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Prospects for uranium extraction using underground well leaching in Ukraine

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Abstract. *The paper considers the prospects of uranium extraction from sandy sedimentary rocks by underground leaching. The main technological processes of uranium extraction and the procedure for carrying out work using the proposed method are considered. Environmental aspects related to environmental protection are considered. Because of the analysis of the proposed solutions, the effectiveness of the proposed technology they proven, with the introduction of technological leaching schemes to provide Ukrainian nuclear power plants with nuclear raw materials.*
Keywords: *uranium, underground leaching, uranium mining, ore, exogenous deposits.*

Today, nuclear energy is a fundamental component of Ukraine's energy supply, and its share has increased significantly (to 50%) in a relatively short period. This has become an important factor in ensuring a reliable energy supply for Ukrainian consumers amid a coal shortage caused by Russia's de facto occupation of part of the Donbas region [1].

For nuclear power plants, uranium is the main raw material for the production of nuclear fuel and the generation of electrical and thermal energy. Ukraine ranks tenth in the world and first in Europe in terms of proven uranium reserves and production volumes [2]. According to IAEA data, as of 01.01.2010, there were over 300,000 tons of uranium in Ukraine's subsoil, of which 52,000 tons we classified as above average in terms of value, and the rest as high [3]. However, Ukrainian uranium deposits are only suitable for underground mining. There are also several very small and poor deposits in Ukraine that we suitable for underground leaching (10,000 tons). Most of them are in the medium cost category. Ukrainian uranium deposits are concentrated relatively compactly in the Dnipropetrovsk and Kirovohrad regions (Fig. 1).

As of 1 January 2021, uranium reserves and resources that can be obtained at a cost of up to $260/kgU amount to 185,389 tU. This figure represents 2.3% of global reserves. At the same time, with production costs of up to $80/kg U, it amounts to 71,841 tU. The price includes the cost of uranium ore mining and enrichment (Table).

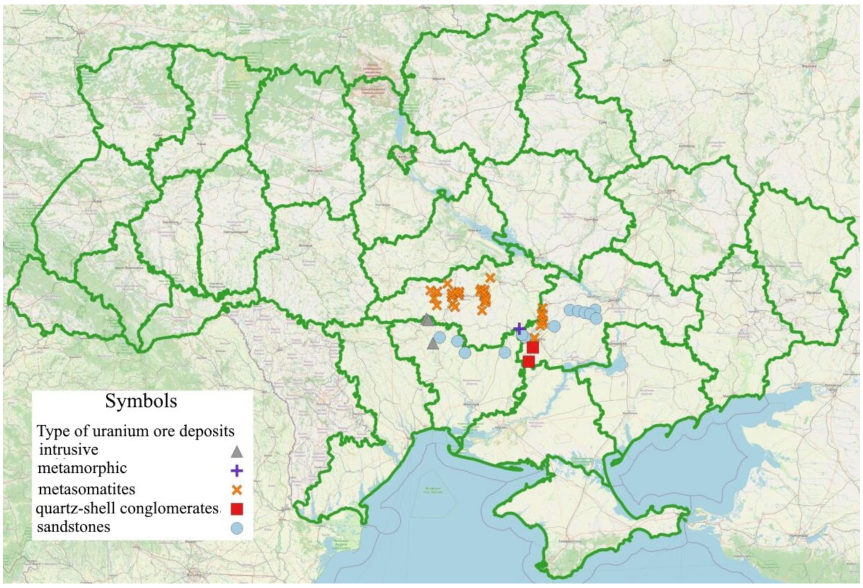

Fig. 1. Map showing the location of uranium ore deposits in Ukraine [4]

Table 1. The amount of uranium reserves in Ukraine depending on the cost of production, extraction method and type of deposit.

Type of deposits	Method of uranium ore extraction	% extraction of useful components, t	<USD 40/kgU	<USD 80/kgU	<USD 130/kgU	<USD 260/kgU
metasomatic	underground	88.7	-	67721	103041	177519
sandstone	underground leaching	75	-	4120	4120	7870

Two main types of deposits are of economic interest in Ukraine:

- Metasomatite type. Deposits of this type are located within the Ingulsky block of the Ukrainian Crystalline Shield. Uranium ores consist of albite veins with complex morphology and a thickness ranging from 2-3 m to 50 m. Ore minerals in uranium ores include: uraninite, coffinite, and branerite. The uranium content in the ore is 0.1-0.2%. Deposits of this type we mined underground. Deposits of this type include Novokostiantynivske, Michurinske, Tsentralne, Vatutinske, Severynivske, Zhovtorichenske, Pervomaiske, and others.

- **Sandstone type.** Deposits of this type are located within the Dnipro-Bug metallogenic zone. This type of deposit includes industrial deposits associated with coal-bearing sediments of the Buchach Formation and lying at depths of up to 70–90 m.

Ore deposits consist of separate ore bodies of stratiform and lenticular shape with a thickness of 3–10 m. Uranium in ore bodies is mainly contained in carbonaceous and clayey matter: uranium-bearing leucoxene and iron hydroxides, sulphides, usually accompanied by uranium black (marcasite, pyrite, millerite, sphalerite, bravoite, etc.). The uranium content in the ore is 0.02-0.06%. In addition to uranium, these ores contain molybdenum, selenium and rare earth elements of the lanthanide group. Deposits of this type they developed by underground leaching. This type of deposit includes: Sadovoye, Bratskoye, Safonovskoye, Devladovskoye, Novogurovskoye, Surskoye, etc. [5]. Other types of uranium deposits we currently classified as non-industrial in terms of mineralisation scale, mining and technical indicators, and other parameters.

From sedimentary rocks, it is more economical and expedient to extract uranium using the underground borehole leaching (UBL) method (Fig. 2) [6, 7].

UBL is a method of developing sandstone-type ore deposits without bringing the ore to the surface by selectively transferring natural uranium ions into a productive solution directly in the subsoil. In this case, uranium-bearing ore remains underground, unlike traditional mining methods (mine and quarry), which require significant costs for recultivation, and therefore this UBL method is highly environmentally safe, low-cost and simple in terms of technological operations.

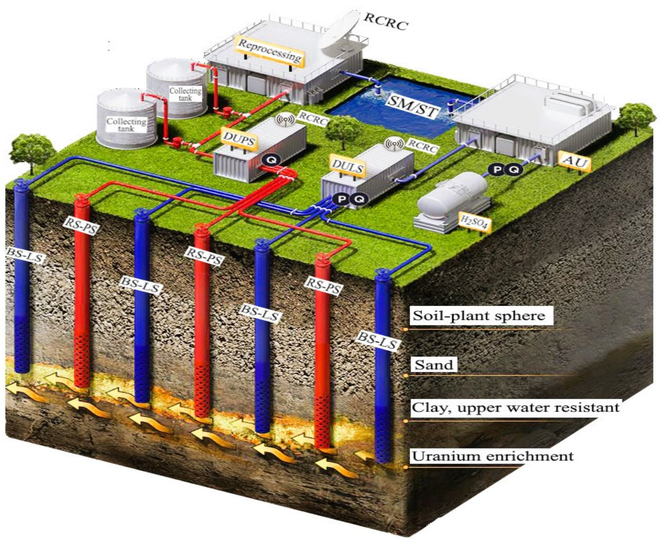

Fig. 2. General diagram of uranium extraction using the underground borehole leaching method [8]. Designations: SM – sorption matrix; AU – acidification unit; ST – sand trap; DULS – distribution unit leaching solution; DUPS - distribution unit productive solution; RCRC – remote control radio channel; RS-PS – red system-productive solution; BS-LS – blue system-leaching solution; Q – expenses; P - pressure

UBL is a closed-loop process comprising the following main stages:

1. Drilling wells, installing technical equipment and technological site facilities.

2. Pumping a weak concentration of sulphuric acid solution into the ore-bearing horizon through injection wells.

3. The main leaching process takes place underground, where uranium they converted into a productive solution.

4. The productive solution is brought to the surface, where sorption and desorption take place in ion exchange columns. The commercial desorbate is then precipitated and dried to obtain a yellow cake.

The diagram (Fig. 2) shows in blue (the movement they indicated by a solid arrow from top to bottom) the movement of the solution from the surface to the first horizon, as well as the enrichment process of the solution passing through the chamber (arrows indicating movement from top to bottom in the ore body). The productive solution that has passed through the mass, indicated in red (movement from bottom to top, arrow with a dot), is pumped out by pumps through the lift to the upper horizon and then to the surface.

The diagram (Fig. 3) shows the movement of the solution and the main technological parameters of the injection wells.

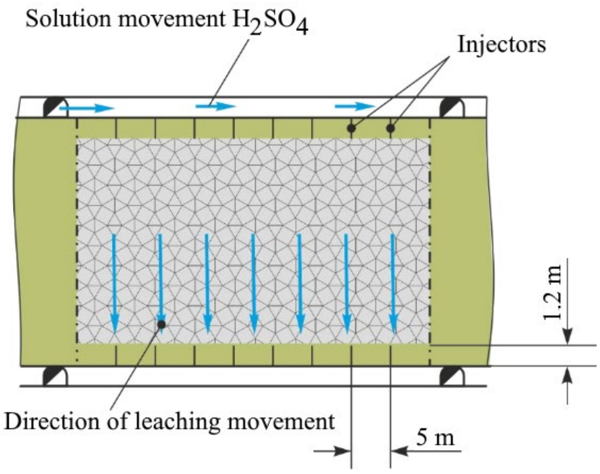

Fig. 3. Schematic diagram of the location of injection holes, waterproofing layer and probable direction of sulphuric acid solution flow [8]

After completion of the enrichment cycle, the solution they fed to the surface for further processing, which is located at the surface complex site (Fig. 2). The duration of the entire process, we estimated to be approximately 260 days, with acidification and settling of the chamber taking about 30–50 days, irrigation and leaching taking about 90 days, and sorption taking about 130 days. Productive solution losses are usually up to 10%, uranium extraction from the mass into the solution is about 50%, and when obtaining uranium from the solution – 60–80%.

Regarding the proposed UBL method, it should they added that when working with sulphuric acid, it is important to remember about employee safety and the possible impact of sulphuric acid vapours on them. Therefore, to protect employees, it is necessary to construct insulating and ventilation barriers to prevent radon from escaping at the boundaries of the injection wells. Such barriers must be made of acid-resistant materials, such as sand-cement mixtures or others.

It should we noted that the UBL method has a minimal negative impact on the environment, which has been confirmed by many years of research. The IAEA recognizes this method as the most environmentally friendly and safe way to develop deposits.

After completion of extraction using the UBL method, the quality of the remaining groundwater they restored to the initial level determined at the start of operation, with the possibility of restoring its previous use. Contaminated water obtained from the aquifer we evaporated or treated using the PLASMA-SORB technology [9] and pumped back.

After decommissioning, the wells we plugged or sealed, the technological installations are dismantled, and the sites are recultivated with the restoration of the soil mass.

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