IntelliMet LLC

Intelligent Metallurgy

High Performance Recovery of Lithium from Mine Solutions

IntelliMet

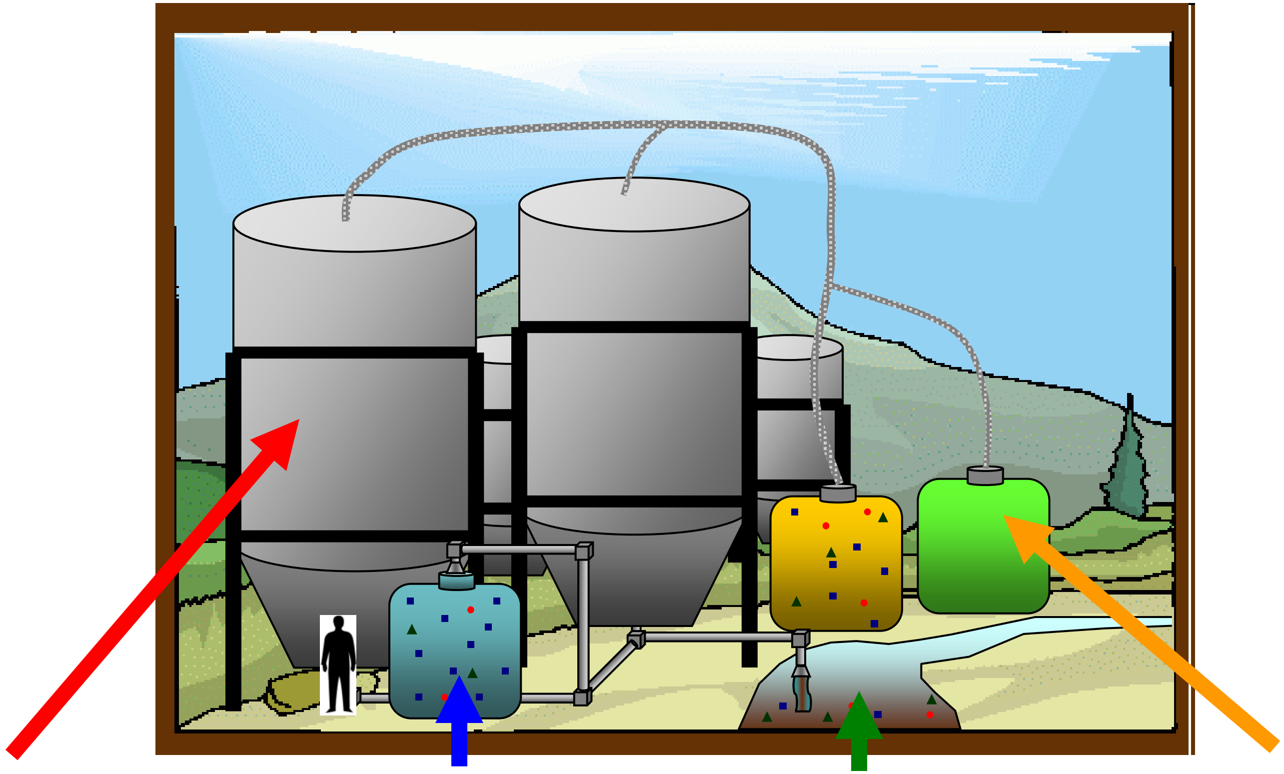
-Stronger Metal Revenues
-Lower Operating Costs
-Greener Mines

The Mining Technology Revolution is Here

About IntelliMet

- IntelliMet is a high tech Silicon Valley startup, with operations centered in Missoula, MT
- We have developed, and patented, a nano-material called the "Spiderweb." The Spiderweb replaced conventional resin, with greatly improved speed and selectivity properties.
- IntelliMet works with mining and remediation operations to develop processes using the Spiderweb Resin to improve the profitability and operating capabilities
- IntelliMet will be installing our first full scale unit at a Uranium mine in Wyoming Q3 of 2010
- The IntelliMet team has decades of experience in hydrometallurgy and process development. We work on all levels of process development, from leaching, to developing custom resins for a particular problem, to process development, piloting, and full scale implementation

Problems of Conventional Hydrometallurgy



System Has -
Large footprint
Expensive to Construct and Operate
Not Readily Movable

Incomplete Recovery of Primary metal
Large rinse volumes, loss of secondary metal values, Low grade ores uneconomical

Unrecovered Valuable Metals and byproducts contaminate aquifer, causes environmental impact, permitting/closure issues

Inefficient Exchanges Require Large Chemical Volumes/ Cost, Dilute metal “concentrates”

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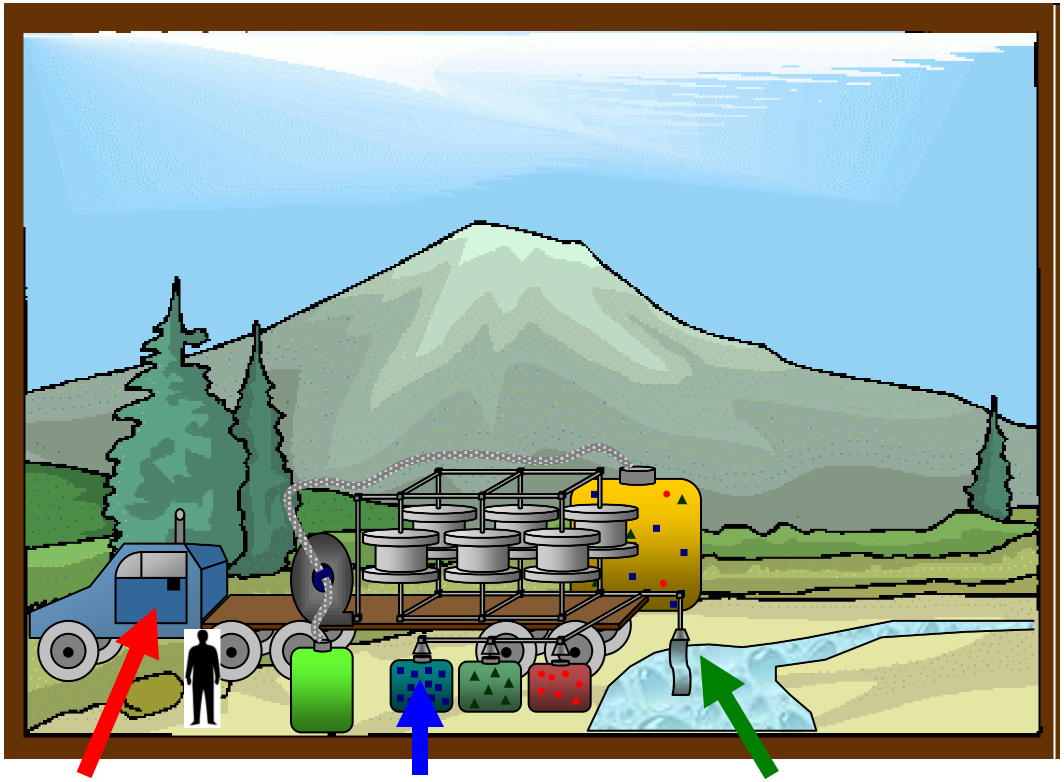
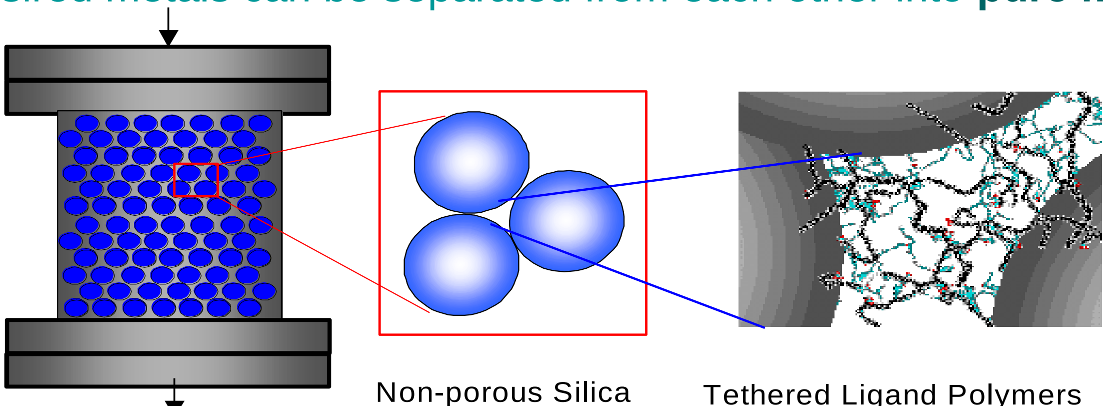
Our Vision for 21st Century Mining



Small, Portable, "Smart," system for cheap/ flexible operation	Quantitative Recovery of Primary AND Secondary Metal Values as Pure Concentrates, Low grade ores economically feasible	Contaminants fully removed, returning pristine water to watershed	Quick exchanges provide low chemical costs and brine volumes

Why Our "Resin" is Different

- Most metal binding materials (resin, carbon, etc), are limited by slow and incomplete exchange of metal into the solid
- With funding by US government grants, the IntelliMet team has developed a fundamental breakthrough in material science, wherein the binding groups are placed *between* the particles, in direct contact with the active solution, by means of a thin polymer network called the "Spiderweb."
- The rapid contact enables almost ***instantaneous* exchange of metals** with solution.
- The rapid exchange of metals allow (1) **high solution throughput**, and therefore small equipment footprints, (2) **rapid and near quantitative metal recovery** from solution, and (3) **selective binding and exchange of metals**, so that desirable components (lithium, niobium, iodide, etc) can be selected from undesirable components (sodium, etc), and desired metals can be separated from each other into **pure metal fractions**.



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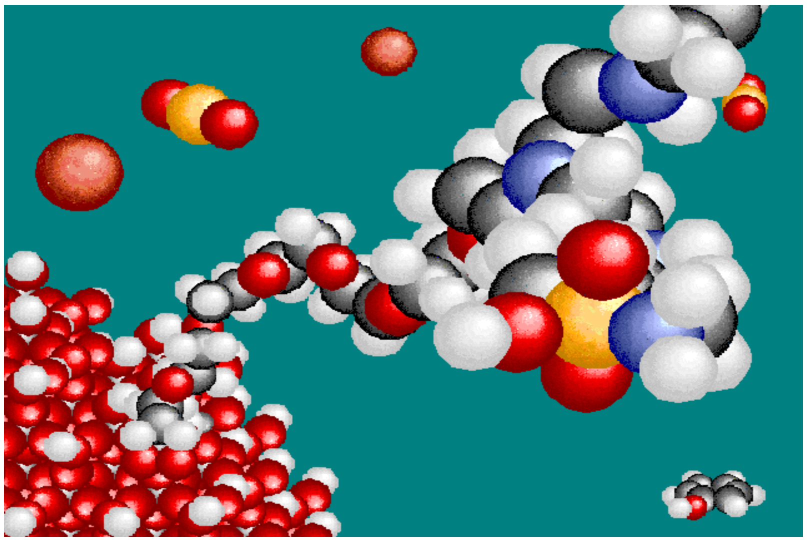
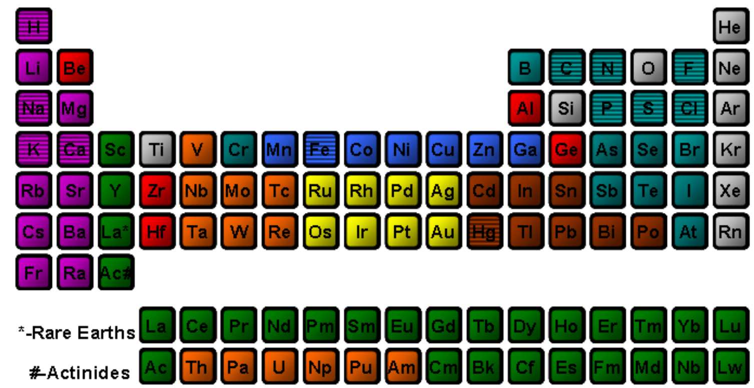
Our Periodic Table of Hydrometallurgy: The World of Mining Opportunities



- Metal and ion binding chemistry can be predicted by their position on the periodic table. Knowing the hydrometallurgical family of a metal directs us towards particular classes of chelators.
- Chelator structure is then modified with greater precision to target the particular metals, separations, and solution environments that are presented by a particular mine leach solution.



Treatability Using Hydrometallurgy

= Recoverable as Primary Metal Value

= Treatable as Byproduct/ Secondary Value

= Insoluble/Not Treatable

Hydrometallurgical Family

= **Weak IEX Cations:** These are generally low charge metal cations which are captured using ion exchange resins. Binding strengths/selectivities can be increased by using large ring/multidentate binding structures.

= **Hard Metal Cations:** These metals form small cations in water, which generally bind best to anionic oxygen or nitrogen containing coordinating chelators. Under basic conditions, these metals tend to form oxoanions (ex Al(OH)4-) and can therefore under basic condtions often be bound with anion exchange resins.

= **Non Metal Anions:** These elements generally form anionic species, either single atom anions (ex. Cl-), or oxoanions (ex. CO_3^{-2}). These are bound most effectively by anion exchange resins. Binding strengths/selectivities can be enhanced including proton/Lewis Acid (metal) acceptors on the chelator. (Note: although chromium is a metal, the dominant form found in water, chromate (CrO_4^{-2}) does not form coordinate complexes with ligands, so its hydrometallurgy is similar to non-metal anions)

= **Rare Earths and Related:** The Rare Earth family of metals (and similar elements in the Actinide family) are characterized by large size and large charge. Generally, anionic chelators that prefer/select for large metals give the best binding selectivities.

= **Metal Oxoanions:** These metals have high positive charges, and as such form negatively charged clusters with oxide (ex. $V_{10}O_{28}^{-6}$) or complex anions (ex. $UO_2(SO_4)_3^{-4}$). These metals are usually best bound with cationic chelators that have metal coordinating donor groups, with which these metals can form direct bonds.

= **Borderline Metal Cations:** These metals are intermediate in properties between Hard Metal Cations and Soft Metal cations, and can have affinity for chelators designed for either of these metal families, particularly containing nitrogen.

= **Soft Metal Cations:** These metals generally prefer supports that contain chelator groups with nitrogen, sulfur, phosphorous, or other "soft" atom donors.

= **Precious Metals:** This class of metals generally forms negatively charged species in water by binding groups such as chloride, cyanide, thiosulfate, etc. They are best captured by anion exchange supports that are capable of engaging in "secondary" binding interactions for these metals.

Our Business Model

- IntelliMet contracts to Mines to develop hydrometallurgy solutions
- Full Scale Units Are installed which have better recoveries, and substantially reduced capital and operating costs than conventional units
- IntelliMet provides replacement media and ongoing support for some portion of the metal revenue which leaves the mine more margin than it would otherwise make

Current Projects

- **Rare Element Resources** - Separation of Rare Earths from Ore leachate from the Bear Lodge Property – Separating Rare Earths from iron and into individual elements
- **Uranium One** – Recovery and Separation of Uranium and Vanadium at Christianson Ranch in Wyoming
- **Canyon Resources** – Removal of Trace Thallium from decommissioned Kendal Gold Mine
- **Barrick Gold** – Removal of trace Uranium and Molybdenum from historic mining district at Grants
- **GreenTech Mining** – Removal of Platinum, Rhodium, and Gold from Montana Mine Tailings

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Separations is an Essential Challenge for Lithium Recovery

While there are large reserves of Lithium in brines worldwide, most of these resource possibilities are inhibited by the presence of large quantities of other ions such as **Magnesium, Calcium,** and **Sodium**

Example: Moab Brines

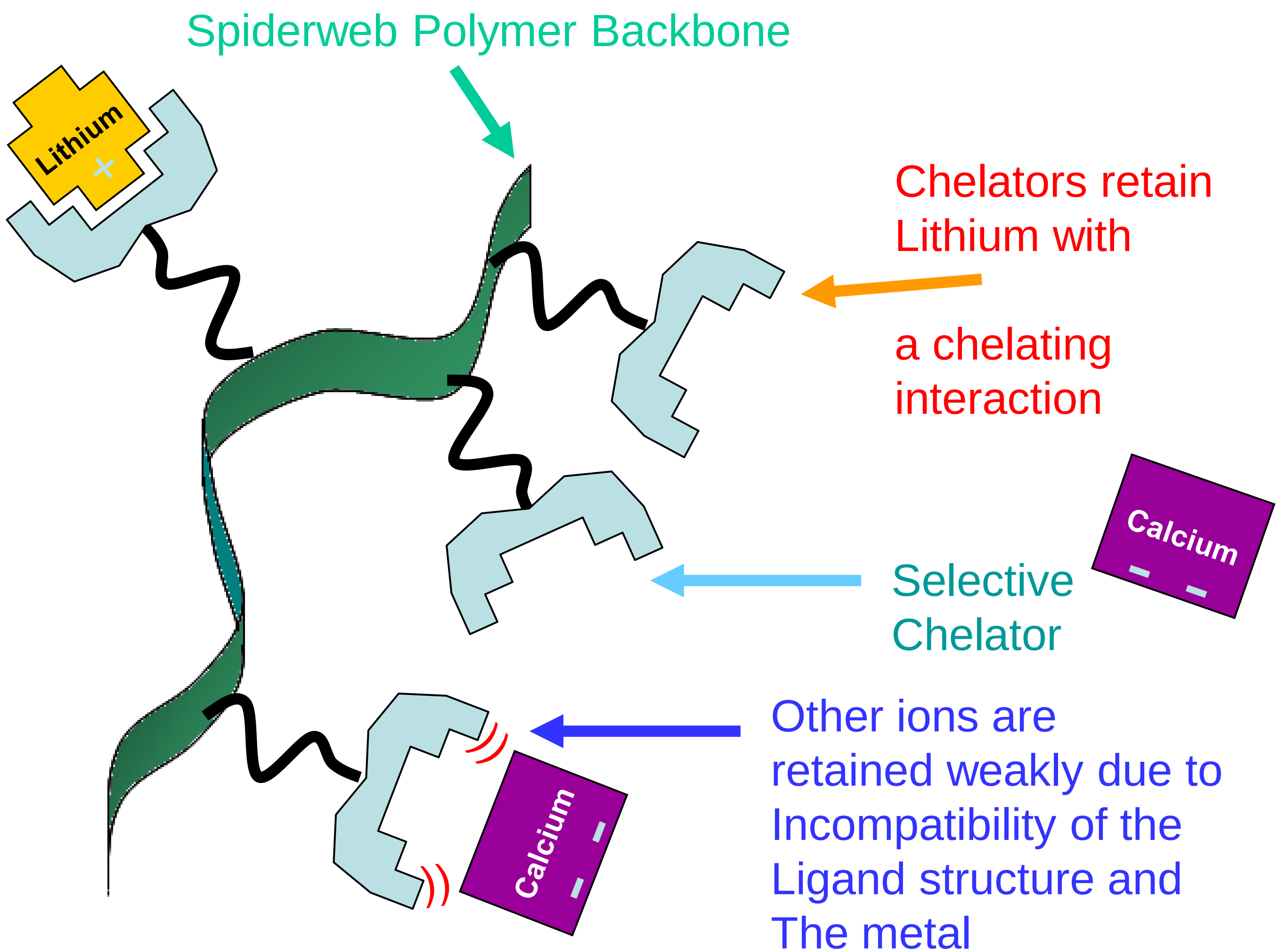
Bicarbonate	1,400 ppm	
Bromine	6,100	
Calcium	65,800	
Chloride	29,800	
Lithium		500
Magnesium	45,500	
Nitrate		6
Potassium	23,400	
Rubidium	700	
Sodium	9,800	
Sulfate		80
Total Solids	439,000	
pH		6.0
Specific Gravity	1.37	

-E. Jay Mayhew and Edgar B. Heylman, *Concentrated Subsurface Brines in the Moab Region, Utah*, a copy provide by Foster Wilson.

“Southern Natural Gas No. 1 Long Canyon, section 9, T. 26 S., R. 20 E., Grand Country. Paradox Formation, clastic zone 31. Analysis by U.S.Geological Survey features the above ion values”

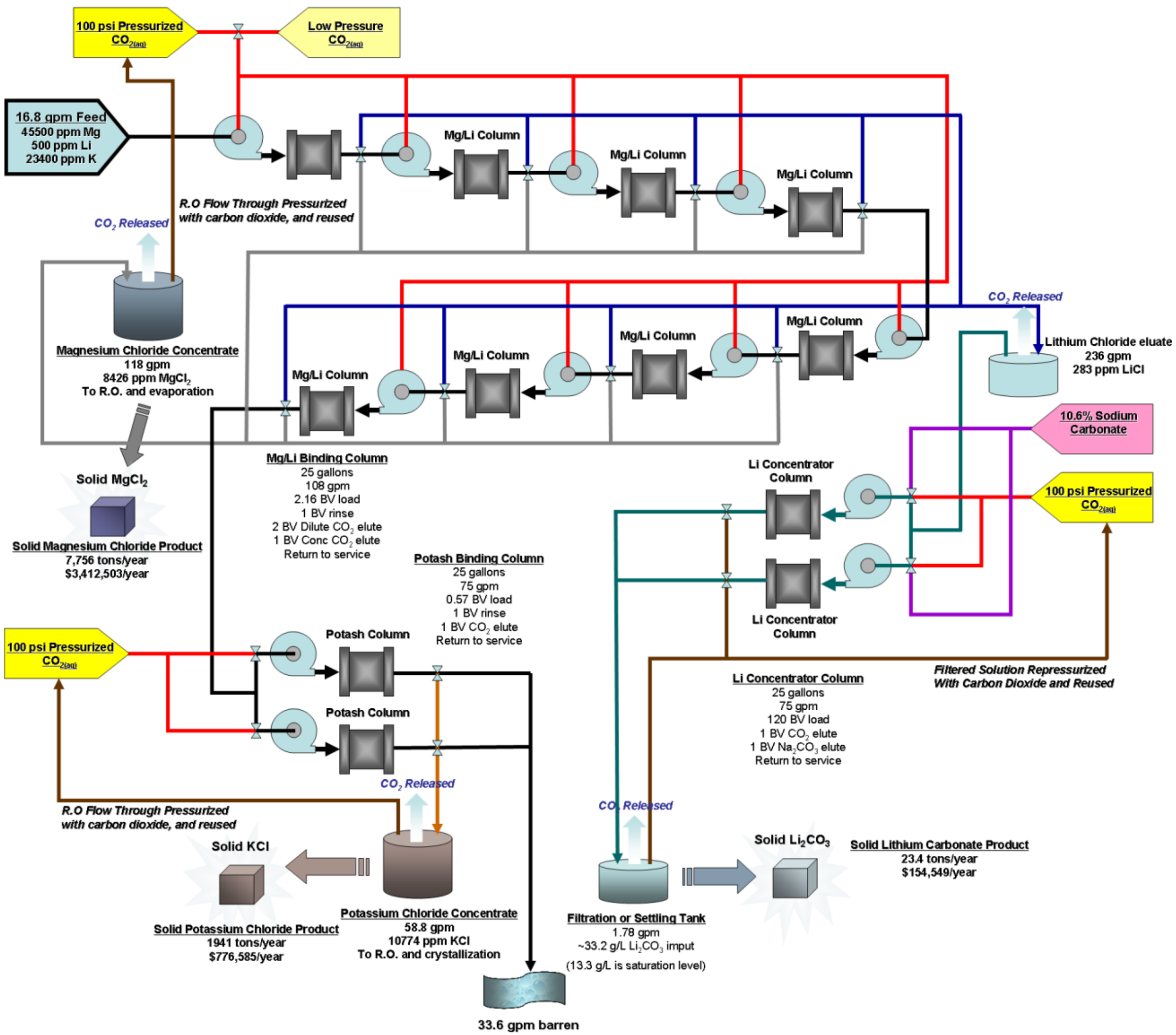
Separating a Little Lithium from Large Quantities of Other Ions

How the Spiderweb separates a small amount of Lithium from large quantities of other ions



Under many brine conditions, lithium and metals occur as a mixture of with magnesium, calcium, sodium, potassium, and other ions. Use of carbonate precipitation (the conventional recovery strategy) is not feasible due to co-precipitation of large quantities of magnesium and calcium carbonate. IntelliMet can attach specialized “chelator” groups to the Spiderweb Polymer which have structures compatible with lithium, and incompatible with other ions. Thus, while other ions are retained weakly, they are displaced by lithium, leaving a pure lithium concentrate on the support.

Proposed Process Diagram for Moab Lithium Brines



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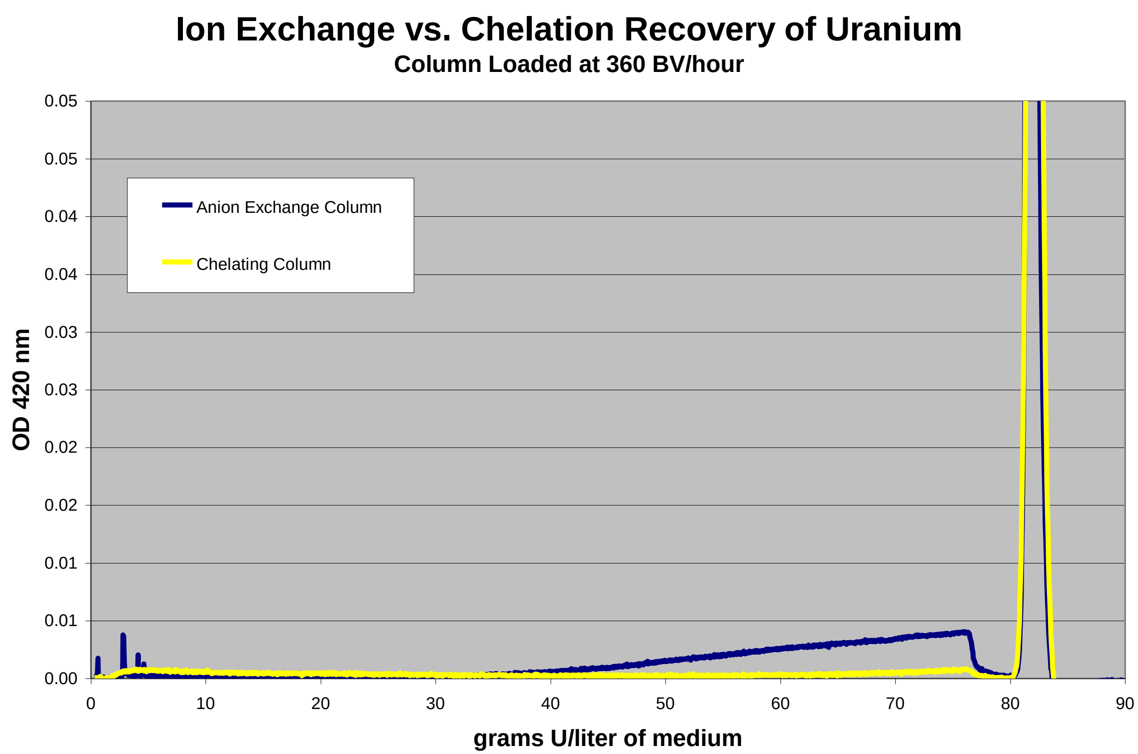
Example: Using Spiderweb Chelators to Recover Uranium and Moly from High TDS Leach

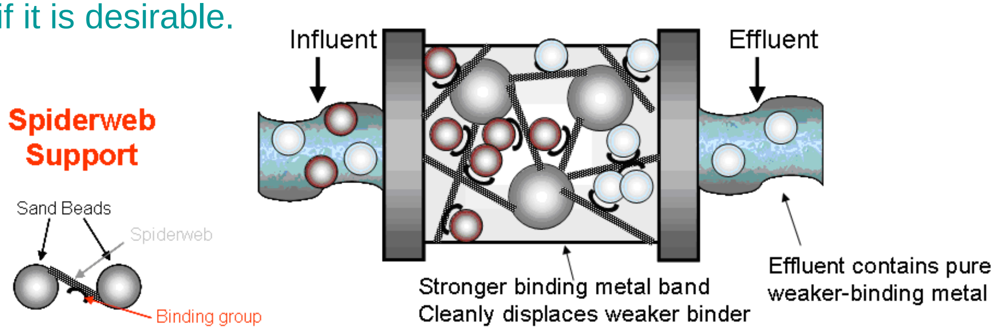
As a demonstration of the effectiveness of chelator columns for recovering uranium from high TDS feeds, particular containing sulfate, a 50 ppm solution of uranium in 1000 ppm sulfate was loaded into two different beds, one containing SAX binding groups (trimethylammonium), the same as those put on conventional DOW resins, and a second column containing our proprietary chelating ligands. As can be seen, **uranium broke through the non-chelating ion exchange** column after loading >35 g/L of uranium into the resin. On the other hand, because the **chelating resin gave greater selectivity** for uranium, it was possible to see near quantitative recoveries at >75 g/L. Acid elution yielded bound uranium from each, showing the spike after loading.



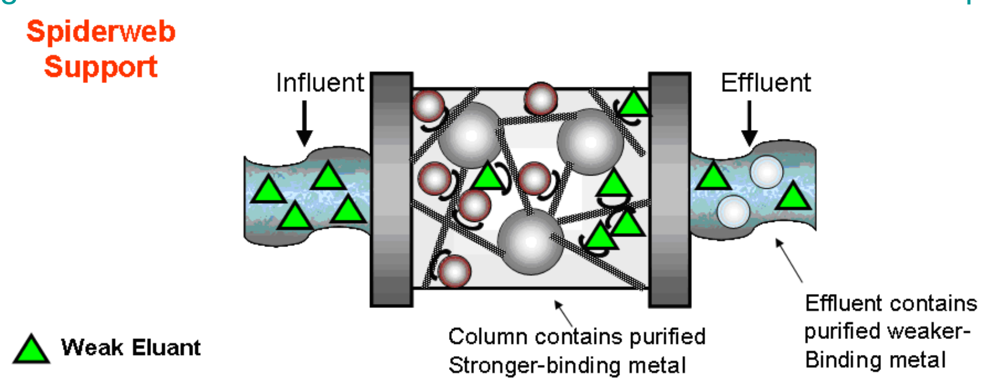
The Process of Metal Separation with the Spiderweb Matrix

- Contamination of Lithium with other metals can decrease the value of the product if not make it completely unsalable.
- On the other hand, if other components can be separated into their respective fractions, they can **add significant value**. In the Moab Brines, for example, magnesium, potash, and bromine offer significant value opportunities.
- Two processes can be used to purify the desired metals: *Selective Binding*, or *Selective Elution*

Selective Binding: Both metals bind initially to the support, but when all binding sites are occupied, the stronger displaces the weaker, leaving the stronger binding target in the column, and the weaker in the stream. The weaker target can then be concentrated in a second column if it is desirable.

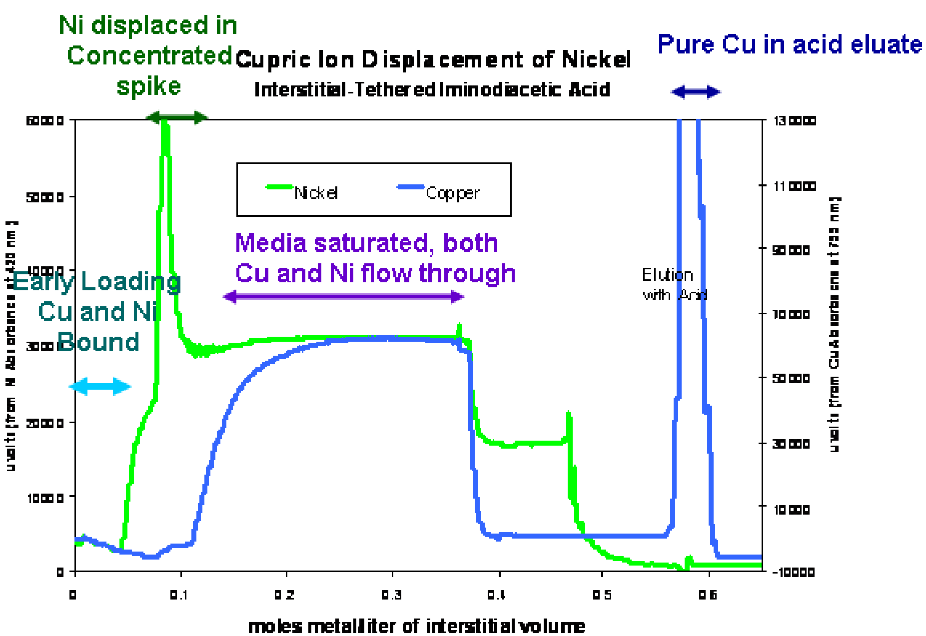


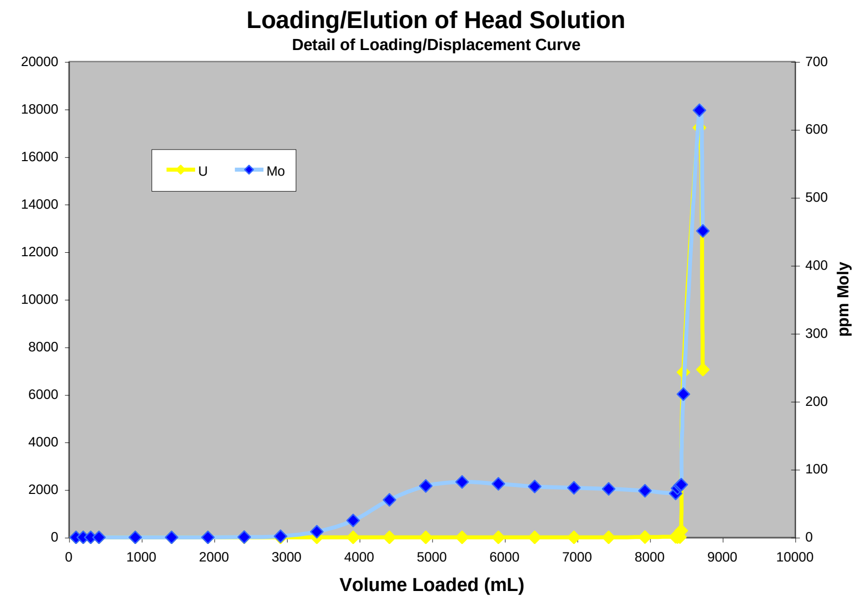
Selective Elution: A weak chemical agent that is strong enough to remove the weaker binding metal, but not strong enough to remove the stronger binding metal, is passed through the media bed. The weaker binding metal is collected in the flow through, while the stronger binding metal is retained on the bed and can be collected in a subsequent elution step.



Examples of Selective Binding

Uranium can be purified from other metal contaminants in solution by using selective binding. Both metals bind to begin with, but once the capacity of the resin is saturated, the weaker binding metal is displaced by the stronger binding metal. Below are shown a selective binding processes to displace nickel from a copper mixture, to yield a **purified concentrate** of copper on elution, and, likewise, a displacement of molybdenum by uranium in an ISL solution from a US uranium mine.





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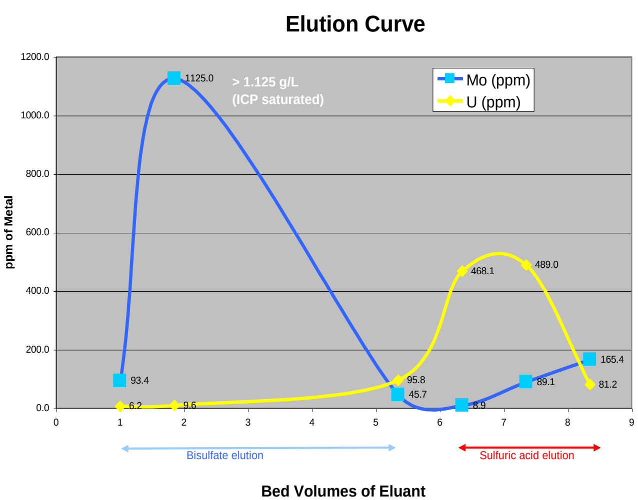
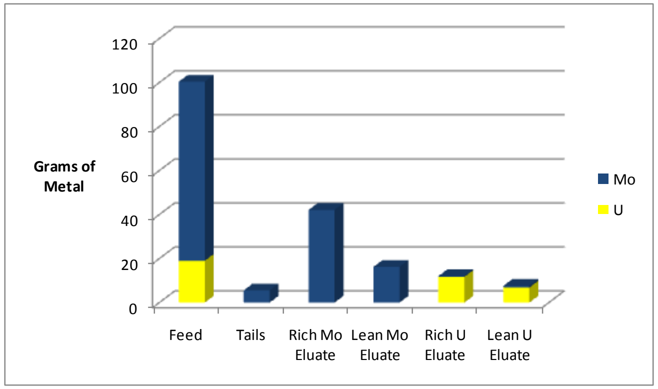
Example of Selective Elution (Separating Uranium and Molybdenum)

Below are pictured recoveries and separation of molybdenum and uranium from ISL solutions. The left shows an elution curve from a barren ISL soluton from a US uranium mine. A weak eluant removes the molybdenum in a highly pure concentrate from column, and a stronger eluant removes uranium in a highly pure concentrate. The right figure shows the mass balances from testing of a model solution of US uranium mine ISL barrens..an barren ISL solution at a US uranium mine (left), and a similar model ISL barren solution. After column loading, moly is removed with a weak eluant, followed by uranium with a strong eluant. **No cross-metal contamination was detectable** in respective eluants. The middle figure shows a photograph of two collected rich eluate solutions, the blue solution containing molybdenum, and the yellow solution containing uranium.



Blue Moly and Yellow Uranium rich eluates separated and recovered by Spiderweb column

Mass balances for uranium/molybdenum recover and separation from ISL barrens



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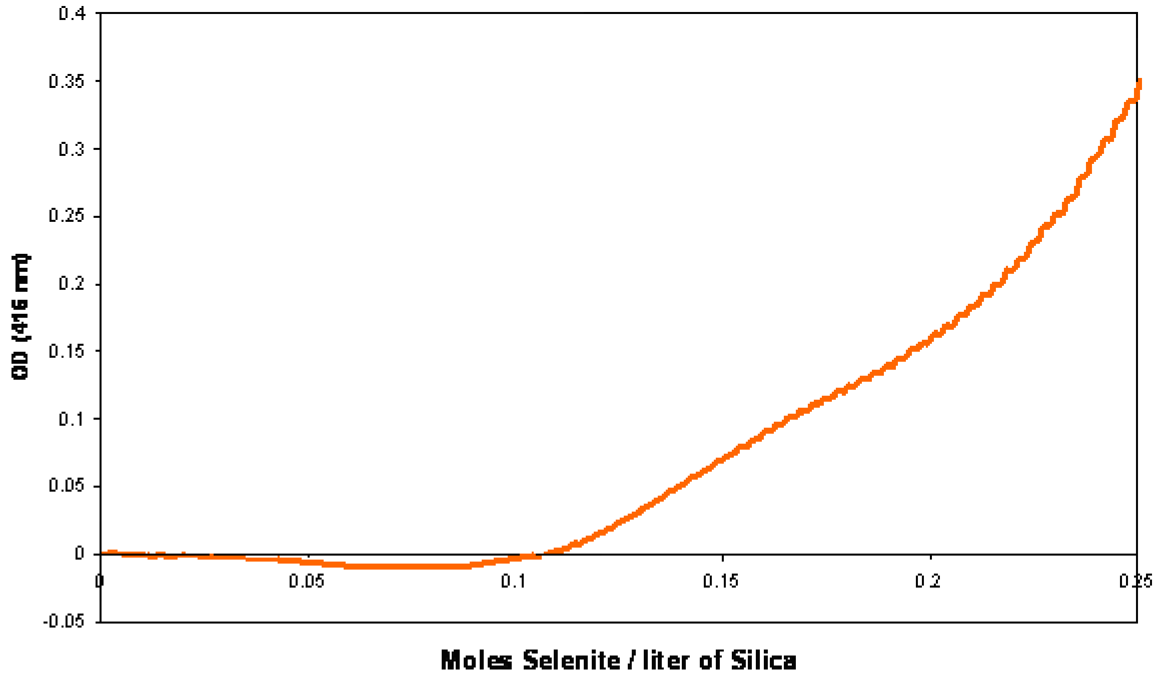
Managing Environmental Impact/Mine Decommissioning

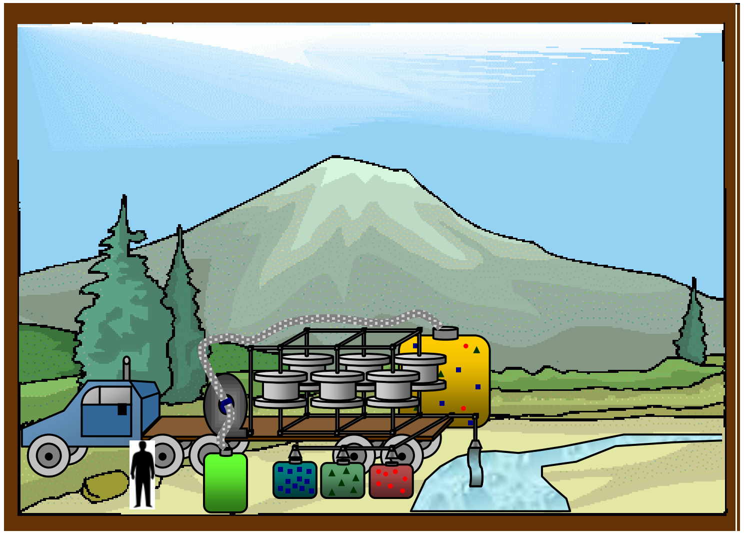
- Frequently, excavation of mineral solutions and disruption of the ground system can introduce toxic and undesirable species into the groundwater, such as **arsenic or selenium.**
- Removal of contaminants is **expensive** and **unpredictable** with conventional technologies
- Because of the rapid and quantitative binding characteristics of the Spiderweb Resin, IntelliMet columns can be prepared which easily reduce these metals to **non-detect** levels for a fraction of the cost of other alternatives. The toxic metal can then be recovered as concentrates and disposed of. In some cases, these metals also have value if pure (ex. Selenium is **$60/lb**).

Example: Removal of Selenium from Water

IntelliMet has done testing of removing selenium from water. In the below figure, an 800 ppm solution was loaded into a Spiderweb column with a chelated iron species. Prior to breakthrough, **selenium levels were <50 ppb (the limit of detection)**. After loading was complete, the selenium could be eluted in one bed volume as a concentrate using an acid strip.



Operational Parameters of an IntelliMet System



- **Solution Processing Velocity**: 4-5 Bed Volumes/min
- **One Pass Metal Recoveries** - >95%
- **Metal Purity Spec**: >99%
- **Metal Concentration Factor:** 100-10,000
- **Processing Units** – Parallel Operating Columns
  - 100 gpm column (36" diameter * 18" height bed, 0.9 m * 0.45 m)
  - 10 gpm column (14" diameter * 12" height bed, 0.35 m * 0.30 m)
- **Footprint:** for a 500 gpm Unit – approx 40 ft * 20 ft (13 m * 6 m)
- **Backpressure:** 50-100 psi
- **Solution Requirements**
  - System requires pre-filtering of solution
  - System can tolerate full range of pH conditions (pH 0-14)
  - System is not sensitive to eH
- Estimated **Startup Cost** for a 100 gpm unit: $300-$800 K, 500 gpm unit $1-2 Million
- **Operating Cost** (including media/equipment replacement, staff, energy, reagent, etc) – variable, but generally significantly less than alternate processes
- **Equipment**: Besides the column(s), the system engineering is quite simple, with basic pumps, valves, and a control system. The system has flange to flange connections. Because of its small size, the whole system can readily be transported by truck for easy deployment/moving.

Project Development

The course of development of a project is dependent on the particular needs and status of that project. This is just an outline of what we often recommend for a development strategy.

An IntelliMet 1 L/min Minipilot Unit

Phase 1: Initial Resin Screening/Optimization – An initial set of IntelliMet binding supports are screened to demonstrate recovery of the most important metal(s). This is done with small, finger size media beds, in order to demonstrate the basic chemistry, so less than 10 gallons of leach solution is required. The focus of this stage is to generate basic feasibility for a process based on the Spiderweb resin. Often, it makes sense to do this step in tandem with Phase 1 (leaching optimization), since removal of leached metals from the stream by the resin can drive the leaching process to higher recoveries.

Phase 2: Resin Recovery Process Optimization – This step further optimizes on the work done in Phase 2. A wider range of chemistries are investigated, with an aim to increase metal purity and recovery, and develop recovery processes for secondary metals of interest in the stream. This is done again with the finger size column units

Phase 3: Mini-Pilot – The goal of this phase is to demonstrate the total process on a larger scale, and provide the engineering data to construct a larger pilot unit. This is usually done with 1 Liter /min flow volumes. Continuous operation of the recovery unit is demonstrated, to collect product samples for analysis, fluid balances, brine volumes, repeatability, etc.

Phase 4: Pilot – This stage is conducted at 10 gpm or 100 gpm, depending on the requirements of the operation. A unit is constructed with one operating column, and necessary, pumps, valves, PLC, etc. Shakedown, and continuous operation for some weeks/months is performed, as a basis to make projections for full scale operation.

Phase 5: Full Scale Operation – A hydrometallurgical system capable of handling the full output of the mine is constructed. This is simply parallel columns of the same size examined in Pilot Phase, so there is no further scale up risks after pilot.

Summary of Benefits of IntelliMet Metal Processing Systems

- Higher lithium recoveries (**increased Top-line**)
- Recovery of Secondary Metals without large increases in operating costs/complexity
- Custom made binding groups enable processing of complicated metal and salt mixtures and leach solution conditions, unlike "off the shelf" conventional resins
- High throughputs mean **small footprint** and ease of transportation
- Toxic leach byproducts can be cheaply recovered and disposed of or sold, reducing regulatory and decommissioning hurdles.
- A **low cost**, **cleaner operating**, "**green**" metallurgical system.

Richard Hammen, Founder

- B.S. Stanford, Ph.D. Chemistry, University of Wisconsin,
- Post Doc UCLA
- 1973-76: US National Cycling Team; competed in World Championships, Pan American Games, etc.
- 1978-80: SRI International, Menlo Park, CA
- 1980-86: Jet Propulsion Lab, Pasadena, CA
- 1982-86: Director, Chemistry Department, Vestar Research, Inc. (later NEXSTAR, then acquired by Gilead)
- 1985-97: ChromatoChem, Missoula (sold to NGK)
- 1996 – 2009: Chela Tech, Montana & California
- 2009-present: IntelliMet LLC

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