



**KEMETCO**  
RESEARCH INC

CONTRACT RESEARCH & TESTING COMPANY

# Metallurgy & Process Design

# Develop Ideas; Test; Create Your Product

**Concept & Design** Development

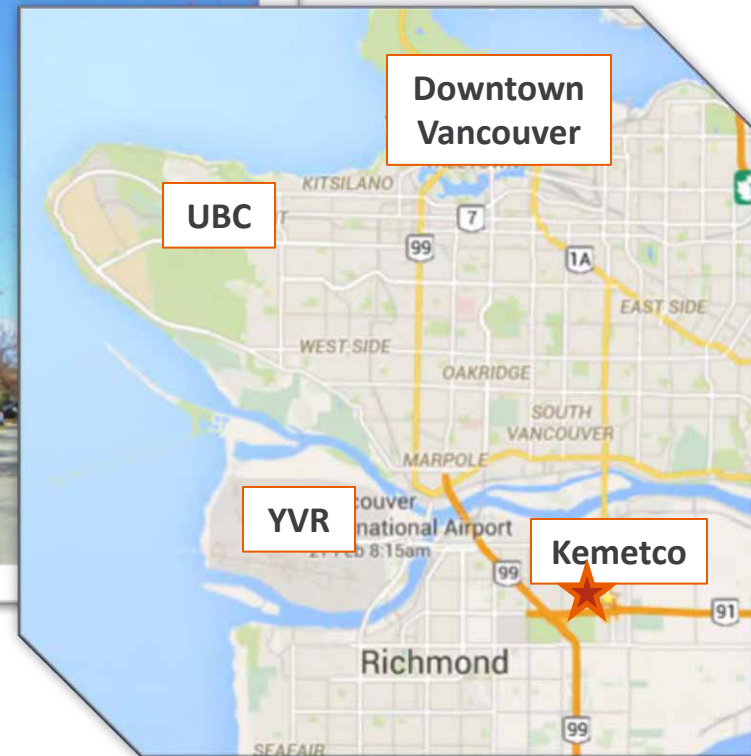
**Bench-Scale** Optimization

**Pilot Plant** Demonstration

**Product/Technology** Commercialization



# New Custom Designed Facility Conveniently Located in Richmond, BC



# Research Facility – 20,000 ft<sup>2</sup>



- ◆ **>24 full-time scientists and engineers**

# Manufacturing Facility – 30,000 ft<sup>2</sup>



◆ 30 engineers, designers and technicians



**KEMETCO**  
RESEARCH INC

CONTRACT RESEARCH & TESTING COMPANY

# > 350 Clients Worldwide

In Mining, Clean Tech, Water Treatment & Environment



# One-Stop Shop for your Process Development

## Bench-Scale Studies

- ◆ Product design
- ◆ System design
- ◆ Proof of Concept
- ◆ Flowsheet development
- ◆ Scale-up strategies
- ◆ Process optimization
- ◆ **In-house analytical testing**

## Pilot Plant Demonstrations

- ◆ General design & layout
- ◆ Structural & electrical specifications
- ◆ Custom modified parts
- ◆ Fabrication to specs
- ◆ Electrical engineering
- ◆ Commissioning
- ◆ HAZOP & safety inductions
- ◆ Continuous or batch operations
- ◆ Responsible waste management
- ◆ **In-house analytical testing**

# Metallurgy & Process Design

- ◆ Scoping Studies
- ◆ Flowsheet development
- ◆ Unit operation testing
- ◆ Pilot Plants
- ◆ Bulk sample processing
- ◆ Market sample creation
- ◆ Integrated in-house analytical support
- ◆ Operational support





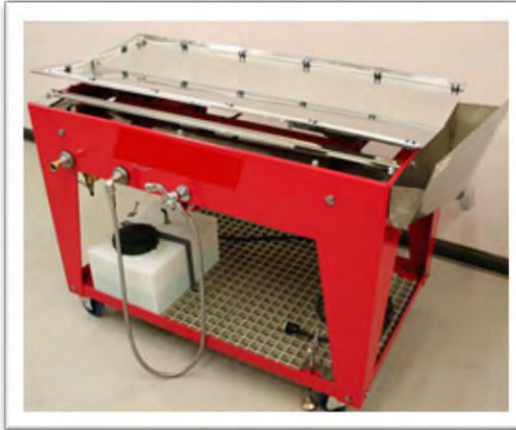
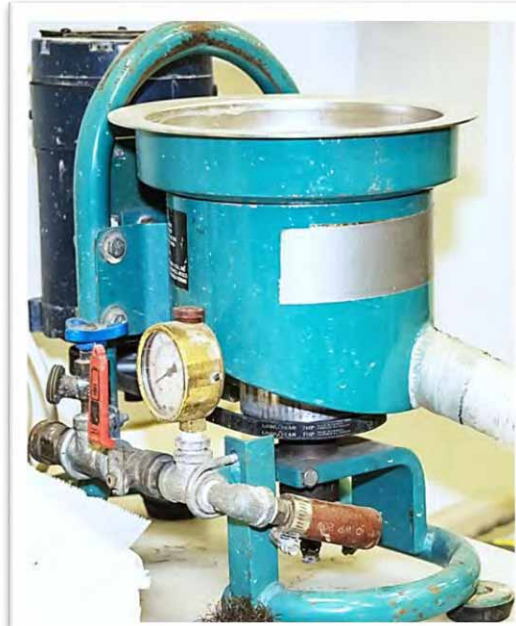
# Mineral Processing

- ◆ Crushing, grinding
- ◆ Liberation studies
- ◆ Particle size distribution



# Mineral Processing

- ◆ Gravity concentration
- ◆ Magnetic separation



# Mineral Processing

- ◆ Flotation schemes, including locked cycle testing
- ◆ Column flotation
- ◆ Pilot Plant flotation



# Solid Liquid Separation

- ◆ Settling
- ◆ Vacuum Filtration
- ◆ Pressure Filtration

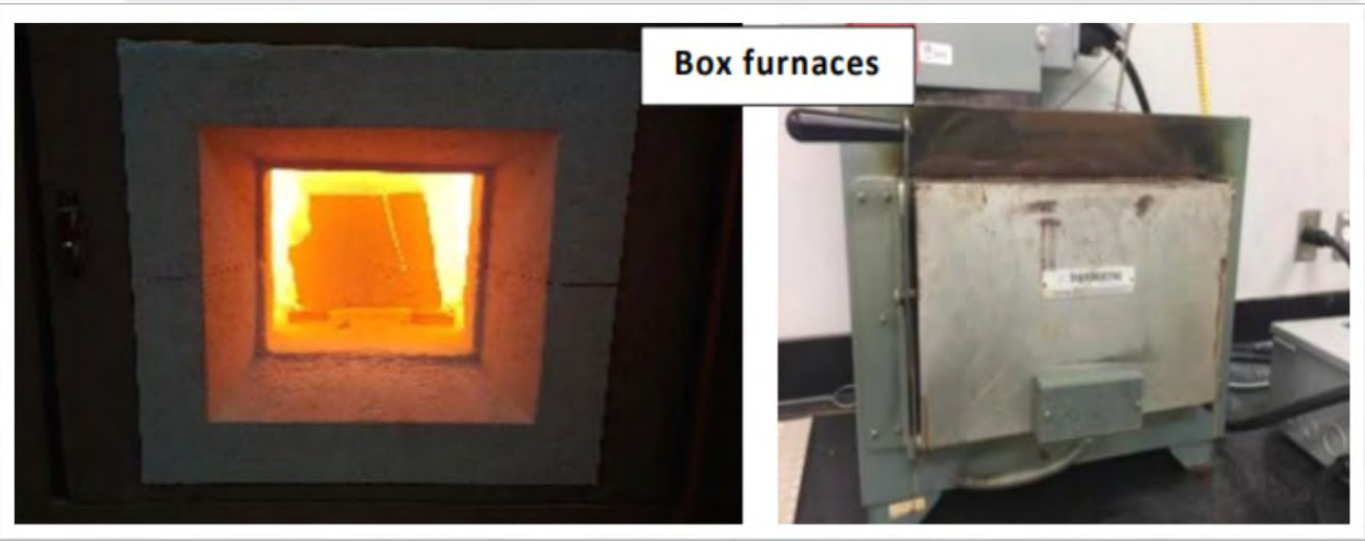
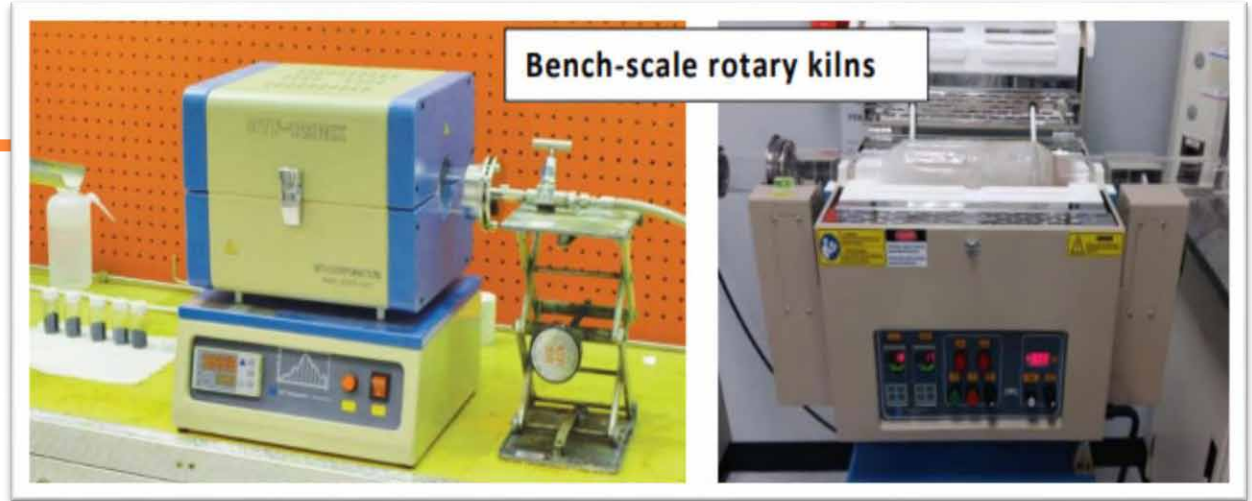


**Pilot-Scale Filter Press**



# Pyrometallurgy

- ◆ Smelting
- ◆ Roasting
- ◆ Reductive roast



# Hydrometallurgy

- ◆ Leach studies
- ◆ Pressure oxidation
- ◆ Precipitation & dissolution



# Hydrometallurgy

- ◆ Solvent extraction batch tests
- ◆ Solvent extraction small- & large-scale piloting
- ◆ Ion exchange bench-scale & pilot plant demonstrations
- ◆ Electrowinning small- & large-scale piloting



# Biohydrometallurgy & Environmental

- ◆ Bioleaching
- ◆ Innovative sulfur-reducing and bacterial reactor designs
- ◆ NF and RO pilot plant studies





# Gold and Silver Extraction Cyanide Destruction



# Our **Gold & Silver Expertise:** Customized Studies

Mineral Processing

Diagnostic Leaching  
& Preg-robbing

Cyanide Leaching

Cyanide Detox

Non-Cyanide  
Leachates

Smelting & Pure  
Au Recovery

Electrowinning  
Circuits

Roasting

Carbon  
Characterization

Carbon Loading &  
Stripping

Carbon  
Regeneration

Cyanide Recovery



**Flowsheet Development, Bench-Scale Simulations, Optimization,  
Scale-Up Studies, Pilot Plant Demonstrations & more**



# Carbon Optimization in Gold Circuits

- ✓ Carbon Characterization
- ✓ Carbon Loading & Stripping
- ✓ Carbon Regeneration



# Diagnostic Leaching of Au & Ag Ores



# Cyanide Leaching of Au & Ag

Cyanide Heap  
Leaching

Electrowin &  
Collect Au & Ag

Smelt Au & Ag  
Doré



Post-Leach Cyanide Detoxification

# Cyanide Detox

- ◆ Cyanide detox technology for gold producers:
  - ◆  $\text{SO}_2$  air/ $\text{H}_2\text{O}_2$ / Caro's Acid processes for cyanide destruction
  - ◆ Test work conducted for several major gold producers, leading to plant design
  - ◆ Developing technology for use of lower cost catalyst



# Bench-Scale Cyanide Detox Optimization



# SO<sub>2</sub> Cyanide Detox System Technology: Gas Handling Building



PCL Oxygen  
Generators



Kaeser Air  
Compressors



Dessicant  
Drier System



# SO<sub>2</sub> Cyanide Detox System Technology: Liquid SO<sub>2</sub> Control Building



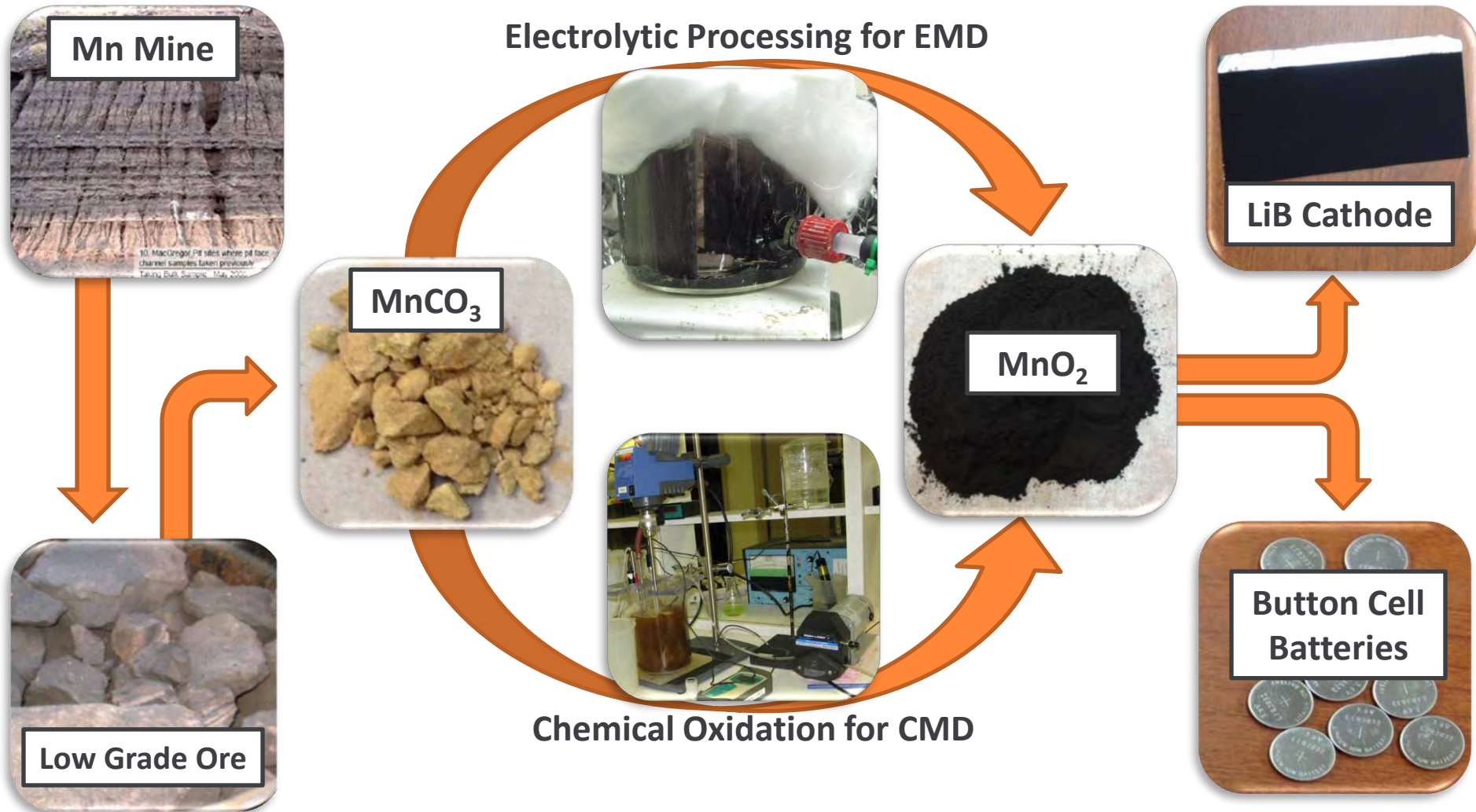
# SO<sub>2</sub> Cyanide Detox System Technology: Liquid SO<sub>2</sub> Storage Tank



# Example Projects

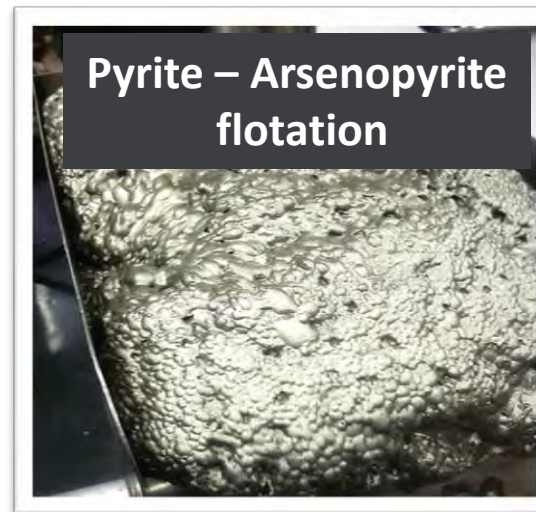


# From Mine to Product: Lithium Ion Manganese Batteries



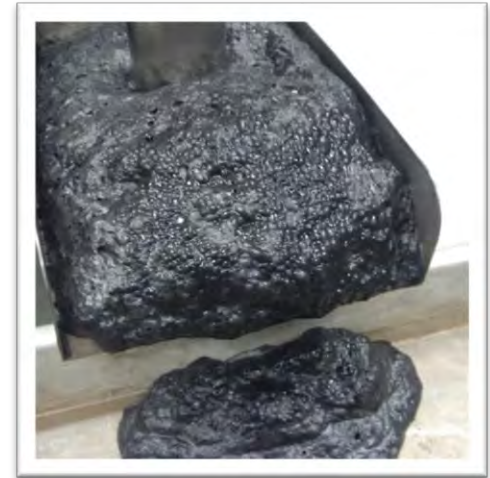
# Specialized Flotation Projects

- ◆ Pyrite-arsenopyrite separation
- ◆ Copper-nickel-cobalt & PGM flotation from ultramafic deposits
- ◆ Impact of process solution on lead zinc silver flotation
- ◆ Copper and gold flotation from vein deposits



# Specialized Flotation Projects

- ◆ Carbonaceous matter flotation
- ◆ Vanadium shale flotation
- ◆ Carbon flotation from e-waste pyrolysis products
- ◆ Graphite flotation for battery recycling
- ◆ Boric acid flotation from brines
- ◆ Sodium carbonate flotation from brines
- ◆ Copper and gold flotation from incinerator ash



# Kemetco Technology: Bio-Metals High Rate Biological Sulfide Generator

## Two Principle Applications:

Acid Mine  
Drainage  
Treatment

Cu heap leaching of low  
grade/end-of-life heaps  
(replacement for SX- EW)

- ◆ 7-12x faster sulfide
- ◆ Smaller plant size →  
lower capital costs
- ◆ Use low-cost nutrients →  
low operating cost



# Biological Methods for Leaching & Mine Drainage Treatment

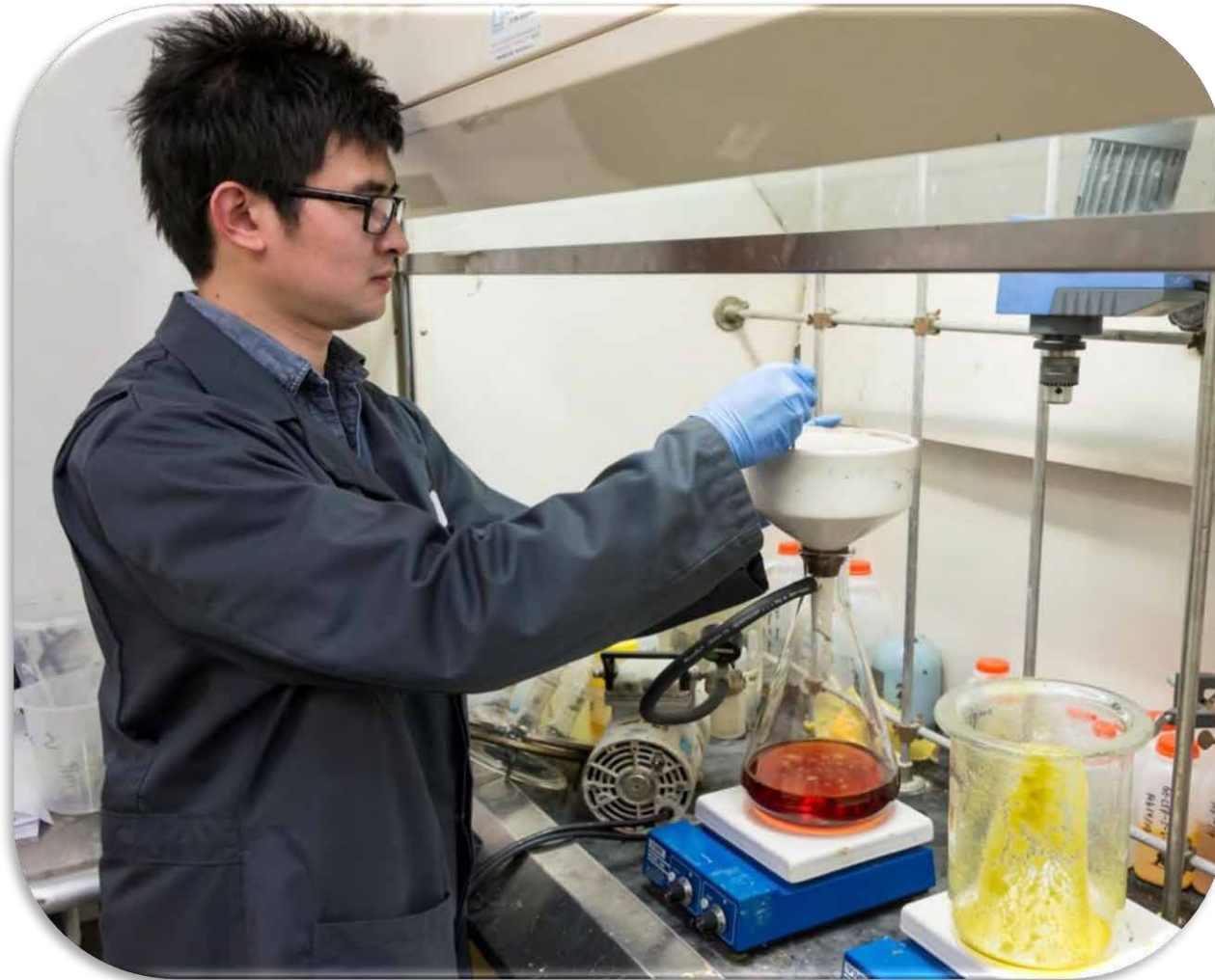




# Process Optimization: H<sub>2</sub>S recovery



# Example Projects

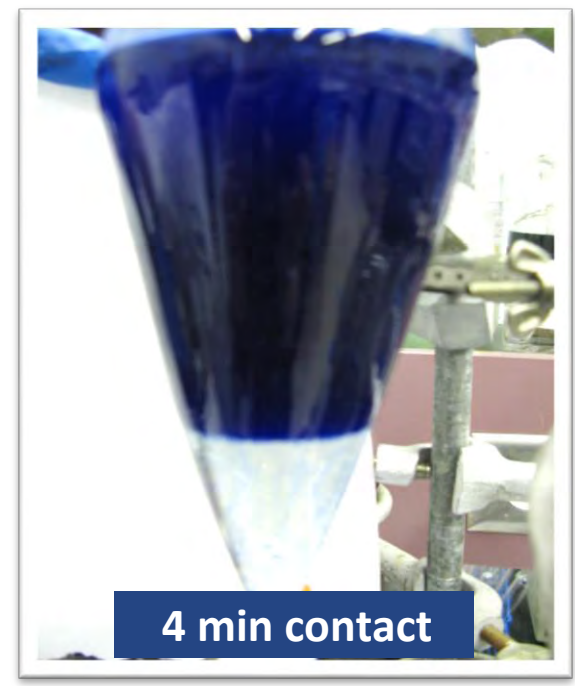


- ◆ Numerous projects in Ag, Zn, Cu, Co, Ni & Pb recovery
- ◆ Recovery of Ag from refractory ores
- ◆ Recovery of Zn from oxide tailings

# Example Projects:

## Optimizing Co-Ni Separation by SX Bench-Scale Study

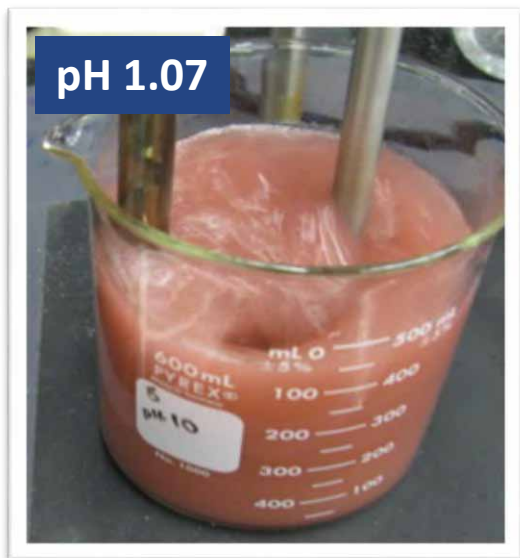
Bench-scale loading kinetic testing



# Example Projects:

## Cu-Co-Ni Separation by SX Bench-Scale Study

Loading as a function of pH



$\text{CoSO}_4$  and  $\text{CuSO}_4$  final products



# Example Solvent Extraction Projects

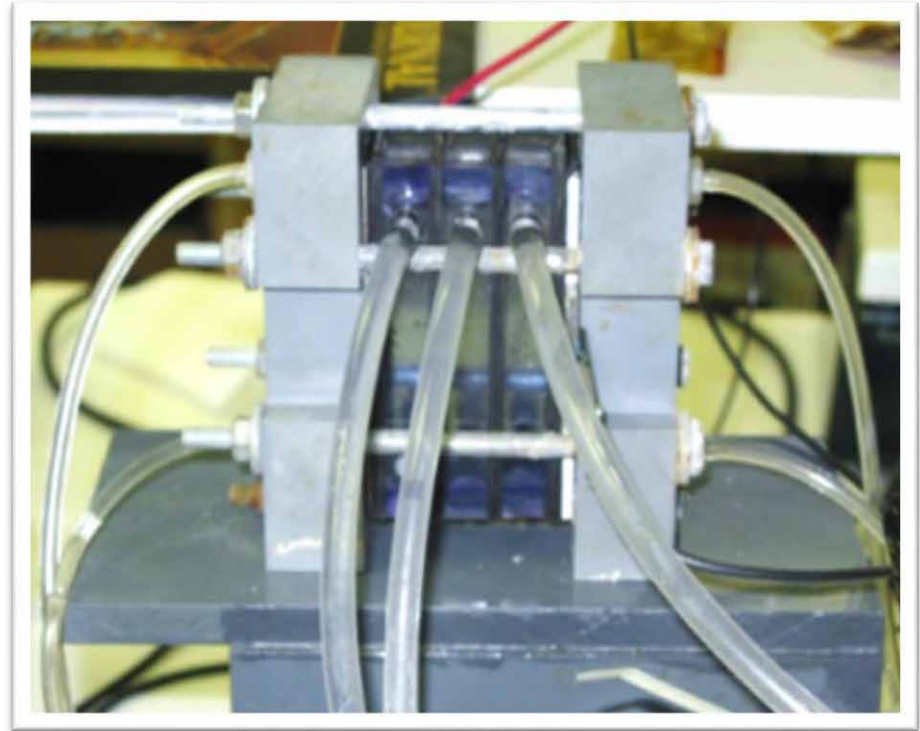
- ◆ Co, Ni and Ag recovery by SX from spent catalyst
- ◆ U-V recovery and separation from ash by SX
- ◆ Mo-Fe-Al separation by SX



V-U SX bench-scale testing

# Example Projects

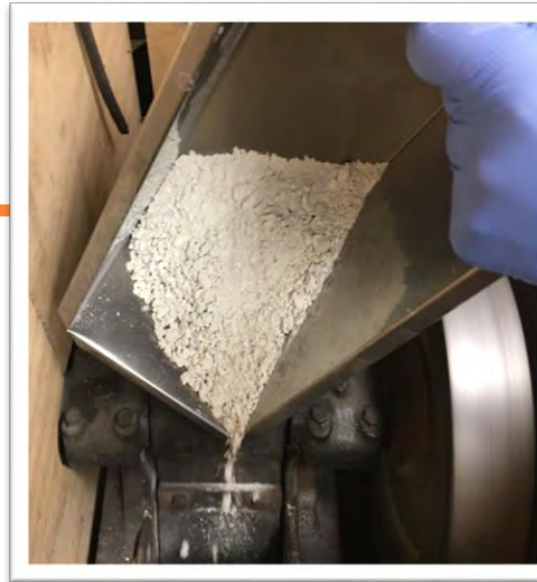
- ◆ Direct LiOH generation from brine by electrodialysis
- ◆ Optimization of electrowinning circuits
- ◆ Cyanide recovery
- ◆ Development of non-cyanide leachants for gold recovery



**Bench-scale electrodialysis set-up**

# Example Projects

- ◆ W upgrading technique by desliming and agglomeration
- ◆ Reductive roasting of barite and pyrolusite
- ◆ Chromite upgrading by gravity separation
- ◆ Carbon testing
- ◆ Lime testing including slaking rate, ALI and neutralization potential



# Clean Technology





# Production of Battery-grade $\text{Li}_2\text{CO}_3$ & $\text{LiOH}$

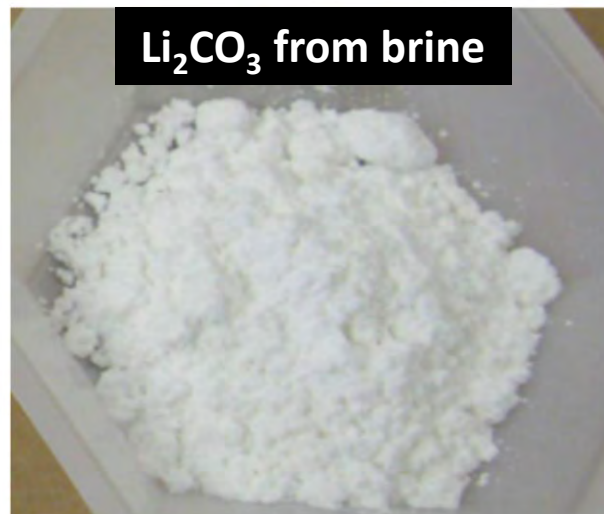
- ◆ Spodumene → Flotation/roasting followed by  $\text{H}_2\text{SO}_4$  leach
- ◆ Brines → purification followed by  $\text{Li}_2\text{CO}_3$  precipitation
- ◆ Brines → purification followed by electrochemical generation of  $\text{LiOH}$
- ◆  $\text{Li}_2\text{CO}_3$  conversion to  $\text{LiOH}$

# Battery-Grade $\text{LiOH}\cdot x\text{H}_2\text{O}$ from Brine

Brine concentration by evaporation



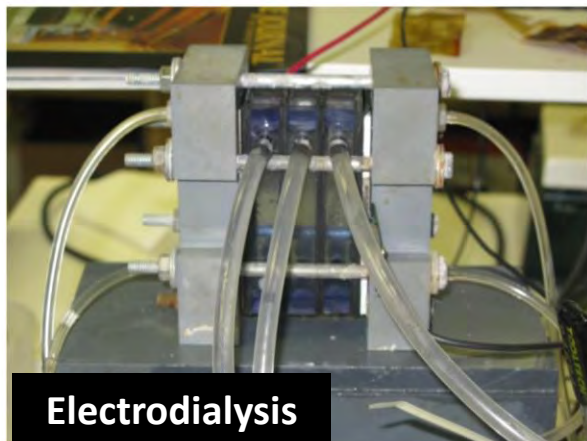
$\text{Li}_2\text{CO}_3$  from brine



$\text{LiOH}$  crystallization



Electrodialysis

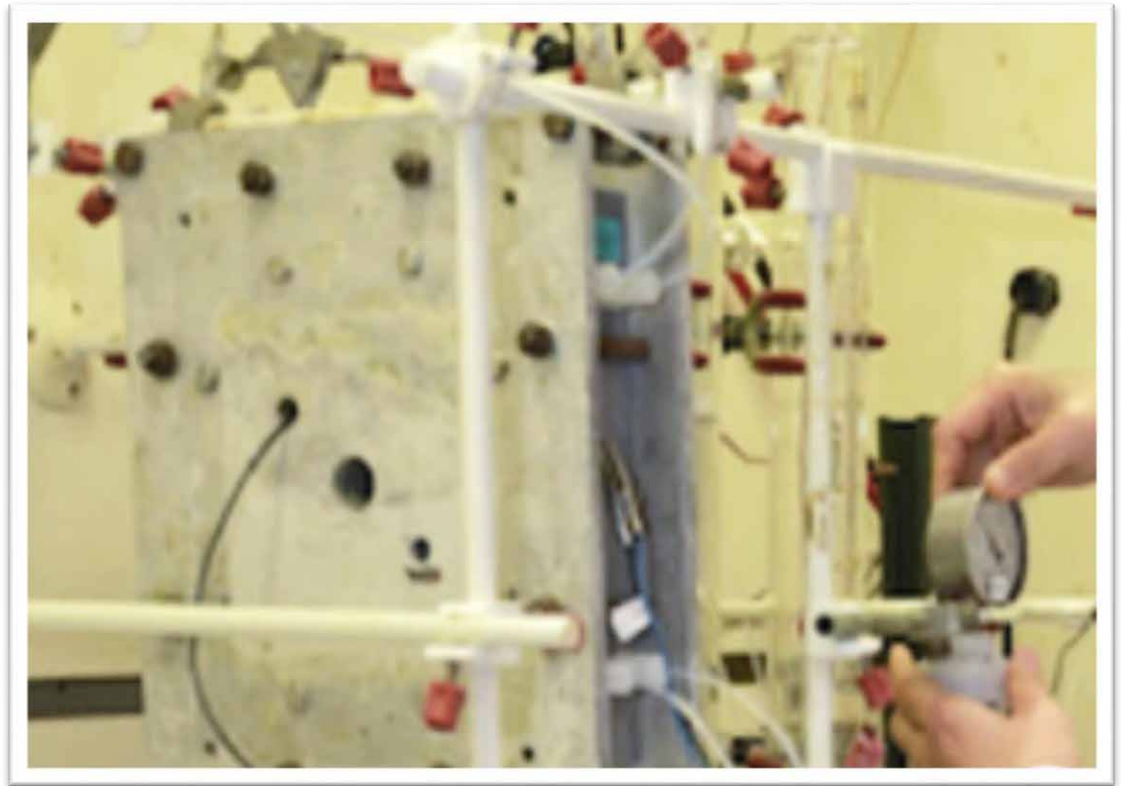


Battery-grade  $\text{LiOH}\cdot x\text{H}_2\text{O}$



# Vanadium Redox Battery (VRB)

- ◆ Redox flow battery
- ◆ Bipolar graphite plates for superior electrical conductivity and chemical resistance
- ◆ Power Conversion System (PCS) that converts raw DC current into usable AC current while charging and discharging the battery



Single VRB cell

# VRB Energy Storage System



VRB pilot: 60 KW

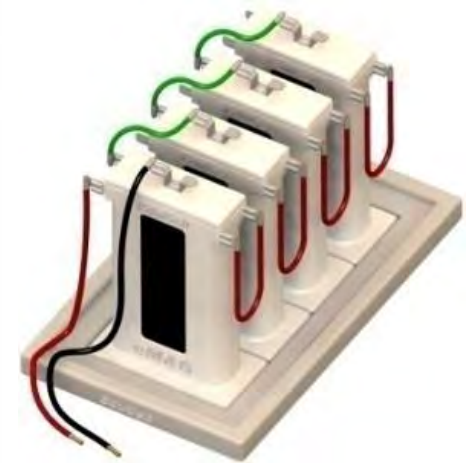
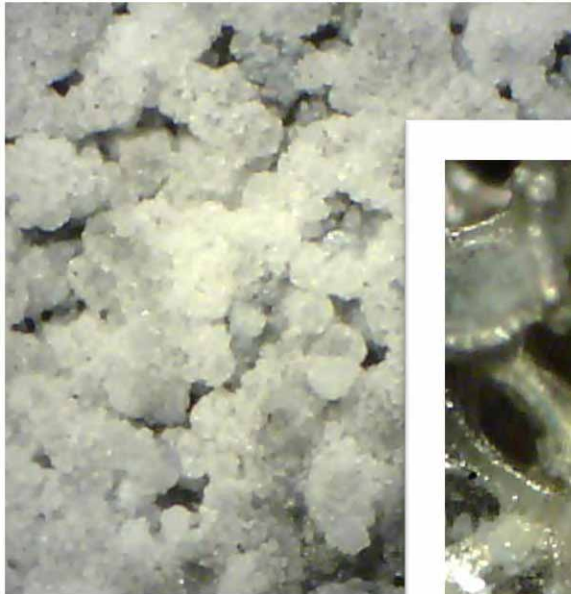


VRP Pilot – electrical & controls panel

# Rechargeable Zn-Air Batteries

***MHD Inc.***

- ◆ Higher capacity through innovative configuration
- ◆ Improved cycle life via magnetic enhanced field
- ◆ System protection to prevent water loss

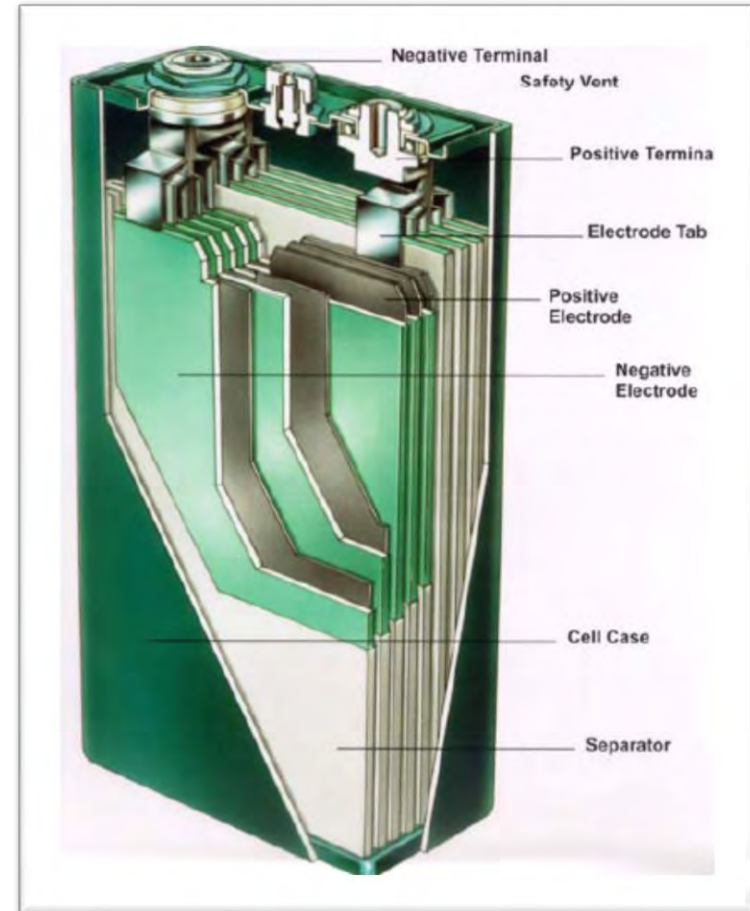


# Zinc Alkaline Rechargeable Battery



**OTI**

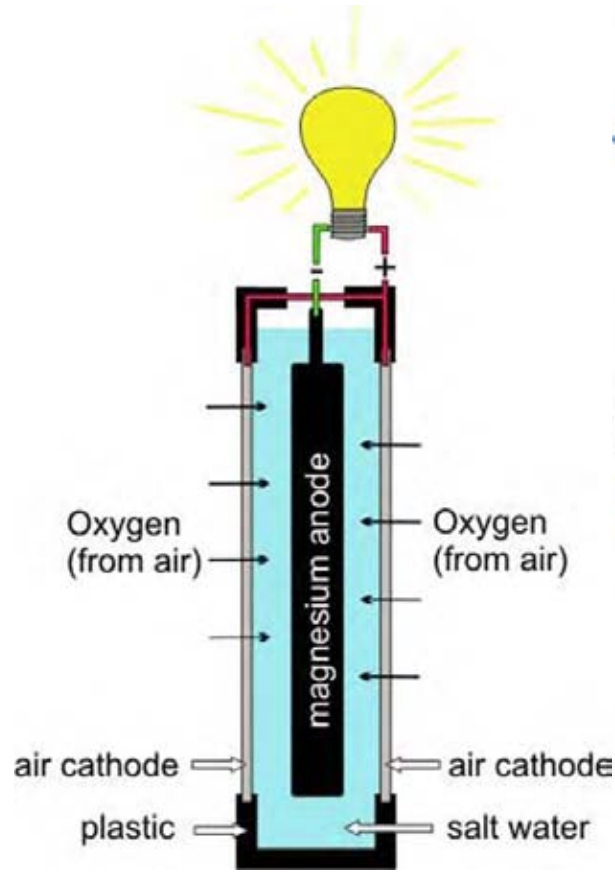
- ◆ Developed from Dr. Karl Kordesch's Patent Portfolio with 35 worldwide patents
- ◆ Smaller Size and Lighter Weight In Comparison to Conventional Lead Acid Battery
- ◆ Superior charge retention of 7 years (low self discharge)
- ◆ No memory effect
- ◆ Environmental superiority



# Zinc-Air Battery Prototypes – 50 kWh

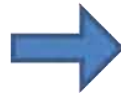


# Mg – Air Fuel Cell





# Lightweight Lead Acid Battery



Conventional Lead Acid Battery

Battery with EVTP Collector

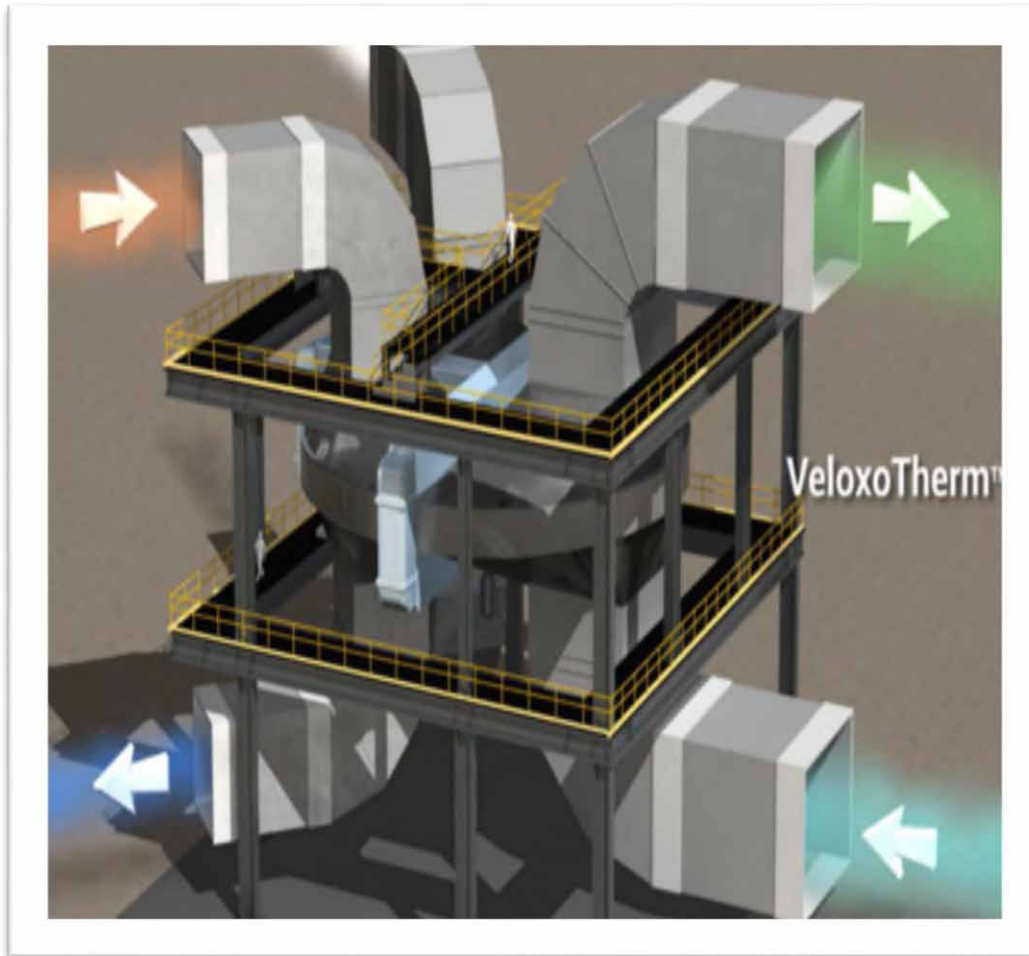
- ❖ 4.5 times higher surface area
- ❖ fit into existing battery manufacturing process;
- ❖ adapts into the existing lead acid battery recycling system.



Identical Output Comparison - 12 V, 75 Ah Batteries

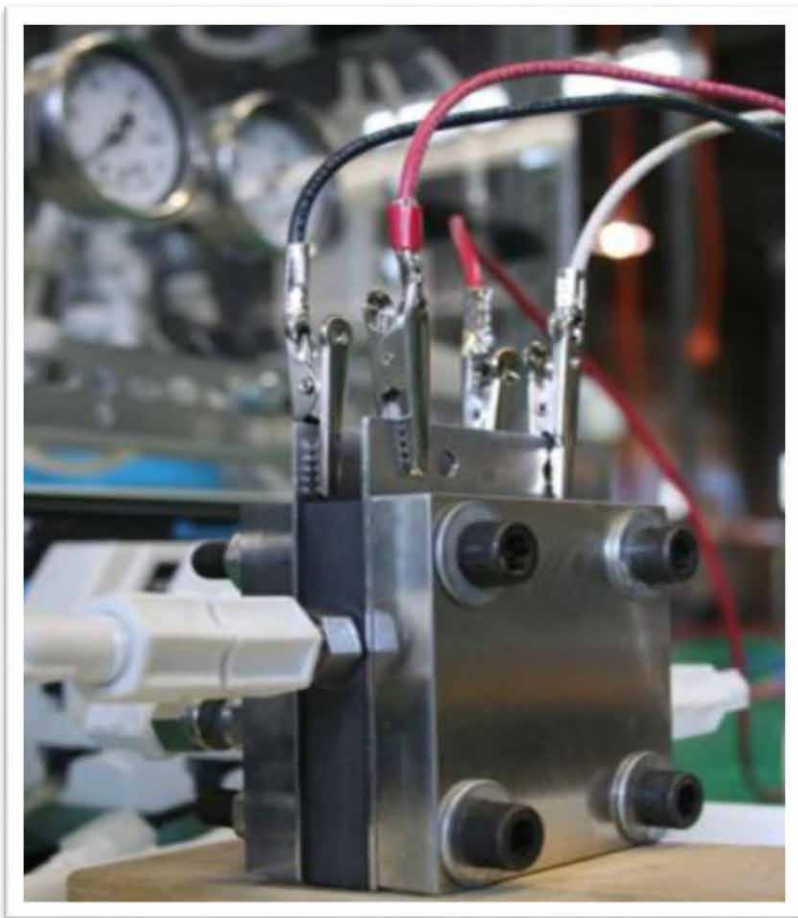
- **30% less weight (Lead)**
- **70% faster in recharge**
- **60% more cranking power**
- **25% smaller footprint**
- **Lower cost**

# CO<sub>2</sub> Capture Technology



- ◆ Flue gas is captured using a rotary adsorption machine
- ◆ CO<sub>2</sub> is selectively adsorbed on proprietary structured carbon adsorbent

# CO<sub>2</sub> Electrochemical Reduction Technology



Bench-scale electrochemical cell



Pilot-scale: 100 kg/day CO<sub>2</sub> to formate/formic acid

# Kemetco Technology: Neutral Salt Electrochemical Metal Cleaning Systems



No fumes or spent acid

# Kemetco Metal Cleaning Innovations: Over 50 systems in use worldwide



**KOREA - SPRING  
WIRE MANUFACTURE**



**BAHRAIN - HIGH VOLTAGE  
POWER CABLE MANUFACTURE**



**CANADA - STAINLESS STEEL  
SCREEN MANUFACTURE**



**USA - VALVE SPRING  
WIRE MANUFACTURE**



**ITALY - FIBRE OPTIC CABLE  
MANUFACTURE**

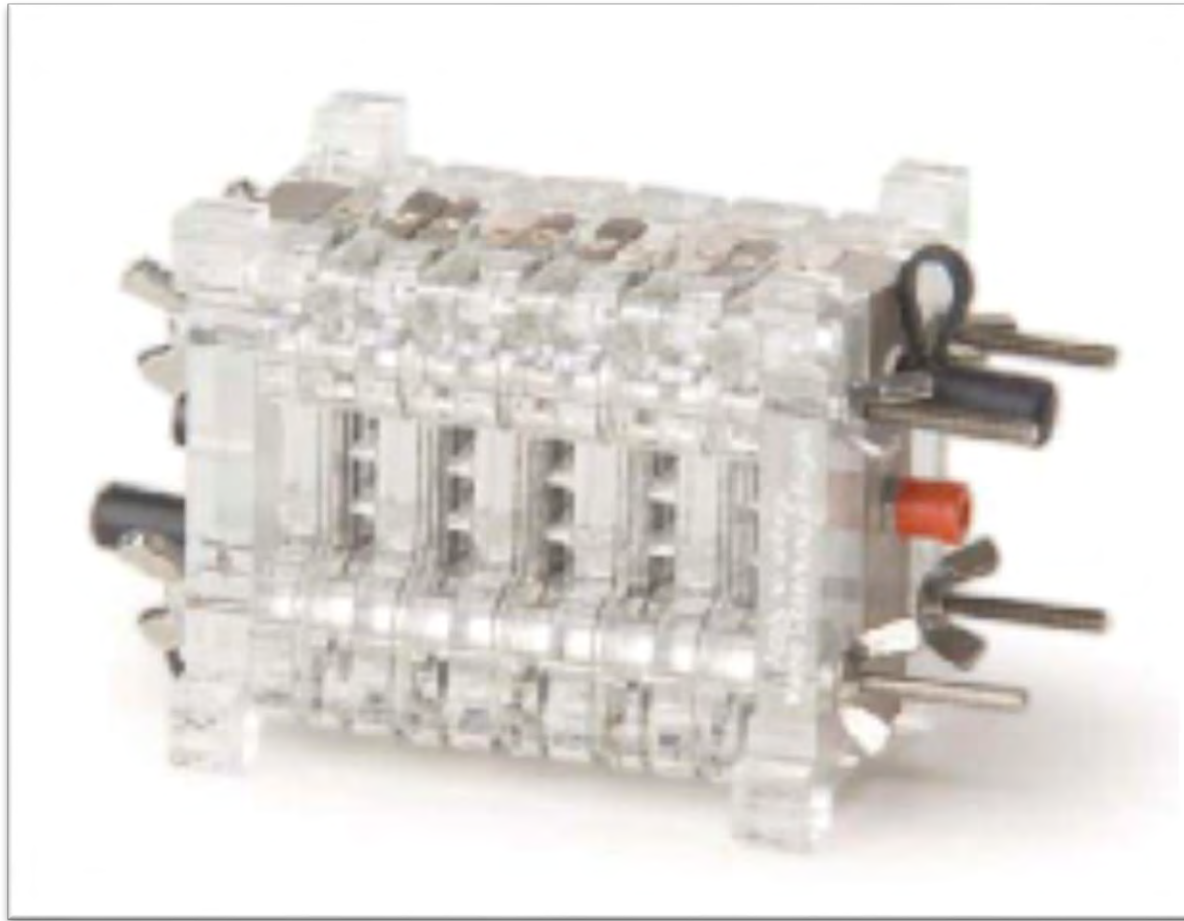


**HITACHI - MACHINING WIRE  
MANUFACTURE**

# Water Treatment & Environment



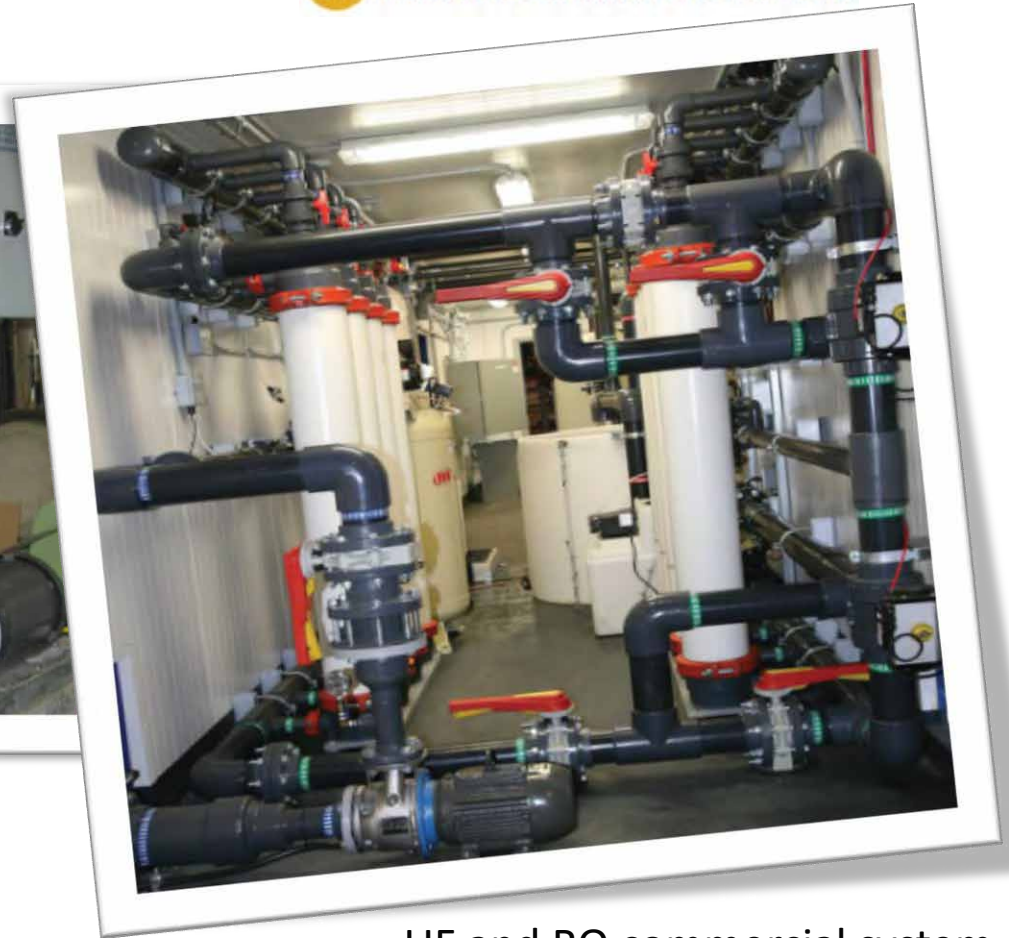
# Electrochemical Waste Water Treatment



# Ultrafiltration, Nanofiltration & Reverse Osmosis Pilot & Commercial Systems



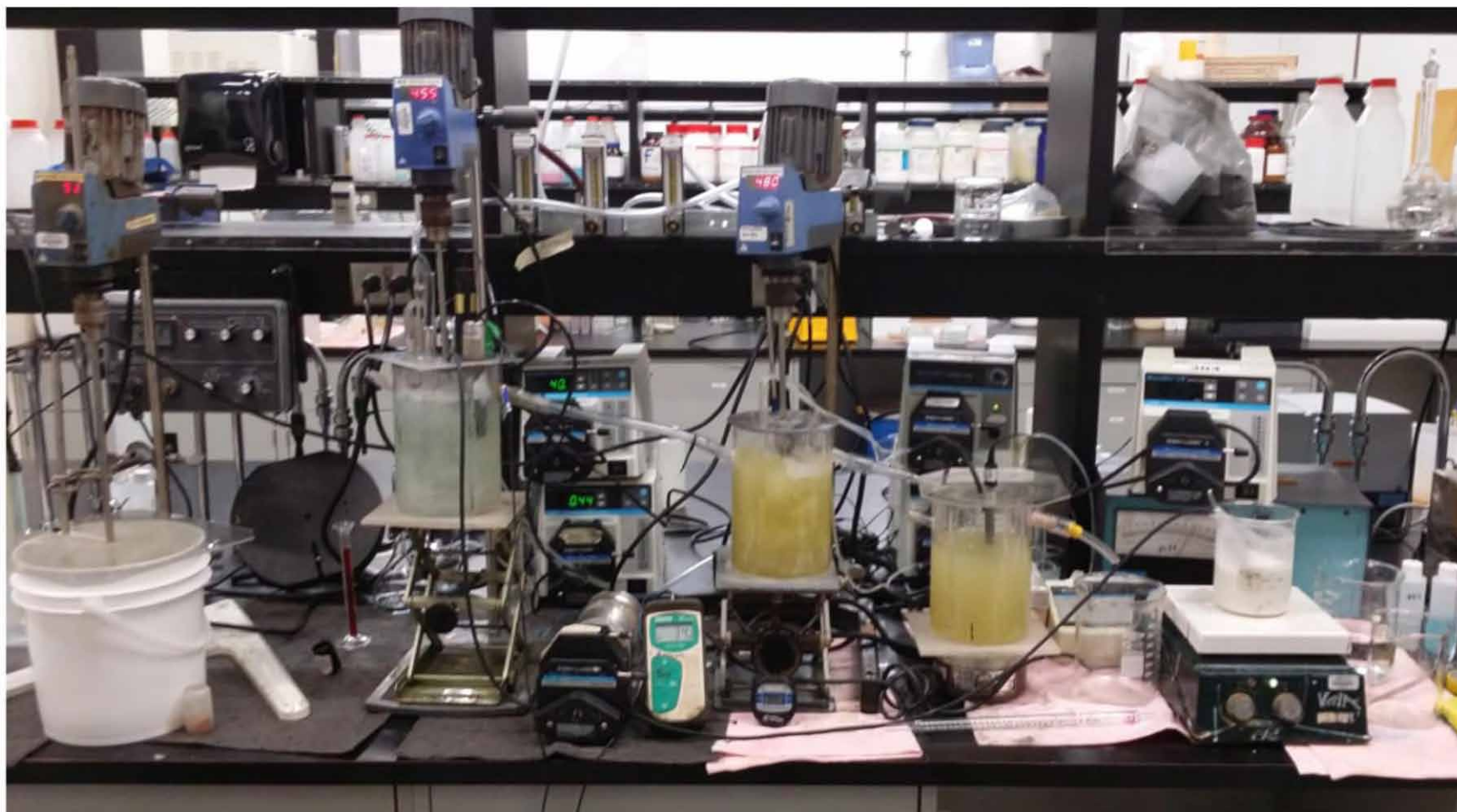
RO bench scale unit



UF and RO commercial system



# Bench-Scale Cyanide Detox Optimization



# SO<sub>2</sub> Cyanide Detox Commercial System

 PROCESS MANUFACTURING



Liquid SO<sub>2</sub> Building



Liquid SO<sub>2</sub> Storage Tank & Tank Housing

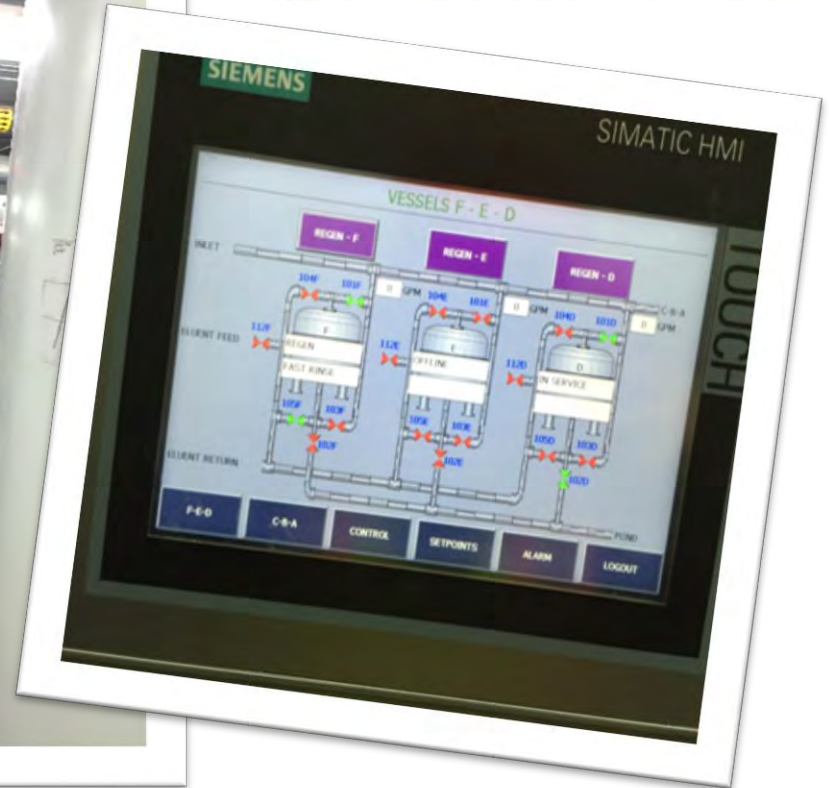
# Ammonia Removal from Mining Effluents



IX Column



Automated IX Pilot  
Trailer Fitted with 6 IX Columns



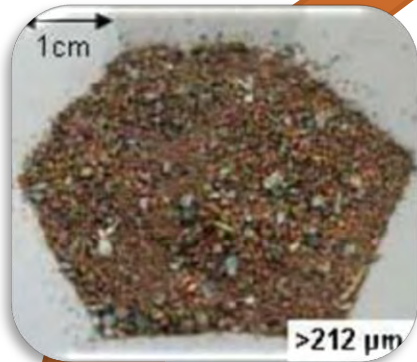
Control Panel

# Biological Mine Drainage Treatment

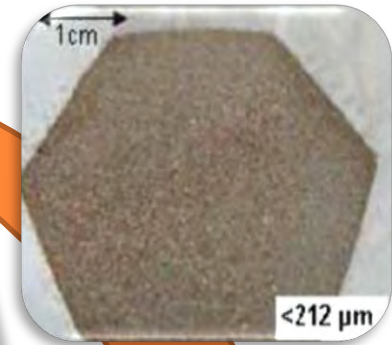


# Kemetco Technology: e-Waste Recovery

## Electronic Waste Metals Recovery Technology



METAL	Fine Powder Weight %
Ag Silver	0.05%
Al Aluminum	0.17%
<b>Au Gold</b>	<b>0.18%</b>
Cu Copper	35.09%
Fe Iron	0.42%
Ni Nickel	0.10%
Pb Lead	16.48%
Sn Tin	25.67%
Zn Zinc	2.97%

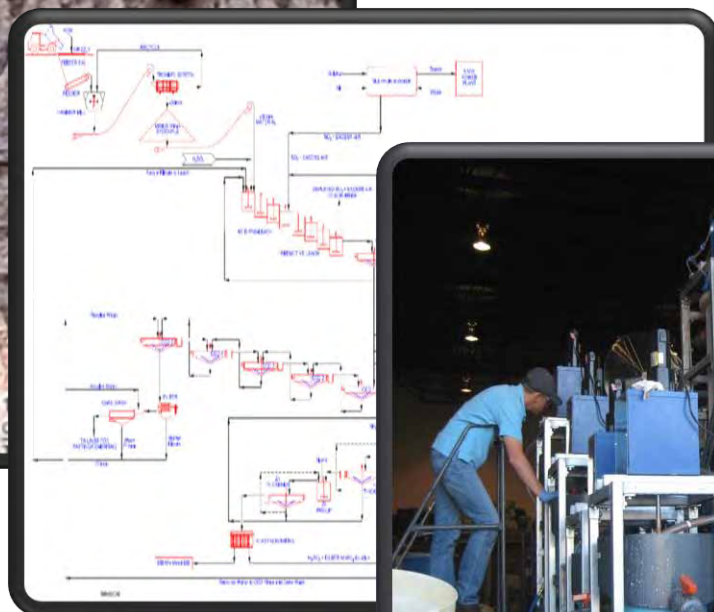
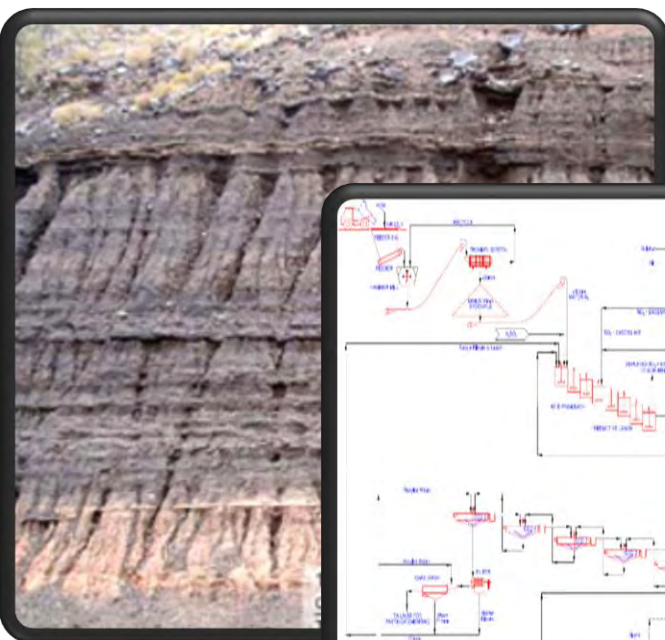


# Scale-up & Pilot Plants



# From Flowsheet Design to Pilot Plant

## *Recovery of Mn from Low Grade Ores*



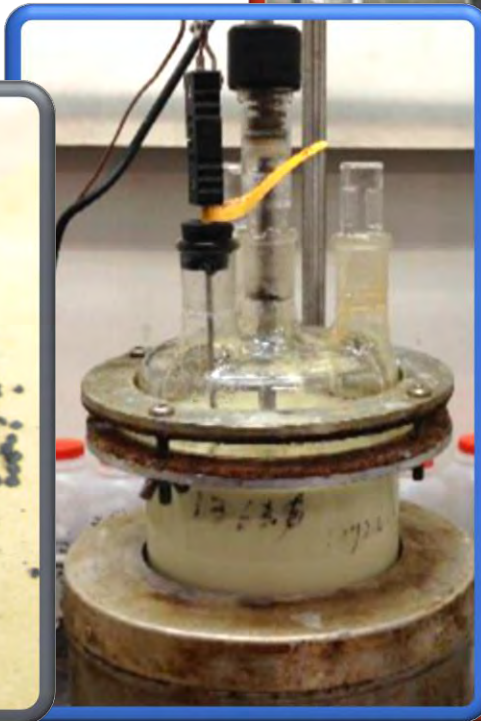
# Recovery of Mn from Low-Grade Ores



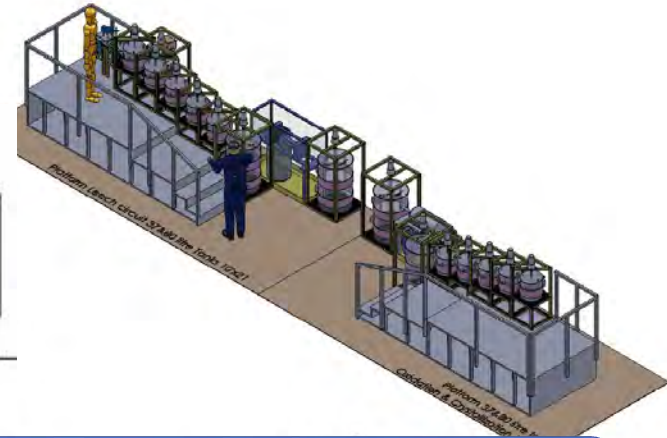
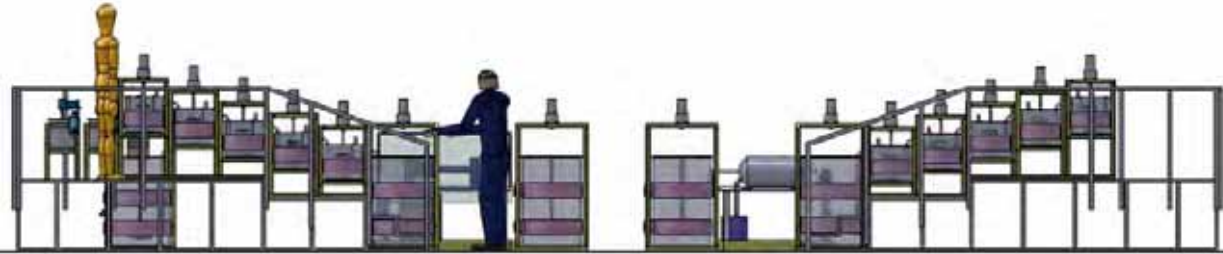


# Arsenic Removal & Stabilization from Copper Concentrates (Bench-Scale Study)

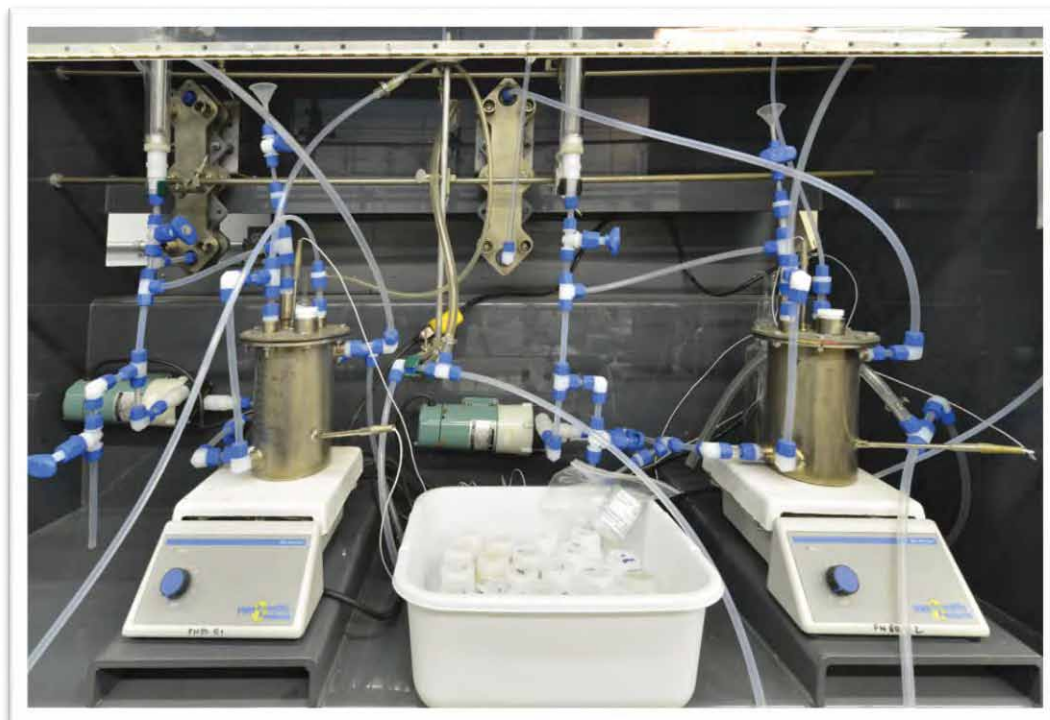
- ◆ Extensive experience with Cu concentrate upgrading & As removal, leading to pilot plant demonstration



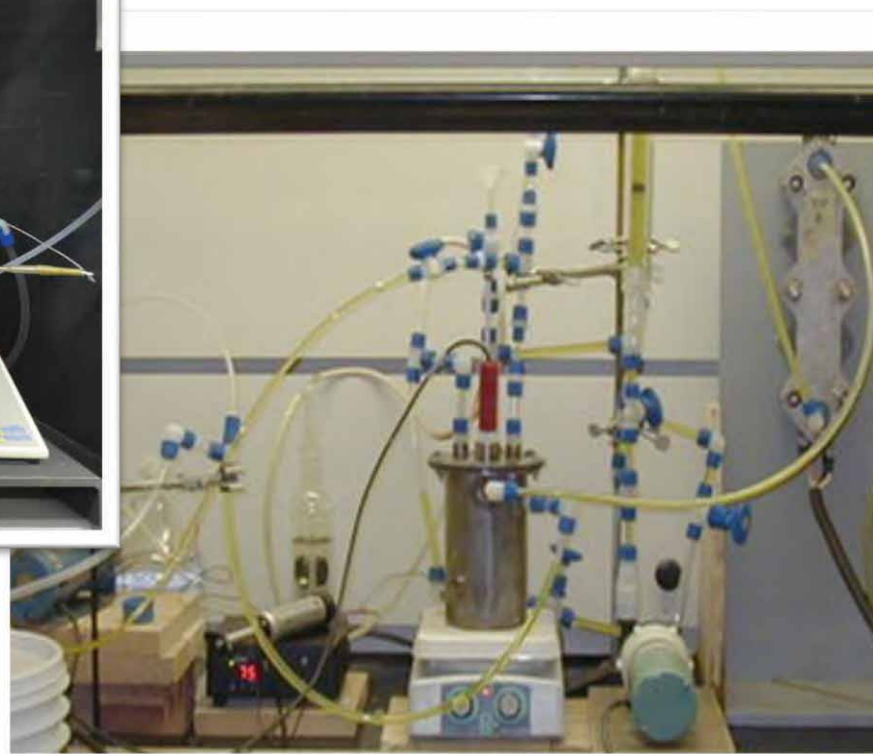
# Pilot-Scale Demonstration of Arsenic Removal from Copper Concentrate



# Bench-Scale Electrochemical Chlorate Generation

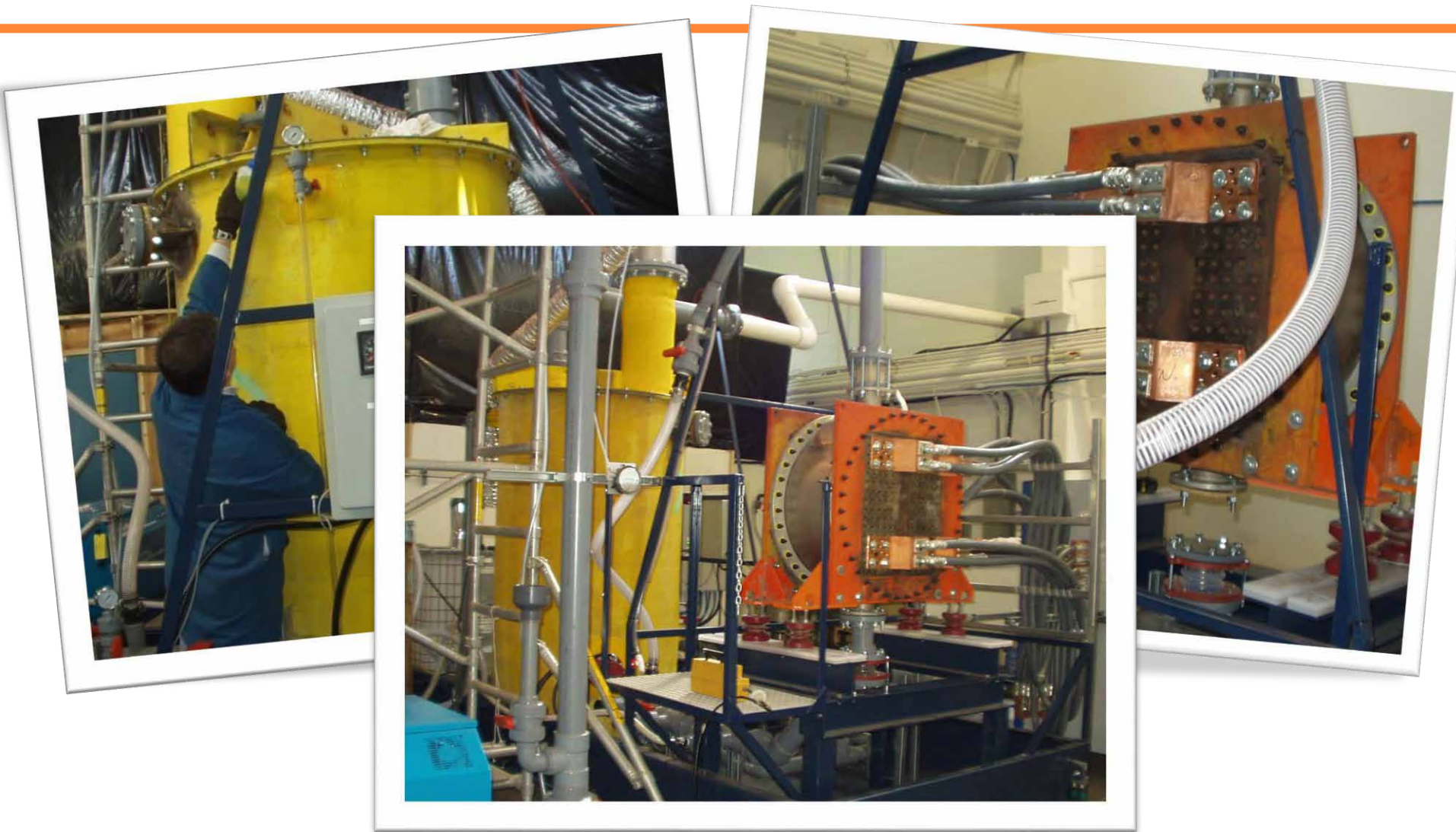


Bench-scale sodium chlorate cells



Bench-scale lithium chlorate cell

# Pilot-Scale Chlorate Electrochemical Cell 15,000 A System



# Calcium Chloride Pilot Plant



# Lithium-Ion Battery Recycling Pilot



High Purity NMC and NCA

# Products from Recycled Lithium-Ion Batteries



# Lithium Carbonate – Boric Acid Pilot Plant



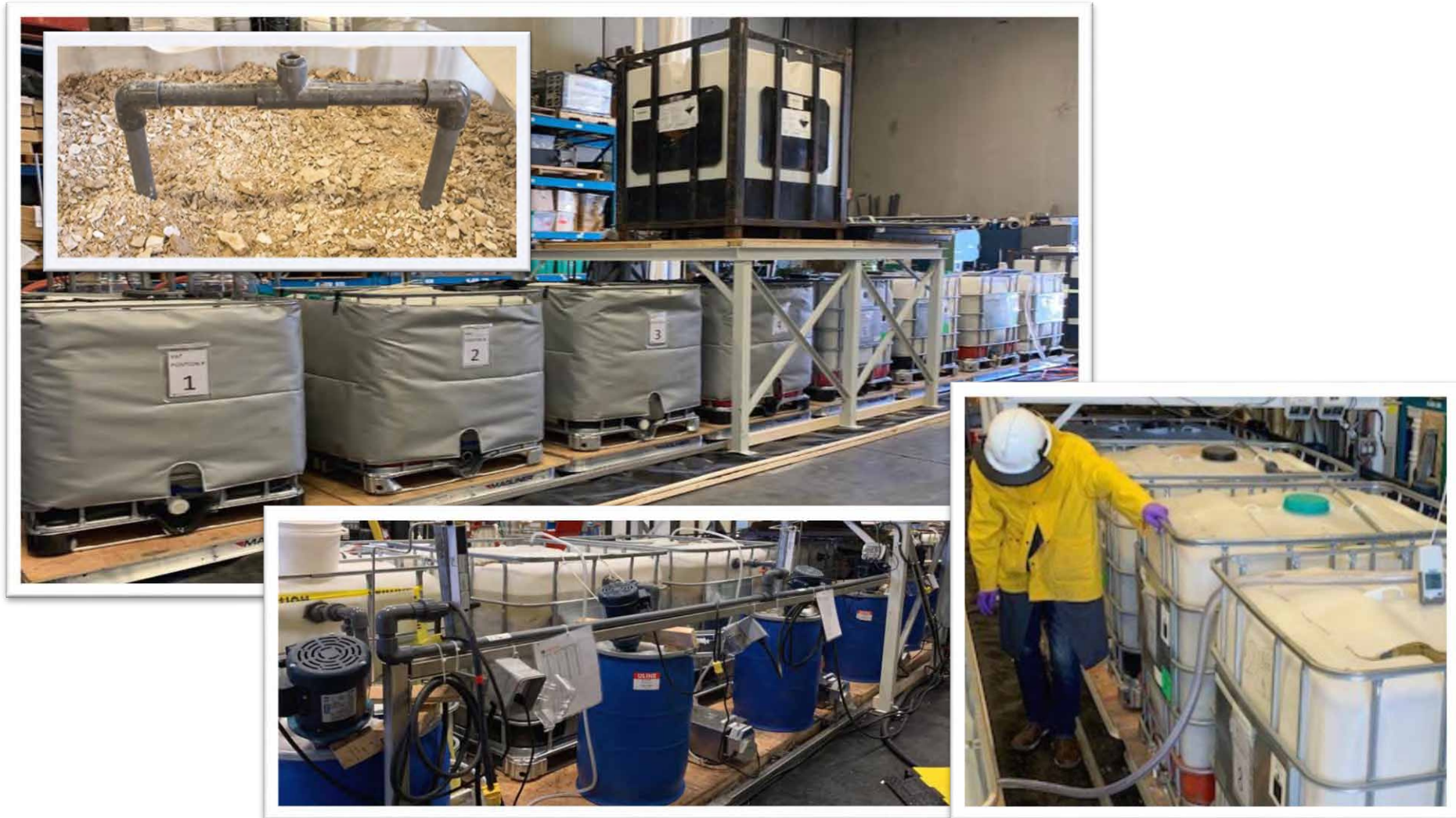
**Boric Acid**



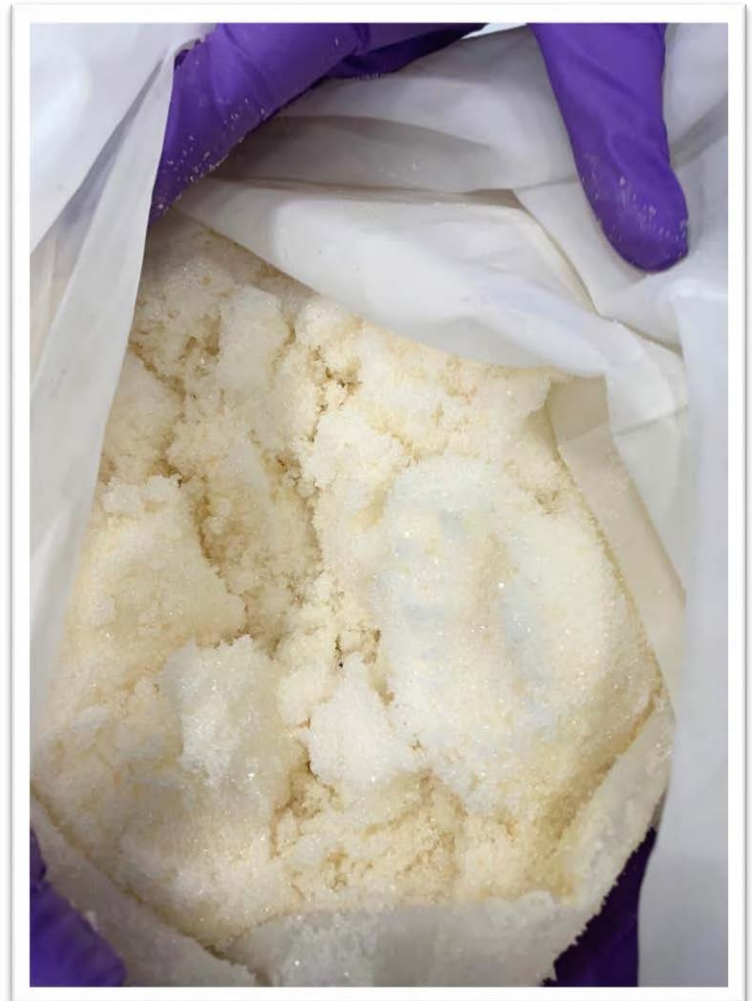
**Lithium  
Carbonate**



# Vat Leaching Circuit



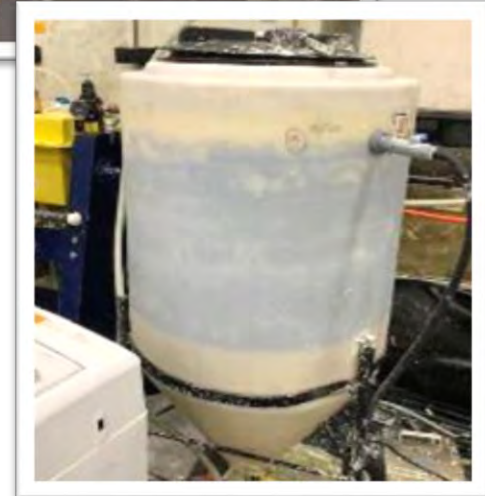
# Crystallization



# Evaporation Train



# Pilot-Scale Flotation



# Neutralization Circuit



# Lithium Recovery Circuit (partial)



