

**IDENTIFICATION AND RECLAMATION OF TOXIC ELEMENTS IN SOILS  
DEGRADED BY URANIUM MINING PROCESSES**

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**Abstract:** Reclamation plays a crucial role within the environmental component of the sustainable development concept. Reclamation is understood as the creation of soil cover based on predefined parameters, that is, a set of comprehensive measures aimed at restoring the fertility and economic value of degraded lands, as well as improving the overall quality of the environment.

### **Introduction**

Uranium mining enterprises have specific features related to ensuring radiation safety, as the processes of extraction and processing of uranium ores release significant amounts of radionuclides into the environment. The level of radioactivity in emissions varies across different deposits and depends both on the initial uranium content in the ore and on the geochemical processes that occurred in the deposit prior to mining, primarily as a result of natural leaching, which determines the ratios between uranium and its decay products.

In general, the level of radioactive contamination of the atmosphere and land surface within modern uranium mining sites is not high. At most deposits, radioactive pollution that significantly exceeds background levels is observed at a distance of 500–600 meters from the main source. Contamination of areas adjacent to mining sites mainly results from the mechanical dispersion of uranium-bearing materials, deposition of radioactive dust and aerosols from ore stockpiles and waste dumps, as well as from emissions associated with the operation of roads and railways.

To date, substantial practical data have been accumulated on the geological characteristics of uranium deposits and the technologies for their industrial exploitation. However, limited progress has been made in establishing systematic approaches for optimizing exploration and extraction processes and in addressing the environmental problems associated with in-situ leaching operations.

Soil plays a central role in natural landscapes and in recovering ecosystems. As a source of fertility for plants, it also provides a habitat for the majority of organisms. Within the soil, the life processes of plants, animals, bacteria, and fungi are continuously taking place. Soil functions as both the beginning and the end of food chains, ensuring nutrient cycling. In addition, it serves as an important sanitary barrier. Although relatively resistant to external influences, soil is

increasingly subjected to degradation under modern anthropogenic pressures, and its disturbance is largely associated with human activity.

The intensive impact of human production activities on landscapes leads to adverse consequences. For example, open-pit mining creates quarries, spoil heaps, and tailings that disrupt soil and vegetation cover as well as the hydrological and hydrochemical regimes of the area. Therefore, in order to preserve soil cover, it is recommended to implement selective mining practices and to collect reclamation resources for their subsequent use in land restoration.

In the Central Kyzylkum region, natural uranium mining operations began in 1958 at the Uchkuduk deposit. Initially, extraction was carried out by open-pit methods. Later, with the development of industry, the in-situ leaching method was introduced in sandstone-type deposits. As a result, since 1994, all uranium production in the Republic of Uzbekistan has been carried out exclusively by the in-situ leaching method.

The diversity of hydrogeological conditions and ore compositions in exploited deposits has enabled enterprises to gain considerable experience in selecting uranium leaching methods and technologies. This factor has allowed the company to consolidate and maintain a leading position in the global uranium mining and export industry for many years.

### **Methodology and methods**

Mining activity, alongside its economic benefits, leaves behind severe disturbances in landscapes and ecosystems. Abandoned quarries, waste deposits, and degraded soils require effective restoration methods. Modern reclamation technologies are aimed at returning disturbed lands into economic circulation or integrating them back into the natural environment.

In assessing the impact of uranium mining enterprises on natural ecosystems, the main task is to identify the actual ecological consequences and to account for the economic damage associated with the degradation of habitats for both wildlife and humans. At “Navoiyuran” JSC, the development and implementation of scientific-innovative solutions for the reclamation of lands disturbed during uranium mining includes technical and biological stages. The technical stage involves shaping the relief and eliminating industrial facilities, while the biological stage focuses on restoring soil and biocenoses. These activities serve to return the territory into economic circulation and to reduce ecological damage. This process is of particular importance in the uranium industry, since radioactive contamination is present.

At the initial stage of the project, a detailed analysis of the site condition and its environmental impact is carried out. This stage mainly includes the following tasks:

1. Assessment of the condition of disturbed lands: The extent of land disturbance under the influence of natural and anthropogenic factors is studied. This involves determining the geological, hydrological, and ecosystem characteristics of the site, as well as the degree of degradation caused by previous activities.
2. Evaluation of contamination levels: Soil and water samples are analyzed to determine chemical and radioactive pollution indicators. This assessment provides the basis for identifying the level of risk in the area and for planning subsequent reclamation works.

3. Development of a reclamation project: Based on the ecological condition of the site and the level of contamination, effective reclamation methods and technologies are selected. The content and stages of the project are designed in accordance with the specific local conditions.

This stage is also crucial for defining the plan of further research and reclamation works, since by identifying the ecological state and risk factors of the territory, it allows for efficient and safe implementation of measures.

## RESULTS

Although the waste rocks generated during uranium mining may not exhibit significant radioactivity, it remains essential to monitor their radiation levels. Rock materials that are not used for mine backfilling are often employed for other purposes—such as creating barriers around the mine site, road construction, and similar applications. If such materials are intended for construction, they must be inspected by authorized regulatory bodies to ensure that the radiation doses to which the population may be exposed do not exceed the permissible limits. Furthermore, cases where waste releases natural isotopes in concentrations higher than background levels must be assessed, and, if necessary, those materials should be collected and reprocessed.

This article presents innovative approaches that can be proposed to address the problem of restoring disturbed and contaminated areas, with special emphasis on their practical application and effectiveness.

1. Phytoremediation – as an environmentally safe method. Phytoremediation is the process of using plants to restore contaminated or degraded lands. This approach is environmentally safe and effective, and it is implemented on the basis of the following principles:

- Plant roots absorb heavy metals and toxins.
- Plants stabilize the soil and prevent erosion.

Advantages:

- Less expensive compared to mechanical methods.
- Simultaneously restores soil while improving the visual appearance of the site.

2. Technical stage of reclamation. The technical stage of reclamation is a process aimed at preparing disturbed lands for further targeted use in the national economy and includes the following measures:

- Land leveling and shaping the relief, stabilizing slopes.
- Excavation, transportation, and replacement of fertile soil layers on reclaimed lands.
- Construction of hydrotechnical and reclamation facilities.
- Burial of toxic rock materials.
- Other necessary engineering works required for reuse.

Engineering measures in the reclamation process are divided into the following categories:

1. Structural-design measures – a set of earthworks aimed at restoring the landscape of disturbed lands, mainly including relief profiling and surface leveling.
2. Chemical measures – characterized by the introduction of various chemical substances to improve soil properties.
3. Hydrotechnical measures – a set of actions aimed at regulating the soil water balance.
4. Thermal-technical measures – focused on ensuring optimal heat and air balance within the reclaimed land plots.

Thus, the technical reclamation of disturbed lands represents the initial stage of restoring the natural state of soils. It is characterized by planning activities and measures aimed at restoring both the physical and chemical properties of the soil.

#### Conclusion

Thus, the results of the conducted research demonstrate that the newly proposed approaches for the reclamation of soils contaminated with radioactive substances are considered the most effective. The experimental works carried out under the proposed method, particularly in the restoration of soils contaminated in uranium mining areas, fully comply with both international and national environmental regulations.

An economically efficient aspect of this approach lies in the significant reduction of chemical reagent consumption and the rational use of natural resources such as water, land, and other materials. This is particularly important in the arid conditions of the Kyzylkum region, where the practical efficiency of this approach has been observed to be high due to the scarcity of water resources.

Furthermore, the proposed methodology and experimental results, if applied on a larger scale, provide the opportunity to reclaim soils contaminated with radioactive substances in accordance with international standardization requirements. This, in turn, contributes to ensuring the ecological safety of the affected territories and significantly optimizes the process of preparing them for economically beneficial use

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