regional analysis of Ukraine aimed at identification the most promising region for geological disposal of radioactive waste. The regional analysis methodology consists in sequential use of the procedures: exclusion, disqualification and estimation. For each procedure was used separate group of criteria, based on the requirements of national regulations and best international practice. Existing geological data and maps were used as initial data for analysis. It was preliminary concluded that Chernobyl Exclusion Zone with adjacent territories is the most promising region for geological disposal of radioactive waste.



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## Introduction

Radioactive waste (RW) disposal is topical problem for Ukraine. This is related to plans for the further nuclear energy use and to the needs for disposal of significant amounts of accidental RW of Chernobyl origin. The Ukrainian legislation (*Law...*, 1995) requires that high level and intermediate level RW (according to the new classification) should be disposed of in deep stable geological formations in geological repositories (GR). The GR site selection process begins with regional analysis of geological formations and regions suitable for GR location (*Requirements...*, 2008).

The purpose of this paper is to describe the preliminary results of regional analysis (in other words - regional screening) of Ukraine aimed at identification the most promising region for GR location.

## Methodology

The regional screening methodology used in this paper was developed on the base of (*Mykhaylov et al.*, 2014) and consists in sequential use of the following procedures:

- exclusion of unsuitable geological structures or their parts;
- disqualification of geological structures or their parts as less-promising;
- assessment of the RW geological disposal concepts developed in Ukraine, as well as structures or their parts to identify the most promising regions;
- additional assessment (by economic and socio-demographic indicators) of the promising regions to choose the most promising one.

For each procedure was used separate group of criteria, based on the requirements of national regulations and best international practice.

## Initial data

The initial data structure was determined by potential screening criteria, which, in turn, were formed based on the availability of the archived information. The basis of the initial data is formed by existing data (maps, reports, etc.) of geological survey, as well as researches carried out by the organizations of the State Service for Geology and Subsoil of Ukraine and the National Academy of Sciences of Ukraine in previous years (*Shestopalov, Shybetkyi*, 2017; *Shestopalov et al.*, 2018).

The GR siting activities were started in Ukraine in 1993. During 1993-1996 the availability of geological formations and regions over the whole Ukraine territory for GR was assessed. According to the results of this work the promising formations were identified, and the possible areas for repository placement were identified within these formations (fig. 1). Since the late 90s, the main attention was paid to the crystalline formations of the Chernobyl Exclusion Zone (ChEZ). However, these results were not summarized by the operator of the future geological repository in the form of a single comprehensive report and were not agreed by stakeholders.

Further we use the scheme of structural-tectonic zoning of Ukraine (fig. 2) as the base scheme for presentation of different screening procedure results.

## Results

**Exclusion.** The purpose of given procedure is to exclude from further consideration the territorial elements (geological structures and their parts or regions), which are unsuitable for geological repository location because of impossibility to ensure its safety. The scale of maps used for this iteration is 1:1 000 000 and smaller. The procedure is applied to the entire territory of Ukraine.

*Exclusion indicators and criteria:*

- seismicity of the territory: the intensity of maximum earthquake exceeds 8 points;
- mineral resources: occurrence of mineral deposits or groundwater fields;
- geothermal resources: a high temperature gradient;
- catastrophic natural and technogenic events: snow slides, mudflows, floods, caving, etc.;
- minimum requirement: absence of potential host formations.

*Initial data:* scheme of structural-tectonic zoning of Ukraine (fig. 2); maps showing distribution of the exclusion criteria (seismicity, minerals, geothermal resources); data on catastrophic events



occurrence, minimum requirement for geological repository location; detailed description of the structures and regions of Ukraine (Atlas, 2001; National Atlas..., 2007).



**Figure 1** Geological disposal options considered in Ukraine (Shestopalov, Shybet'skyi, 2017). Numbers are meant: 1 - granitoids of Korosten Pluton; 2 - granitoids and gneisses of ChEZ; 3 - granitoids of Saksagan Iron mine; 4 - host crystalline formations of Uranium mines; 5 - Salt-domes of the Dnieper-Donets depression; 6 - bedded salts of Donbas; 7 - clays of Black Sea depression; 8 - salts and clays of Forcarpathian depression



**Figure 2** Scheme of structural-tectonic zoning of Ukraine (National Atlas, 2007)

Results of the exclusion procedure are shown in the table 1.

**Disqualification.** The purpose of the procedure is to exclude from further consideration the territorial elements (geological structures and their parts) that are of poor promise for geological repository location in view of the need to compensate for insufficient contribution of geological barriers to the repository safety by providing additional expensive engineered barriers. It is advisable to avoid areas with potential transboundary impact. The scale of the used maps is 1:1 000 000 and smaller. The procedure is applied to structures remaining after implementation of the exclusion procedure.

**Disqualification indicators and criteria:**

- seismicity of the territory - the intensity of maximum earthquake exceeds 7.0 points;
- dangerous natural phenomena - the presence of natural and technogenic karst;
- technogenic impact - the presence of abandoned mines;
- minimum requirement - formations are limited in area, thickness and unfavourable depth;



- transboundary impact - the territory is coastal, adjacent to the border, or located in the basin of rivers flowing out from Ukraine.

**Table 1** Results of the exclusion

Structure	Seismicity (points)	Natural resources		Catastrophic events	Minimum requirement	Result
		Mineral	Geothermal			
I: Ukrainian Shield (USh)	< 8	Yes	No	No	Yes – crystalline	Further consideration
II: Volyno-Podolian Plate	< 8	No	No	Yes (karst)	?	Further consideration
III: Lviv Depression	< 8	Yes	No	No	?	Further consideration
IV: Black Sea Depression	> 8	Yes	Occur	No	Yes - clays	Exclusion
V, VI: Dnieper-Donets Depression (DDD)	< 8	Yes	Occur	No	Yes – clays, salts	Further consideration
VII: Slopes of the Voronezh Massif	< 8	No	No	No	Yes – crystalline	Further consideration
VIII, IX, X, XIII, XVII: the Crimea	> 8	No	Occur	No	?	Exclusion
XI: Donbas	< 8	Yes	Occur	Yes	Yes – salts	Exclusion
XI, XII: Dobrudja	> 8	Yes	Occur	No	?	Exclusion
XI, XIV, XV, XVI: Carpathians	> 8	Yes	Occur	Yes	Yes – clays, salts	Exclusion

*Initial data:* scheme of structural zoning of Ukraine; maps showing the distribution of disqualification criteria (seismicity, technogenic impact); data on dangerous phenomena occurrence, minimum requirement for geological repository creation and assessment of potential transboundary impact.

*Results* are shown in the table 2.

**Table 2** Disqualification results

Structure	Seismicity (points)	Dangerous phenomena	Technogenic impact	Minimum requirement	Transboundary impact	Result
I: Ukrainian Shield (Ush)	<7	No	Yes (mining regions)	Yes – shallow crystalline	No	Further consideration
II: Volyno-Podolian Plate	<7	Yes	No	?	Yes	Disqualification
III: Lviv Depression	<7	Yes	Yes	?	Yes	Disqualification
V, VI: Dnieper-Donets depression (DDD)	<7	Yes ( in the central and southern parts)	No	Yes – clays, salts	No	Further consideration (northern part)
VII: Slopes of the Voronezh Massif	<7	Yes	No	Absent	Yes	Disqualification

**Assessment (technical evaluation).** The procedure is used to compare and determine the rank (promising degree) of: 1) the geological disposal concepts developed in Ukraine; 2) structures remaining after exclusion and disqualification procedures. The assessment results in the ranked list of structures (or their parts or regions) suitable for geological repository creation.

*Assessment (technical evaluation) criteria*

- comprehensive analysis of the advantages and disadvantages of the concepts (or structures) in terms of geological repository safety;
- distance of structures (regions) containing suitable host formations from the main RW sources, availability of transport infrastructure;
- risk of future accidental intrusion;

*Initial data:* description of geological disposal concepts, exclusion and disqualification results.

*Results* are shown in the table 3. According to the assessment procedure, the most promising for Ukraine is the concept of geological disposal in crystalline rocks. The most promising region is the



northern part of the Ukrainian Shield (Korosten Pluton and the northeast slope of the Ukrainian Shield) within the ChEZ and adjacent territories of Kyiv and Zhytomyr regions.

**Table 3** Assessment results

Concept (formation), structure (region)*	Advantages	Unfavorable factors	Risk of intrusion	Distance from RW sources	Rank
1: Crystalline formations, Korosten Pluton, USh	Mechanical stability	Mineral resources, tectonics, social factors	Medium	Minimum	2
2: Crystalline formations, ChEZ, USh with its northeast slope	Mechanical stability, social acceptable	Study complexity	Low	Minimum	1
3, 4: Crystalline formations, iron and uranium mines, USh	Mechanical stability, high level of study	Technogenic disturbances, hydrogeological conditions, social factors	High	Medium	3
5, 6, 8: Salt formations, DDD, Donbas, Forcarpathian depression	Thermal properties, absence of water	Social factors, mineral resources, instability	High	Maximum	4
5, 7, 8: Clay formations, DDD, Black Sea Coast, Forcarpathian depression	Sorption properties	Filtration properties, social factors, resources	Medium	Maximum	3

\*Note. Numbers indicate the concepts under consideration. Their location is shown in Fig. 1

**Additional assessment.** The procedure purpose this is assessment of the territorial elements by economic and socio-demographic factors. The procedure combines two types of assessment: 1) the area suitability for the GR location; 2) GR influence on the area in both positive and negative sense. Both assessments were performed using a same set of indicators and criteria that consider social aspects, preventive mitigation of possible social tension and the reduction of disposal costs. Impact and suitability assessments were performed on a qualitative level. They are of an expert nature and limited to a relative comparison of the areas being assessed against a number of indicators. Results show that the Chernobyl Exclusion Zone is the most suitable for GR location.

### Conclusions

Based on examination of geological conditions of the Ukrainian regions, geological disposal concepts, economic and socio-demographic factors, it was preliminary concluded that:

- Chernobyl Exclusion Zone with adjacent territories is the most promising region for geological disposal of radioactive waste;
- Crystalline rocks are the most acceptable host geological formation in this region.

### References

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