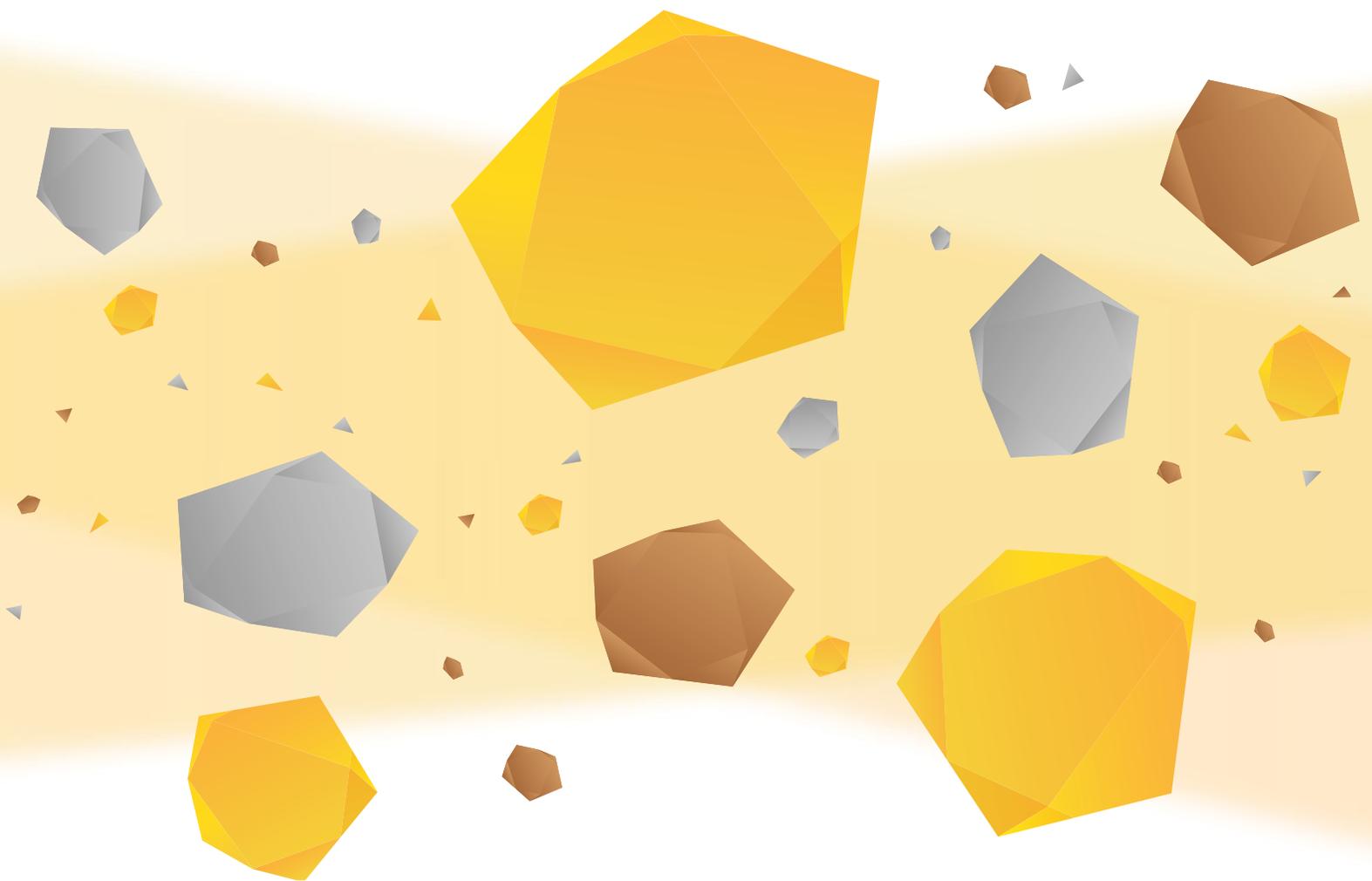


# Hydrometallurgy Applications

Puomet™ and Purogold™ resins for metals  
removal, recovery and sequestration



The uses and advantages of ion exchange resins  
for sorption and recovery of target metals.



**This Application guide presents information for using ion exchange technology for the primary recovery of metal or the removal of impurities to increase the value and purity of the final product.**

Metals can be extracted from ores using several methods including chemical solutions (hydrometallurgy), heat (pyrometallurgy) or mechanical means. Hydrometallurgy is the process of extracting metals from ores by dissolving the ore containing the metal of interest into an aqueous phase and recovering the metal from the resulting pregnant liquor. This process often provides the most cost-effective and environmentally friendly technique for extracting and concentrating different metals. Often, various hydrometallurgical processes are used in the same flowsheet, such as combining ion exchange and solvent extraction for the recovery and purification of uranium. Hydrometallurgical processes can also be combined with non-hydrometallurgical extractive metallurgy processes.



# Applications of ion exchange

Ion exchange technology is used for the primary recovery of metal(s) of interest or the removal of specific impurities in order to increase the value and purity of the final product.

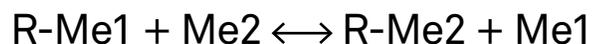
A wide variety of process streams benefit from the application of ion exchange resins, as shown in Table 1.

Table 1 – Applications of ion exchange in hydrometallurgy	
ORIGIN OF STREAM TO BE TREATED	ION EXCHANGE APPLICATION
Ore, after heap or agitated leach	Primary recovery of metal(s) of interest, e.g. gold, uranium
Volatile compounds captured in off-gases from smelters and roasters	Recovery of rhenium from off-gases produced by roasting of molybdenite and smelting of copper concentrates
Slags and calcines from roasting and smelting operations	Recovery of various metal(s) of interest, after leaching
Electrolyte	Removal of copper and zinc impurities from cobalt and nickel advance electrolytes to ensure higher metal purity
Tailings treatment	Recovery of copper, cobalt, gold, etc. from historical mine tailings, as well as current arisings
Acid mine drainage	Treatment of process water to enable recycling or safe disposal

## Ion exchange resins

Ion exchange resins are synthetic polymer materials carrying chemically or physically bound functional groups that are capable of exchanging or capturing specific ions. Once ions are captured or exchanged, many have the important ability to reverse this functionality.

The following simple expression can be used to describe the principle of ion exchange:



*The character “R” denotes the polymer matrix of a resin with a functional group fixed on it that is capable of ionic or coordinate bonding with a mobile ion “Me1.” While “Me1” is an ion that is initially bound to the functional group of “R,” “Me2” is an ion that is present in the solution. As a result of the ion exchange reaction, the “Me2” ion replaces the “Me1” ion on the resin.*

Ion exchange resins (IX resins) are usually produced in the form of spherical beads. The typical bead size ranges from 300 – 1,300 microns. The degree of particle size uniformity and the average particle diameter can vary widely. Resins with a particle size of < 200  $\mu\text{m}$  or > 2000  $\mu\text{m}$  are produced for special applications.

Copolymers of styrene or derivatives of acrylic or methacrylic acid, with a crosslinking agent—mostly divinylbenzene—serve as the polymer base. Due to crosslinking, the copolymer has a high temperature tolerance and does not dissolve in conventional aqueous media (acidic and alkaline) or organic solvents.

Ion exchange resins have distinct selectivities for different metal cations or anions, depending on the functional group. This characteristic of a resin can be used to selectively remove a specific metal from a background containing high concentrations of other (unwanted) metals.

### **Examples of selectivity ranges for different types of ion exchange resins:**

#### **Carboxylic resins:**

$\text{Cu}^{2+} > \text{Pb}^{2+} > \text{Zn}^{2+} > \text{Cd}^{2+} > \text{Ni}^{2+} > \text{Ca}^{2+}$

#### **Phosphonic resins:**

$\text{Cu}^{2+} > \text{Zn}^{2+} > \text{Cd}^{2+} > \text{Mn}^{2+} > \text{Co}^{2+} > \text{Ni}^{2+} > \text{Ca}^{2+}$

#### **Aminophosphonic resins (at acidic pH):**

$\text{H}^+ > \text{Fe}^{3+} > \text{Pb}^{2+} > \text{Cu}^{2+} > \text{Zn}^{2+}, \text{Al}^{3+} > \text{Mg}^{2+} \geq \text{Ca}^{2+} \geq \text{Cd}^{2+} > \text{Ni}^{2+} \geq \text{Co}^{2+} > \text{Na}^+$

#### **Iminodiacetic resins:**

$\text{Cr}^{3+} > \text{In}^{3+} > \text{Fe}^{3+} > \text{Al}^{3+} > \text{Hg}^{2+} > \text{UO}_2^{2+} > \text{Cu}^{2+} > \text{Pb}^{2+} > \text{Ni}^{2+} > \text{Cd}^{2+} > \text{Zn}^{2+} > \text{Co}^{2+} > \text{Fe}^{2+} > \text{Mn}^{2+} > \text{Ca}^{2+} > \text{Mg}^{2+}$

#### **Strong acid resins:**

$\text{Fe}^{3+} > \text{Ca}^{2+} > \text{Fe}^{2+} > \text{Cu}^{2+} > \text{Mg}^{2+} > \text{K}^+ > \text{NH}_4^+ > \text{H}^+$

#### **Strong base resins:**

$\text{SO}_4^{2-} > \text{CO}_3^{2-} > \text{NO}_3^- > \text{Cl}^- > \text{HCO}_3^- > \text{F}^- > \text{OH}^-$

#### **Bis-picolylamine resins:**

$\text{Cu}^{2+} > \text{Ni}^{2+} > \text{Fe}^{3+} > \text{Zn}^{2+} > \text{Co}^{2+} > \text{Cd}^{2+} > \text{Fe}^{2+} > \text{Mn}^{2+}$



All the characteristics of IX resins are interdependent and the choice of resin is often a trade-off between the different technical parameters of the resin.

Parameters that are controlled during the manufacturing of ion exchange resins:

**Functionality**

Determines the selectivity of the resin for certain metals over others.

**Ion exchange capacity**

A high capacity is desirable to reduce the size of the plant and subsequently the cost of capital investment and elution reagents.

**Mechanical stability**

The ability of the resin to withstand breakage from abrasion and pressure.

**Grading**

Smaller beads are used in fixed bed operations that benefit from the improved kinetics of smaller beads. Resin-in-pulp (RIP) operations require larger beads to allow for ease of separation of the resin and pulp.

**Osmotic stability**

The ability to endure sudden changes in solution concentration and temperature.

# Ion exchange contactor design

Ion-exchange contactors perform two key functions:

- They provide conditions that favor efficient mass transfer between the process solution and the ion exchange resin.
- They ensure the efficient mechanical separation of the ion exchange resin from the solution or pulp.

Ion exchange contactor designs are quite diverse, varying as a function of the properties of the medium being treated, the resin used and capital expense optimization considerations. The selection of a suitable ion-exchange contactor design is a function of the suspended solid content in the pregnant flow, as summarized in Table 2.

Table 2 – Choice of IX contactor based on solids content of feed	
SOLIDS CONTENT	ION EXCHANGE CONTACTOR
Clear liquid, <1 ppm solids	Fixed bed column
Liquid with low solids content, <1000 ppm solids	Fluidized bed column
Pulp, 10 – 50% solids	Resin-in-pulp (RIP), air agitated Pachuca or mechanically agitated vessel

In a fixed bed operation, any solids present in the pregnant leach solution (PLS) will collect on the top of the resin bed (in the case of 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 also customary to provide for 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 ensures expansion of the resin bed, typically 100 – 150%. In this instance, the resin does not retain the suspended solids, and the solids are able to move freely past the resin beads with the solution. Fluidized bed reactors have larger cross-sectional surface areas than fixed bed reactors to allow for reasonable volumetric throughputs. Vessels consisting of vertical stages are also much taller to allow for expansion of the resin bed.

When processing large flows, it makes sense to use continuous or semi-continuous processes. Resin contactor designs treating clarified or partially clarified liquors vary widely and can include moving resin beds with a 2-column set-up (lead-lag), a 3-column system (merry-go-round), and systems using multiple columns in sequence with special valves that manage distribution of the different liquors to the various columns.

Pulps form during the leaching of mineral raw materials, which consists of two-phase systems made up of the pregnant solution and fine mineral particles. Solid-liquid separation requires high capital and operating expenses, especially in the case of ores with high clay content.

The use of ion exchange resins make it possible to avoid this expense since sorption on resins is accomplished directly from the pulps. A resin may be added to a pulp after leaching, called resin-in-pulp, or leaching and sorption may happen simultaneously. This is referred to as “resin-in-leach” (RIL). An added advantage of the RIL process is that the sorption of a valuable component from a pulp’s liquid phase reduces the concentration of the component being sorbed in the pulp, thereby shifting the chemical equilibrium. This makes it possible to increase the degree of a given component’s recovery from the mineral particles by several percentage points.

The density and viscosity of a pulp is dependent on the pulp particle size as well as the nature of the minerals being processed. For example, some pulps have very high clay content resulting in poor filterability, even at relatively low solids content. In such cases, RIP or RIL offers an economical solution. RIP operations consist of a series of stirred tanks where the resin and pulp move counter-currently.

Resin beads are used in RIP/RIL operations. To ensure efficient separation of resin and pulp via mechanical screening, resin that is several hundred microns larger than the maximum mineral particle size should be used.

Table 3 indicates a typical size ratio for RIP operations.

Table 3 – Size ratio for resin separation in Resin in Pulp operations	
Resin	< 1% finer than 700 µm; < 5% finer than 800 µm
Mineral particles in a pulp	Maximum 250 µm; 75% finer than 200 µm
Mechanical screen effective opening (orifice, slit) size	600 µm

Additionally, an optimum resin bead size distribution should be selected.

Table 4 – Optimum resin bead size distribution			
RESIN GRADING	AVERAGE BEAD DIAMETER µm	BEAD SIZE IN FRACTION µm	SYSTEM
Puropack	600 – 700	—	Fixed and fluidized beds
Puropack (Macroporous or acrylic)	650 – 850	—	Fixed and fluidized beds
Resin in pulp (RIP)	850	800 – 1,300 (5% max. < 800)	Resin in pulp



## Principles of project-specific resin volume estimation

In order to make an initial estimate of ion exchange plant size, it is necessary to calculate the resin volume that is sufficient to reach the performance target. This is calculated from the mass balance equation for the target metal:

### Mass balance:

$$C_{\text{PLS}} \times F_{\text{PLS}} = C_{\text{R}} \times F_{\text{R}}$$

$C_{\text{PLS}}$  Metal concentration in PLS, kg/m<sup>3</sup> (PLS)

$F_{\text{PLS}}$  Flow rate of PLS, m<sup>3</sup> (PLS)/h

$C_{\text{R}}$  Operating metal capacity of the resin, kg/m<sup>3</sup>(R)

$F_{\text{R}}$  Flow rate of the resin, m<sup>3</sup>(R)/h

### IX resin flow rate:

$$F_{\text{R}} = (C_{\text{PLS}} \times F_{\text{PLS}}) / C_{\text{R}}$$

### Total Resin Inventory (m<sup>3</sup>):

$$V_R = F_R \times (T_1 \times k + T_2 + T_3)$$

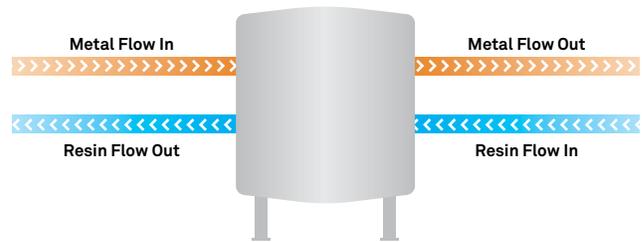
Where:

**PLS** Pregnant Leach Solution

**R** Resin

**T<sub>1</sub>** Residence time at sorption provided that:

- Concentration of the metal in the tails is reduced to the target limits
- (i.e., < 5 ppm for most uranium projects)
- Resin metal capacity reaches maximum



A resin “safety” volume should be provided for the sorption stage; for this volume, the  $T_1$  parameter should be multiplied by a  $k$  factor with a value of 1.1 – 1.5 (the process designer selects the actual value).

**T<sub>2</sub>** Residence time for desorption

**T<sub>3</sub>** Residence time in auxiliary operations

- Reduce CAPEX by minimizing  $F_R$  and  $T$
- In order to minimize  $F_R$ , a resin must have a maximum capacity
- In order to minimize  $T_1$ , a resin must have the best ion exchange kinetics
- In order to minimize  $T_2$ , a resin must have efficient desorption; e.g., complete and rapid
- To minimize  $T_3$ , the desorption and regeneration processes must be simple to avoid or minimize additional processing steps

# Selecting the optimum resin

There are a number of important considerations in choosing the correct resin:

## **The target metal**

If the metal is valuable, effective recovery will be critical. For impurities, the most efficient targeted removal of the metal is an important factor.

## **The matrix**

Acidic (sulfate, chloride, etc.) or alkaline (cyanide, sodium carbonate, etc.).

## **The solution pH**

Performance of resins is affected by the solution pH.

## **Recovery from pulp (RIP) or clear solution Resin in Solution (RIS)**

This determines the contactor type required, as well as the physical properties of the resin (e.g. size and physical strength).

## **Presence of competing ions**

It is important to choose a resin with a high selectivity for the metal of interest.

## **The solution temperature**

While increased temperatures generally benefit most reactions, IX resins are temperature sensitive. For hydrometallurgical applications, a maximum operating temperature of 60 °C is usually recommended.

## **Integration with other unit operations**

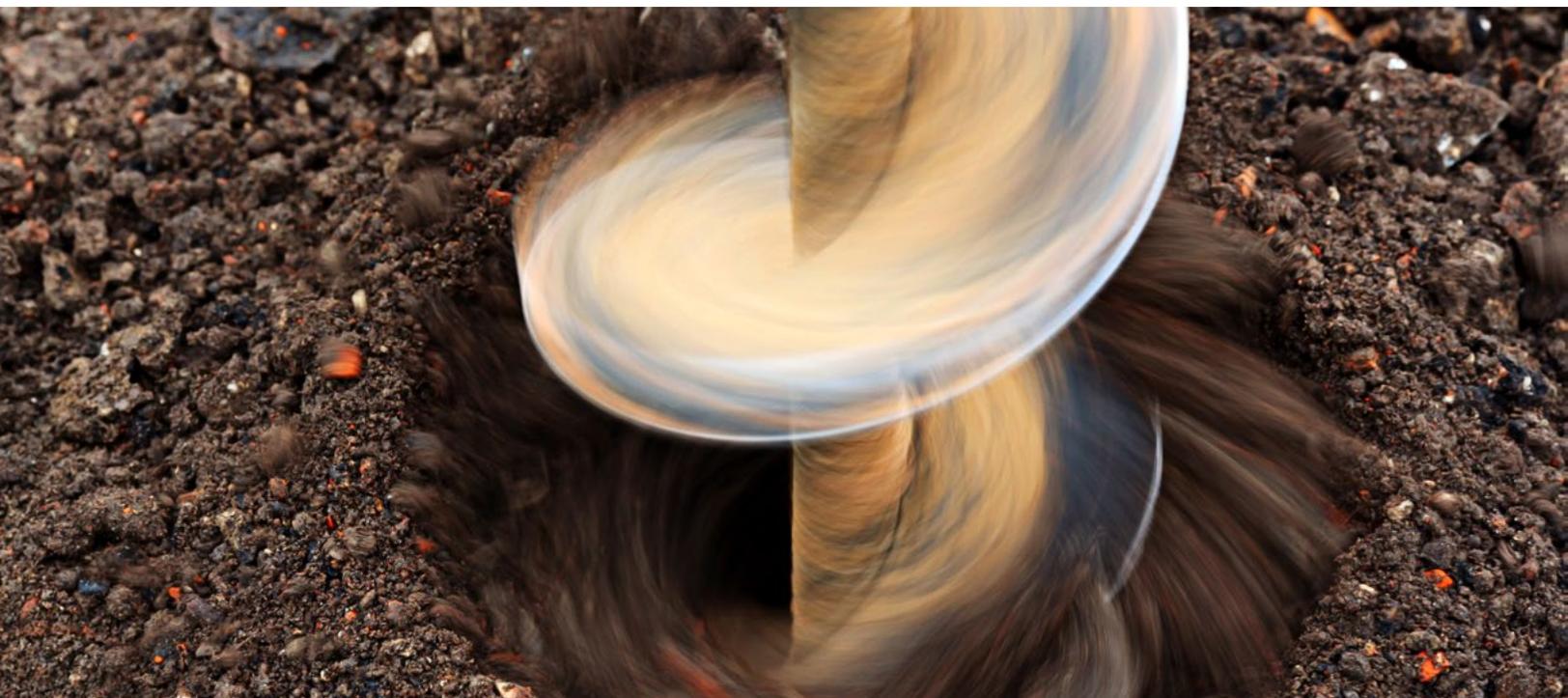
As an example, the choice of elution reagent is often dictated by requirements / limitations of downstream processes.

## **Process flexibility**

Consider if it is possible to change the pH of the solution to benefit the IX unit operation while having minimal impact on the rest of the circuit.

## **Environmental limitations**

As an example, the choice of elution / regeneration reagents is influenced by disposal regulations.



**Table 5 – Suggested Purolite resins for hydrometallurgical applications**

TARGET METAL	DETAIL	PUROLITE RESIN(S)
Antimony	Various liquors and waste waters	Puromet™ MTS9500 Puromet™ MTS9570
Bismuth	Various liquors and waste waters	Puromet™ MTS9500 Puromet™ MTS9570
Copper, nickel, cobalt, zinc	Acidic liquors or pulps	Puromet™ MTS9300 Puromet™ MTS9301 Puromet™ MTS9600
Copper & zinc impurity removal	Cobalt and nickel electrolyte	Puromet™ MTS9500
Gold	Cyanide liquors and pulps	Purogold™ MTA1930 Purogold™ MTA9920
Gold	Thiosulfate leach	Purogold™ MTA5011 Purogold™ MTA5013
Gold	Acidic liquors or pulps	Puromet™ MTS9140 Puromet™ MTS9200 Puromet™ MTS9240
Iron	Electrolyte purification	Puromet™ MTS9500 Puromet™ MTS9570
Mercury	Various liquors and waste waters	Puromet™ MTS9140 Puromet™ MTS9200 Puromet™ MTS9240
Molybdenum	Acidic liquors or pulps	Puromet™ MTA1011
Nickel	Acidic liquors or pulps	Puromet™ MTS9300 Puromet™ MTS9301 Puromet™ MTS9600
Precious metals	Acidic liquors or pulps	Puromet™ MTS9100 Puromet™ MTS9200 Puromet™ MTS9240 Puromet™ MTS9850
Rare earth elements	Acidic liquors or pulps	Selection of cation exchange resins
Rhenium	Acidic liquors or pulps	Puromet™ MTA1701 Puromet™ MTA1721
Uranium	Acidic liquors or pulps	Puromet™ MTA8000 Puromet™ MTA4601PF Puromet™ MTA5012 Puromet™ MTA5081 Puromet™ MTA6001 Puromet™ MTA6002PF Puromet™ MTA6601
Uranium	Alkaline liquors or pulps	Puromet™ MTA8000 Puromet™ MTA5081

### Americas

150 Monument Road  
Bala Cynwyd, PA  
19004  
T +1 800.343.1500  
T +1 610.668.9090  
F +1 484.384.2751  
Americas@purolite.com

### Europe

Llantrisant Business Park  
Llantrisant  
Wales, UK  
CF72 8LF  
T +44 1443 229334  
F +44 1443 227073  
Europe@purolite.com

### Asia Pacific

Room 707, C Section  
Huanglong Century Plaza  
No.3 Hangda Road  
Hangzhou, Zhejiang, China 310007  
T +86 571 876 31382  
F +86 571 876 31385  
AsiaPacific@purolite.com



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