ACME Case Study

Metal Removal Utilizing Ceramic Microfiltration

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“Two things are infinite: the universe and human stupidity; and I'm not sure about the universe.”

Albert Einstein

When the well's dry, we know the worth of water.

Benjamin Franklin
Discussion Outline

• Introduction
• Environmental requirements
• Different treatment technologies
• Total cost of ownership
• Summary
Water Treatment systems are a sunk cost of industry

“The primary driver is to lower Total Cost of Ownership while at the same time meeting process requirements and or discharge regulations”
• Metals Removal is a central process to industrial water filtration

• Traditional Metals Removal processes have many shortcomings
  • High Total Cost of Ownership
    • Frequent Replacement, High Labor, High Energy, Chemical & Water Use
  • Inefficient Performance
What is a Membrane

- A Membrane is simply a semi-permeable barrier that can be used to separate a mixture of two or more components.
Different Types of Membranes

• Polymeric
  – Tubular – cross flow
  – Spiral wound
  – Hollow fiber

• Inorganic
  – Cross Flow
  – Metal – SST
  – Ceramic
Ceramic Microfilters

- We typically utilize ceramic membrane microfilters manufactured to specification in Germany for metals removal
- Consist of high purity alpha alumina (Al₂O₃), zirconia oxide (ZrO) or titanium oxide (TiO₂)
- Excellent chemical, thermal, and mechanical properties.
- Extremely long lifetimes – 10+ years
Membrane Properties

- 0.01, 0.1, 0.2, 0.8, or 5.0 micron absolute pore size
  - Microfilters
  - Nanofilters
  - Asymmetric

- 12, 19 or 85 - bore configuration
  - operated in cross-flow mode
  - 2.5 to 14.2 ft² of membrane area per element

- Elements are installed in modules
  - 1 to 24 elements per module
  - 2.2 to 340 ft² of membrane area per module
Asymmetric Membrane Crossflow Mode

Wastewater Flow

- 0.2 um
- 0.8 um
- 5 - 7 um

Feed  

Permeate

Reject

Electron Microscope Picture of Membrane Surface with Depth
Cross Flow Filtration

- Wastewater in one end of the cross-flow filter
- Filtered permeate out the side of the filter
- Solids need high velocity to keep suspended
- Back pulse backwards through the filter
Properties of Ceramic Membranes

- Stable up to 800 °C.
- Resistant to virtually any chemical.
  - except for HF and H₃PO₄
  - pH range of 0 - 14
  - allows for aggressive cleaning
- Burst Pressure > 1000 psi
  - Allows for backpulsing - on line cleaning
- 40 % porosity rating.
  - High flow rates at low pressures
Heavy Metals in Wastewater

• Heavy metal waste is produced by many industries.
  – Metal plating shops, circuit board shops, etc

• Acid Mine Drainage
  – exposure of pyrite to water and oxygen produces sulfuric acid, which leaches heavy metals into water.

• Cause many environmental and health problems
Membrane Systems

• Effective barrier to removal – eliminates violations to the permit if the pH, pressure and turbidity are in specifications

• Due to pore size, the removal is predictable due to solubility curve (next slide)

• Inorganic membranes are more robust in this type of environment
  – Flux recovery
  – Ease of cleaning with aggressive chemicals
Heavy Metal Precipitation

- Solubility is a function of pH and concentrations
- Clarifiers work “above the line” due to floc carryover
- This is for hydroxide precipitation – sulfide and oxide precipitations are lower by one to two orders of magnitude
- Note, at higher pH values, calcium and magnesium will also precipitate adding to sludge generation
Precipitation chemistry issues

• Utilization of sodium hydroxide – simple to control
• Electro-coagulation – precipitation at lower pH values with oxide precipitation potential
• Sulfide precipitation also available but carries safety risks
• Iron co-precipitation is a key element
Iron Co-Precipitation

- Iron and oxidation with a high pH result in higher than predicted removal rates
Simplified Treatment Technology

- This is the same simplified process flow diagram used at Upper Blackfoot Mine in Montana.
EPA Gregory Incline Pilot Test in 2000 and 2001

- $650,000 Pilot testing program authorized by Congress
- Pilot program in Colorado on AMD
- Outstanding results – statistical analysis by EPA
Product Verification

- Bullwhackers – Black Hawk - 1995
- EPA START Program under EPA at Summitville
  - Technology evaluation in October 1997
- EPA – DOE MSE Evaluation on Gregory Incline 2001
  - Successful removal of heavy metals
  - Reduction in the amount of sludge generated
  - Lower operating costs
  - 4,500 sf facility
  - 300 gpm nominal flow with 500 gpm peak flow
  - $3,000,000 facility cost (2001 dollars - $5M in today’s costs)
    - Compared to HD clarifier at $12M to $15M in the same location
  - $3.38/1,000 gallons for O&M
Upper Blackfoot Mine – Lincoln Montana - 2009

• CDM Design/Build Project
• System is up and running for approximately 3 years
• Cost (capital and O&M) of the system was significantly lower when compared to a clarifier system
• The footprint of the CMF System building and associated piping was 80% smaller to the clarifier
• Skid mounted system – Ease of installation
• Operations by the State of Montana in 18 months
• See EPA website for additional information
Upper Blackfoot Mine
Western Digital Facility in Freemont CA

- Replacement of ion exchange system
- Flow of 300 gpm
- Reduction of operator time by 60%
- Reduction of chemical requirements by 40%
- Very reliable and recoverable system
ACME Industries

- Flow of system is 10 to 20 gpm
- Treatment of zinc and chromate operation
- Need to meet 40 CFR 433 regulations
Goals of the system

- Obtain system from different project – reduction in 40% of capital cost
- Meet timing – 4 months construction
- Meet Criteria for discharge and reuse
- Allow of sludge delisting by CDPHE
- Durable
- Reduction of labor costs
- Simple operation
- Robust membranes for cleaning
Cost reductions by CMF

- Labor – 1 operators for 1 to 2 hours per day, depending on activities at the site
- Problems require additional operations
- Off site monitoring of the facility – turbidity, pH and pressure are alarm points
- Chemical reduction costs as a result of lower pH requirements
- Lower sludge generation due to lower precipitation pH
- Skid mounted for construction
Water Quality Results for Overall Performance

• Removal of heavy metals of interest – over 99% or better for all metals of interest
• Agencies (EPA and State DEQ’s) could not perform a statistical analysis due to the non-detects of the effluent
• Sludge is classified as non-hazardous and allows for disposal of solids on site
• Issues with cold water and meeting new and tougher standards
Results meet new standards

- Oxidation was able to achieve the standards of the new permit at lower pH values
- Permanganate was able to meet the new standards at very high flow rates and low temperature waters
- Electro-coagulation met the new standards but requires more infrastructure for electrical requirements. However, advantages are lower chemical requirements.
Conclusions

• Significant capital cost savings as evidenced by the overall costs
• Lower operating costs when compared to clarifiers or ion exchange
• Discharge levels are normally near or below detection levels
Questions?