Purolite™ Resins for Uranium Extraction

Purolite Resins are engineered to provide efficient and effective solutions for uranium extraction. Known for their superior ion exchange properties, Purolite Resins are widely utilized in the mining industry to ensure high recovery rates and uranium purification. These resins are designed to withstand harsh processing conditions, making them an ideal choice for uranium recovery operations.

Purolite Resins for Uranium Extraction

Inside this Application Guide, you will find an overview of Purolite Resins for uranium extraction. For more detailed information on any product, or to find a product for an application not mentioned, visit PuroliteResins.com or contact the closest Ecolab regional office listed on the back cover.

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Introduction

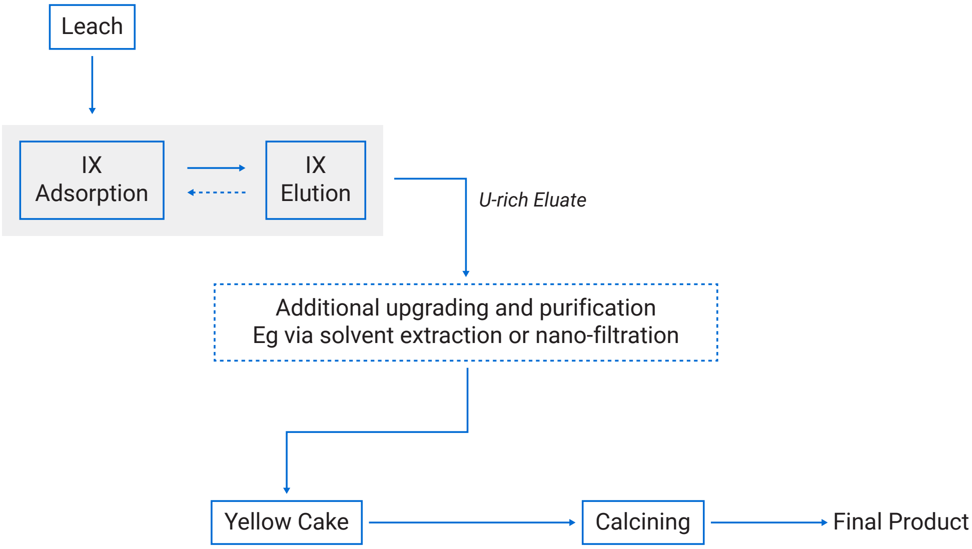
The demand for clean alternative energy sources has increased the focus on expanding and developing new global nuclear power. According to the International Atomic Energy Agency's (IAEA) high projection case, nuclear energy could contribute about 14% of global electricity in 2050. The recent increase in nuclear industry activity necessitates strengthening the supply chain, particularly for uranium.

Uranium has been extracted using ion exchange (IX) resins for decades. The 1950s marked the beginning of widespread adoption of IX resins in the uranium industry, driven by the growing demand for nuclear energy. Over the decades, advancements in resin technology have significantly improved the efficiency and selectivity of uranium recovery processes. Today, strong base anion exchange resins are the standard for uranium extraction, offering high capacity and durability in both acidic and alkaline environments. This technology is extensively used in major uranium-producing regions, including North America, Australia, Kazakhstan, and parts of Africa, supporting the global nuclear power industry and various other applications.

The position of the ion exchange unit operation is shown in a typical flowsheet in Figure 1.

FIGURE 1

Example Uranium Extraction Flowsheet



Uranium Extraction and Processing

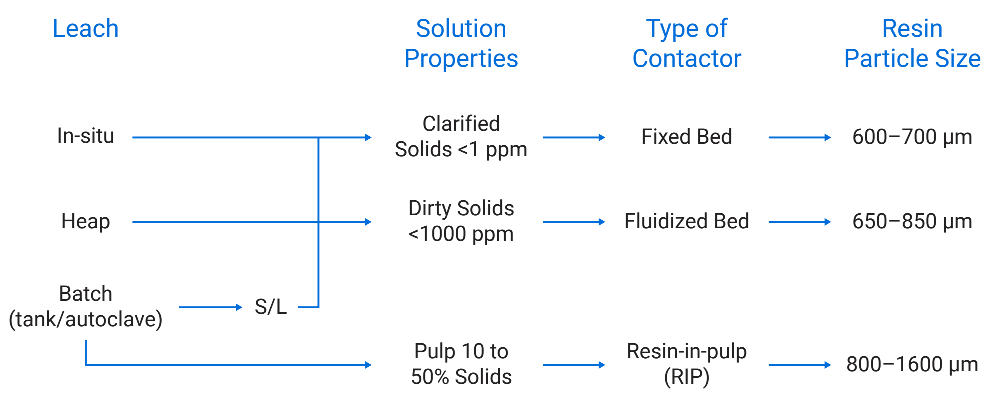
There are two principal methods of ore processing:

- **Extraction of ore from the ground** (via underground mines or open pits). The ore is transported to a central facility, crushed and milled. The milled ore is further processed via heap leaching or batch leaching (autoclave, tank, vat leach). The leached pulp may be treated 'as is' in a resin-in-pulp (RIP) configuration, or solid-liquid separation may be done via belt filters or counter-current decantation (CCD) to produce a clarified or partially clarified liquor that forms the feed to the ion exchange unit operation.
- **In situ treatment,** also referred to as In Situ Leach (ISL) or In Situ Recovery (ISR). This technique involves dissolving uranium directly from the ore body using appropriate lixiviants while the ore remains underground. The lixiviant is pumped into the ground via a series of injection points. Pregnant leach solutions (PLS) is collected from a central well. ISL produces "clean" PLS with Total Suspended Solids (TSS) less than 50 ppm.

The choice of ion exchange contactor is dependent on the solids content of the feed material. This in turn, dictates the optimum particle size distribution of the resin, as show in Figure 2.

FIGURE 2

Operating Conditions and Resin Selection



In a fixed bed operation, any solids present in the PLS will collect on the top of the resin bed (assuming down-flow operation). Over time, this may form a dense layer that will lead to an increase in pressure drop across the resin bed and consequently to an increase in the mechanical load on the resin and excessive consumption of energy to pump the solution. Therefore, efficient clarification of the liquor prior to the ion exchange unit operation is critical. It is customary to include periodic backwashing of the resin, either in the same or in a separate vessel.

In the case of fluidized bed operation, the upward flow of solution results in expansion of the resin bed, typically to 100% of initial height. The resin does not retain the suspended solids, and the solids can freely move past the resin beads with the solution. Vessels typically consist of vertical stages. Such contactors are much taller and wider than fixed bed systems, to allow for expansion of the resin bed.

In RIP configurations, the resin is contacted directly with the leached pulp, negating the need for solid-liquid separation. This potentially results in significant cost savings, especially in the case of ores with a high clay content that is difficult to filter. This method is also often used when uranium is a by-product of the recovery of other metals, such as gold in South Africa or copper.

The lixiviant of choice depends on several factors, including the grade and geology of the ore.
The main routes are:

- Sulfuric acid leach
- Bicarbonate leach
- Carbonate leach

Uranium is leached from ores as U(VI) and exists in the pregnant leach solution in both cationic (as hydrated uranyl UO_2^{2+}) and anionic forms (mainly as uranyl trisulfate or uranyl tricarbonate), depending on the lixiviant. The ratio between these cationic and anionic forms depends on the pH of the solution as well as the anion background.

The typical pH range for the acid leach method is between 0.5 and 2.5, with uranium concentrations ranging from 60 ppm to 2 g/l, depending on the process design and ore grade. Bicarbonate leaching results in PLS with a pH of 6 to 8, while carbonate leach solutions have a pH around 10 to 11. In practice, both bicarbonate and carbonate are present in the alkaline solutions, with their specific concentrations determined by equilibrium constants that depend on pH, where higher pH favors more carbonate, and vice versa.

Ion Exchange Resins

Strong base anion (SBA) exchange resins, with quaternary ammonium functional groups, are most commonly used for commercial uranium extraction, both from acidic and alkaline liquors and pulps.

Resin Properties

The combination of various process parameters creates diverse conditions for the use of ion exchange resins in uranium recovery. These conditions influence the resin properties required for optimal economic performance. The resin properties must be selected to match specific working conditions and includes:

- **High operating capacity** involves having a high chemical affinity of the resin functional groups towards uranyl compounds, high selectivity for uranyl compounds (meaning lower affinity for undesirable species in the feed source), and high kinetics of ion exchange during both adsorption and elution.
- **Efficiency of regeneration** is defined by the applicability of available reagents, the production of lower volumes of more concentrated desorbates, the prevention of fouling impurities build-up, and low residual uranium content in the regenerated resin.
- **Service life durability** is determined by mechanical strength, resistance to chemical fouling or degradation, and resistance to osmotic shock. Ion exchange resins undergo multiple cycles of adsorption-elution and typically last for several years before replacement is required.
- **Particle size distribution**, chosen to ensure maximum efficiency for the chosen contactor design.

The optimal characteristics of an ion exchange resin often involve compromises between these sometimes contradictory requirements. Enhancing one specific property may require sacrificing another. Therefore, all these aspects must be considered to select the best resin for a particular project.

Contaminant Considerations

The presence of certain components in the leach liquor influences the uranium sorption performance of ion exchange resins. These components can be categorized into three groups:

- **Substances Depressing Uranium Sorption**
  These compounds strongly compete with uranium for ion exchange sites. Common examples include vanadate, molybdate, chloride, and nitrate.
- **Substances Fouling Ion Exchange Resins**
  These compounds form inert deposits or salts inside and/or on the surface of ion exchange resins, which are not removed by common treatments and require special care. A typical example is the fouling of SBA resins by silica.
- **Substances Causing Downstream Issues**
  While these substances do not affect uranium extraction directly, they can create problems in downstream processes. For instance, zirconium can cause foam formation in downstream uranium solvent extraction (SX) refinery circuits.

Purolite Resins for Uranium Recovery

Ecolab's extensive experience in the uranium industry has allowed the development of a portfolio of ion exchange resins, as listed in the table below, aimed specifically at providing optimum performance in various uranium applications.

TABLE 1 **Ecolab Range of Uranium Resins**

Industry	Application	Product Name
Mining	Liquors	MTA8000PPSO4
		MTA6002PF
		MTA4601PF
	Pulps (RIP)	MTA5014SO4
		MTA6601
Groundwater Remediation	Potable Water	PGW6002E

A Note on the Ionic Form of the Resin

SBA resins are typically in the chloride form when produced. Operations that use sulfuric acid or carbonate/bicarbonate for leaching do not want to introduce additional chlorides into the system, since chlorides are corrosive and their presence in the PLS results in suppressed uranium resin loading. To assist our customers in optimizing conditions, we can supply the resin in the appropriate ionic form that fits the matrix of the end-user, i.e. chloride, sulphate or bicarbonate.

Ecolab is a global developer, manufacturer, and supplier of Purolite™ Resins including ion exchange, catalyst adsorbent and advanced polymers that make the world cleaner and healthier.

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