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LIMITING RADIONUCLIDE MIGRATION IN NUCLEAR ENERGY: ANALYSIS OF ISOLATION AND MULTI-BARRIER SYSTEMS

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Annotation

This paper analyzes the role of isolation and multi-barrier systems in preventing radionuclide migration within nuclear energy facilities. Special attention is given to the context of Uzbekistan, where the development of nuclear energy is increasingly relevant. The analysis integrates international experience and scientific standards, including IAEA and OECD-NEA guidelines, with local conditions, emphasizing the importance of geological stability, climatic factors, and infrastructural readiness. Findings suggest that multi-barrier concepts are essential for ensuring long-term safety and public trust in the nuclear energy sector.

Keywords
Nuclear energy, Radionuclides, Containment, Multi-barrier, Uzbekistan, Safety

Introduction

The safe management of radioactive waste and the prevention of radionuclide release are critical challenges for nuclear energy worldwide. In Uzbekistan, plans to expand nuclear power generation highlight the need for reliable safety frameworks. The country is cooperating with international organizations such as the IAEA to build its first nuclear power plant near Lake Tuzkan in the Jizzakh region. Considering the arid climate, seismic activity, and developing infrastructure, an effective multi-barrier approach is key to ensuring sustainable nuclear development.

Isolation and Containment Strategies

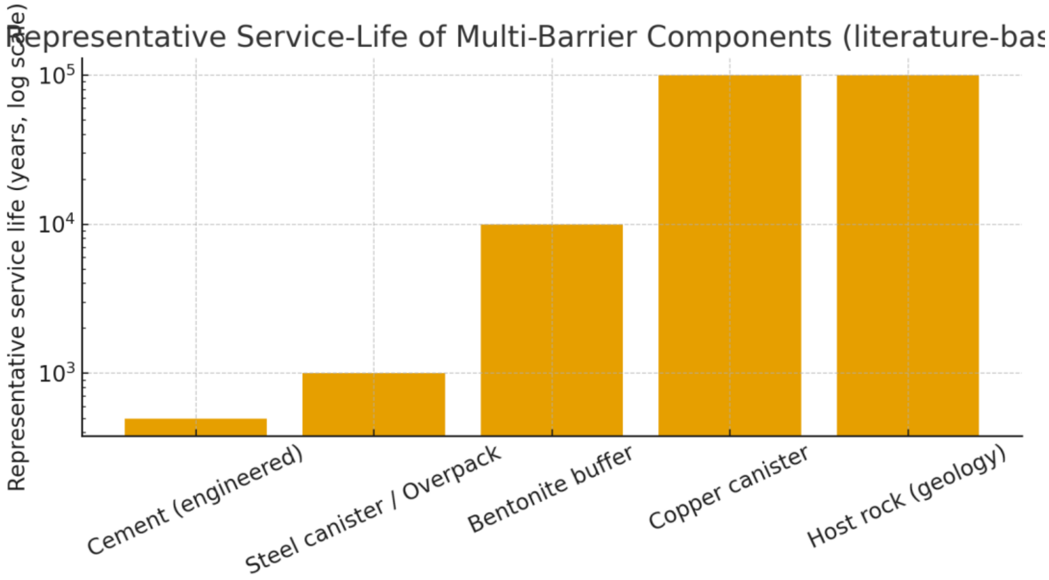
Isolation strategies involve engineered and natural barriers that limit the escape of radionuclides. Engineered barriers include waste containers, cementitious materials, and metallic overpacks, while natural barriers rely on host rock formations and hydrological stability. According to IAEA Safety Standards, no single barrier can provide complete protection. Instead, a combination of multiple barriers ensures redundancy and long-term reliability.

Multi-Barrier Systems in the Uzbekistan Context

For Uzbekistan, with its diverse geology and arid climatic conditions, multi-barrier systems must be adapted to local environments. Stable rock formations in certain regions provide favorable conditions for deep geological repositories. However, seismic activity necessitates additional safety layers. International practices such as those applied in Finland’s Onkalo repository and France’s Cigéo project demonstrate the feasibility of combining engineered barriers with natural isolation. These models can serve as references for Uzbekistan’s nuclear future, provided that investment in infrastructure and scientific expertise continues.

Comparative Effectiveness of Barriers

Figure 1 illustrates the effectiveness and longevity of various barriers used in radioactive waste containment. Host rock provides the greatest long-term stability, while engineered solutions such as overpacks and containers ensure short- to medium-term containment.



Experince of other countries

Iran's experience in radioactive waste management provides a useful regional comparison for Uzbekistan, as both countries share arid climates and significant seismic activity. The most notable example is the **Anarak near-surface repository** in Isfahan Province, developed by the Iranian Radioactive Waste Management Company (IRWA) under the Atomic Energy Organization of Iran. Preliminary safety assessments of this facility, conducted using IAEA methodologies and simulation tools, highlight the importance of radiomonitoring and multi-barrier concepts even for low- and intermediate-level waste. In parallel, Iranian researchers have investigated the performance of engineered barriers, such as clay buffers enhanced with basalt fibers, to improve mechanical stability and reduce permeability under local conditions. Moreover, Iran's seismic risk assessments, particularly in regions such as Tehran, underscore the challenges of designing nuclear facilities that must remain robust under frequent and potentially severe earthquakes. While Iran does not yet operate a deep geological repository for high-level waste, its efforts in repository safety assessment, barrier material research, and integration of international safety standards demonstrate practical steps toward addressing radionuclide containment in a seismically active and climatically arid environment.

Similarly, Kazakhstan provides another regional example where arid climatic conditions intersect with a challenging nuclear legacy. Although the country is also at an early stage of developing a modern nuclear energy program, decades of experience managing contamination from the Semipalatinsk test site have given it practical expertise in radiological monitoring and long-term safety assessment. This context offers Uzbekistan valuable lessons on the importance of environmental monitoring and institutional readiness alongside technical multi-barrier solutions.

Discussion

The comparative data confirm that no single barrier is sufficient on its own. In Uzbekistan, a combination of engineered containers and cementitious barriers should be complemented by stable geological formations. This integrated approach is consistent with IAEA guidelines and international best practices. Furthermore, continuous monitoring systems and seismic-resistant designs must be incorporated to ensure safety in the Uzbek context.

Conclusion

The study concludes that multi-barrier systems provide the most effective strategy for minimizing the risk of radionuclide release in Uzbekistan's nuclear program. A combination of engineered and natural barriers, aligned with international safety standards, is essential to address local geological and climatic challenges. Strengthening research, infrastructure, and public awareness will further support safe and sustainable nuclear energy development in Uzbekistan.

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DESIGN AND APPLICATION OF MPU6050-BASED INERTIAL MEASUREMENT UNITS IN MEDICAL AND ROBOTIC SYSTEMS

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Abstract. This article is dedicated to analyzing the capabilities of the MPU6050 module – a compact, energy-efficient, and affordable sensor used in the development of Inertial Measurement Units (IMU). The use of Sensor Fusion algorithms (such as Complementary Filter or Kalman Filter) to address accuracy issues caused by sensor drift and noise is substantiated. The practical part of the research focuses on applying the MPU6050-based system in two main areas: in medicine — gait analysis and objective monitoring of body movements during rehabilitation; in robotics — precise spatial localization and stability assurance for mobile devices and unmanned vehicles. It is demonstrated that this technology holds significant potential for implementing