Enhancing Uranium Recovery from Coal Ash Using Semipermeable Membranes and Radiochemical Methods: A Novel Approach

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Today's energy transition requires not only the development of renewable energy sources, but also the efficient use of available strategic resources. Uranium, as a nuclear fuel, plays a key role in providing stable, low-carbon electricity. Although its main sources are natural deposits exploited by mining, alternative ways to obtain them, including secondary raw materials, are gaining attention. One of these is the ash from coal combustion, a material in which uranium can reach higher concentrations than in coal itself. Recovering this element from waste materials not only supports the economy of raw materials but also reduces dependence on traditional sources, which are geographically concentrated.

The study presented here proposes a novel method for recovering uranium from such ashes, based on a combination of chemical leaching and separation using a semipermeable membrane. Radiochemical techniques were used at the beginning of the process to accurately determine the uranium content and monitor its behaviour during extraction. These procedures, known for their high selectivity and sensitivity, played a key role in evaluating the efficiency and controlling each step of the experiment.

The experiments carried out demonstrated a useful methodology for separating and recovering uranium from calcined ash. The process of leaching the ash according to the adopted methodology was found to be extremely effective, with an average efficiency of 96.7%.

Analysis of the kinetics of the process, including both the rate of uranium release and its transport through the membrane, allowed the identification of optimal operating conditions and the development of a predictive model that can be used for further applications. Understanding the dynamics of processes is important for the energy and economic efficiency of the entire solution, especially in the context of processing materials with low but useful concentrations of radioactive elements. This type of data is essential for planning industrial-scale processes, where extraction stability and repeatability are critical.

Importantly, the proposed method can be transferred to other industrial wastes in which the presence of uranium has already been confirmed, for example, phosphoric or metallurgical wastes. This approach not only broadens the base of available uranium sources but also supports the concept of a closed-loop economy and sustainable development of the nuclear sector.

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