

Keeping Mine-Water Membranes Clean

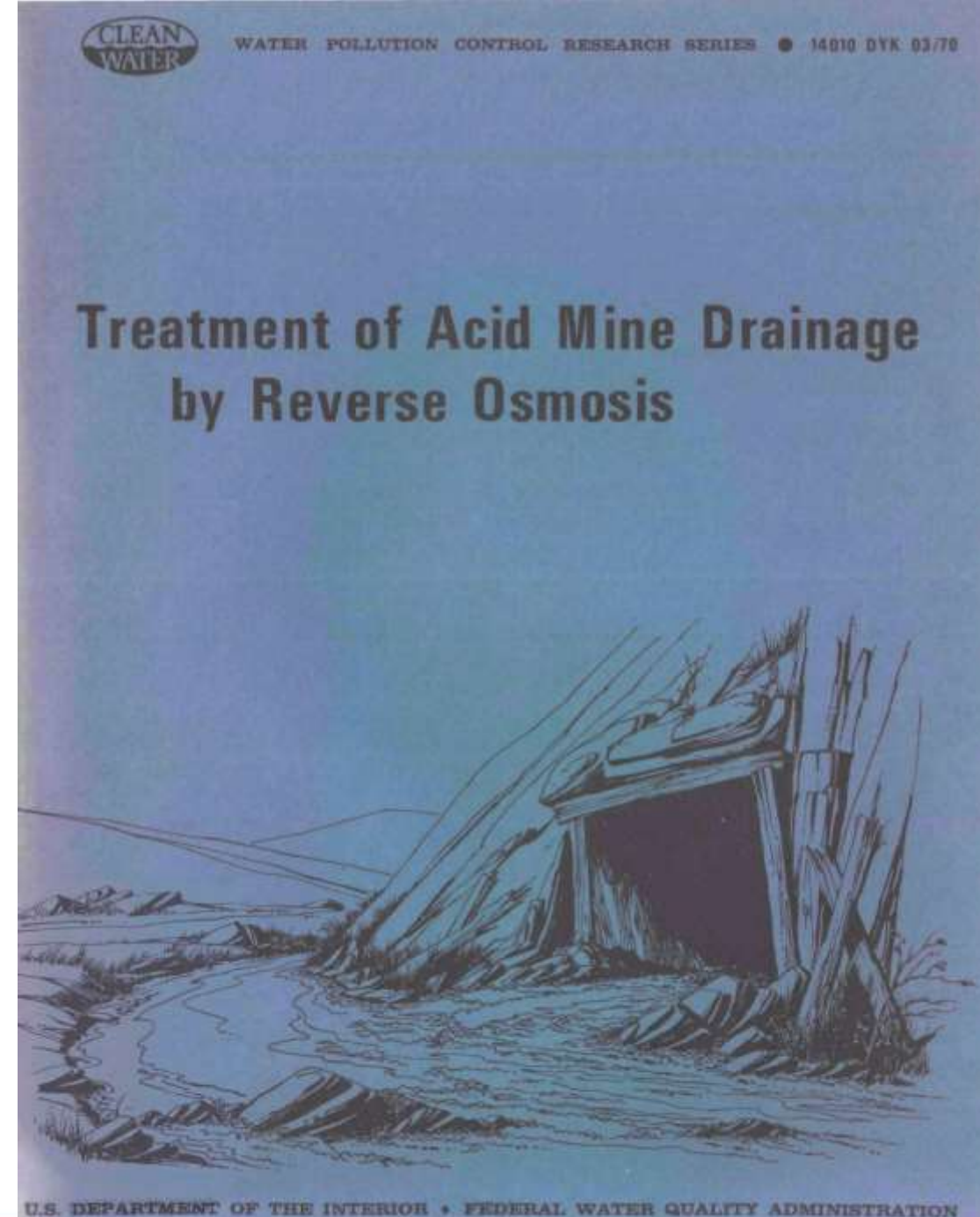
Steve Chesters
Genesys International

Agenda

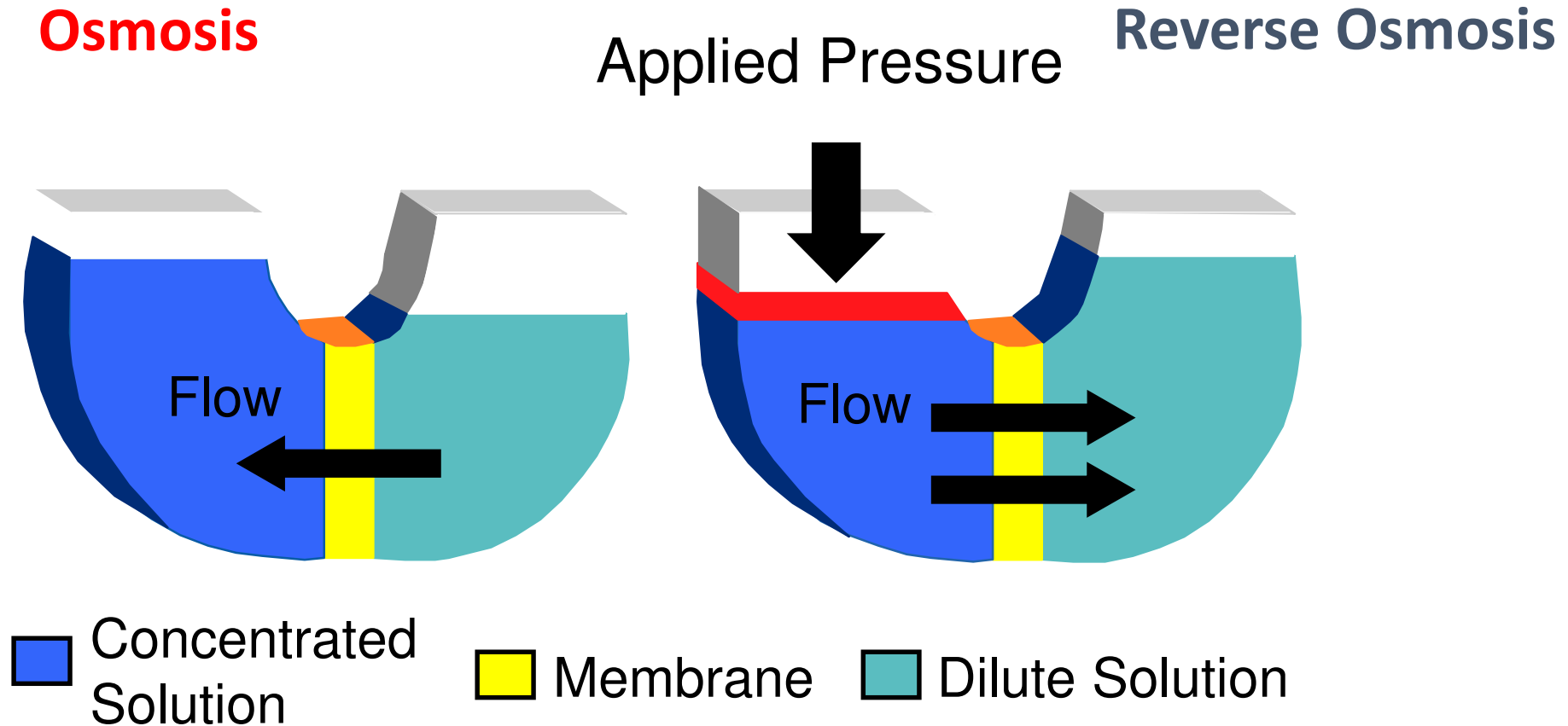
- What is a Reverse Osmosis Membrane?
- What do membranes do?
- Why useful in mining?
- Where are they used?
- What are the problems?
- New methods to keep membranes clean

First reference – 1970 Written by Rex Chainbelt Inc. for US Dept. of the Interior.

Concluded good quality water could be obtained but problems of membrane fouling, iron & gypsum(calcium sulphate)

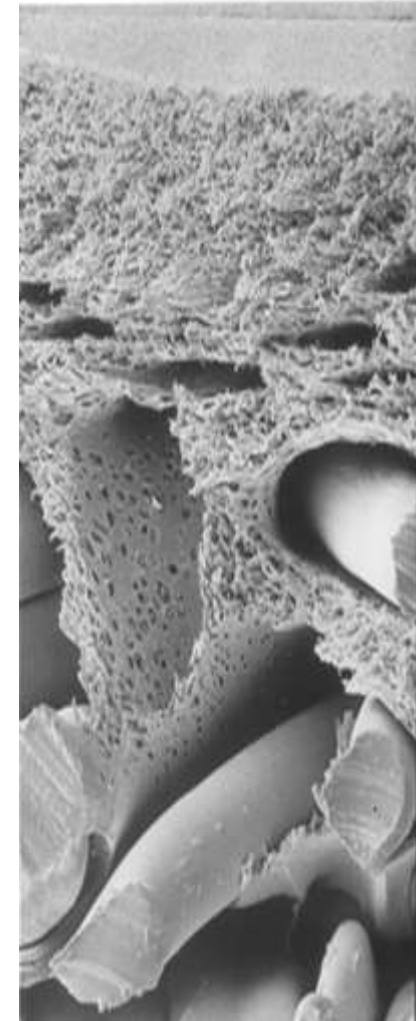
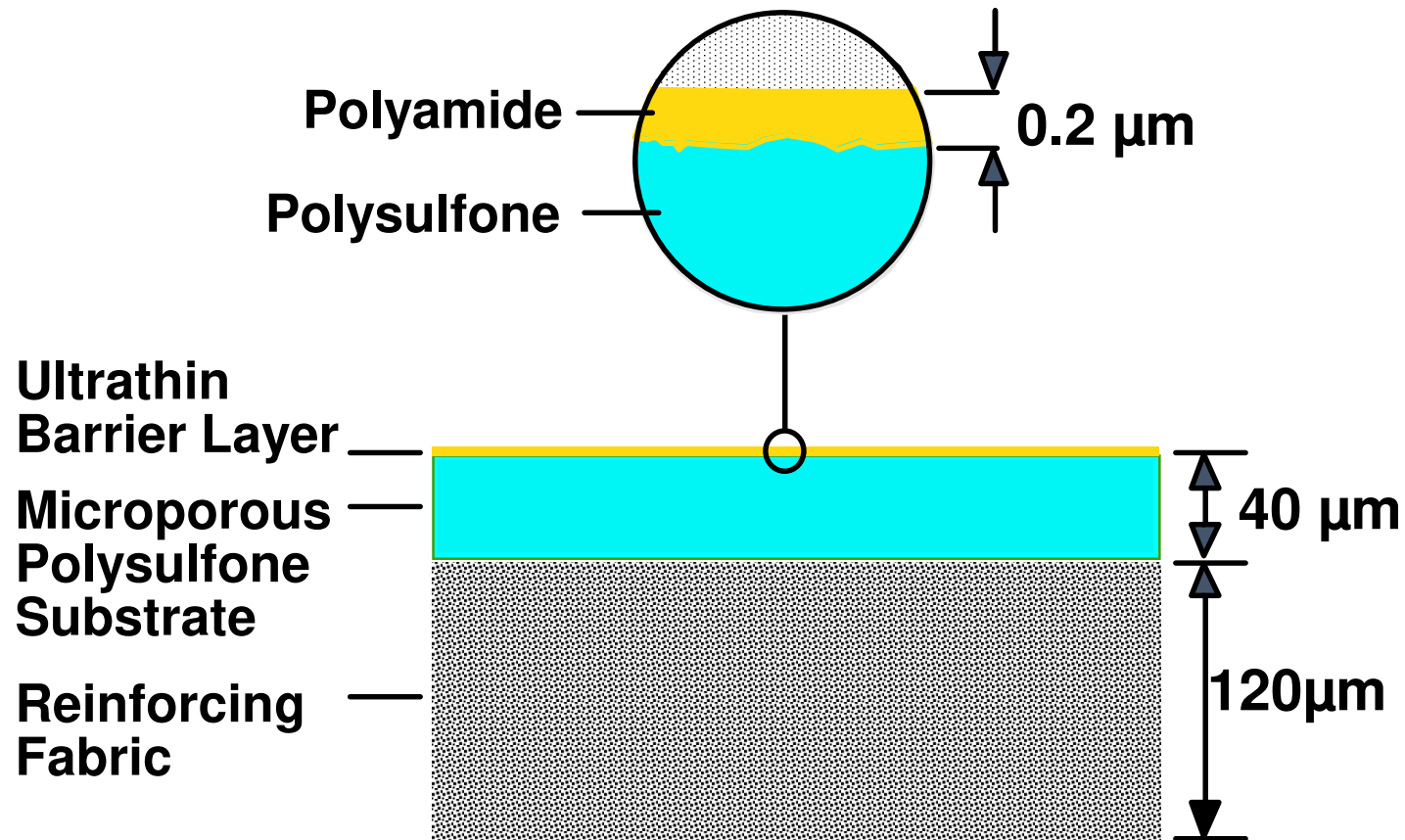


What is reverse osmosis?

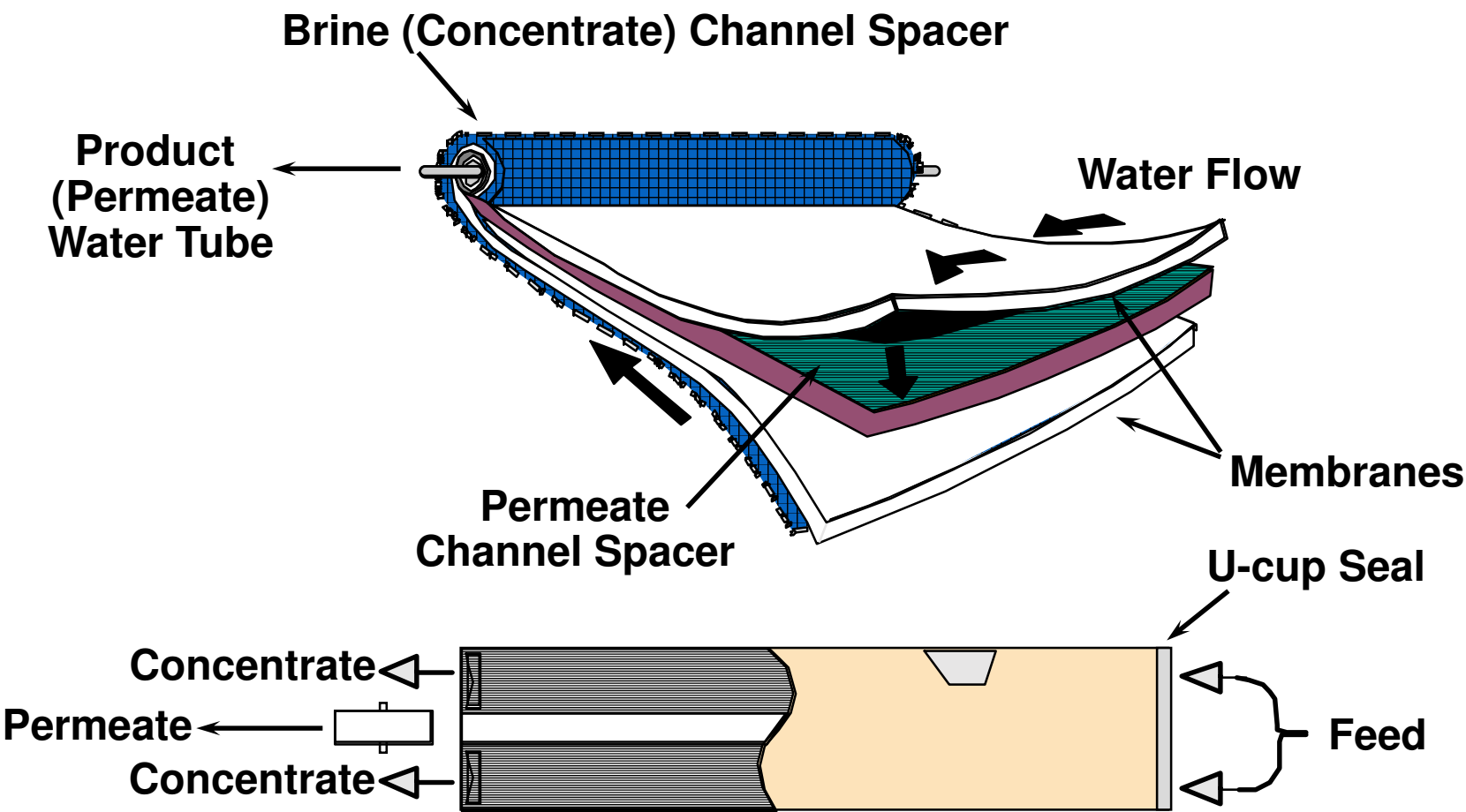


100mg/l TDS = 1 psi pressure

Thin Film Composite Polyamide Membrane



Spiral Wound Element



Membrane Leaves



RO Membrane Elements

Proven technology

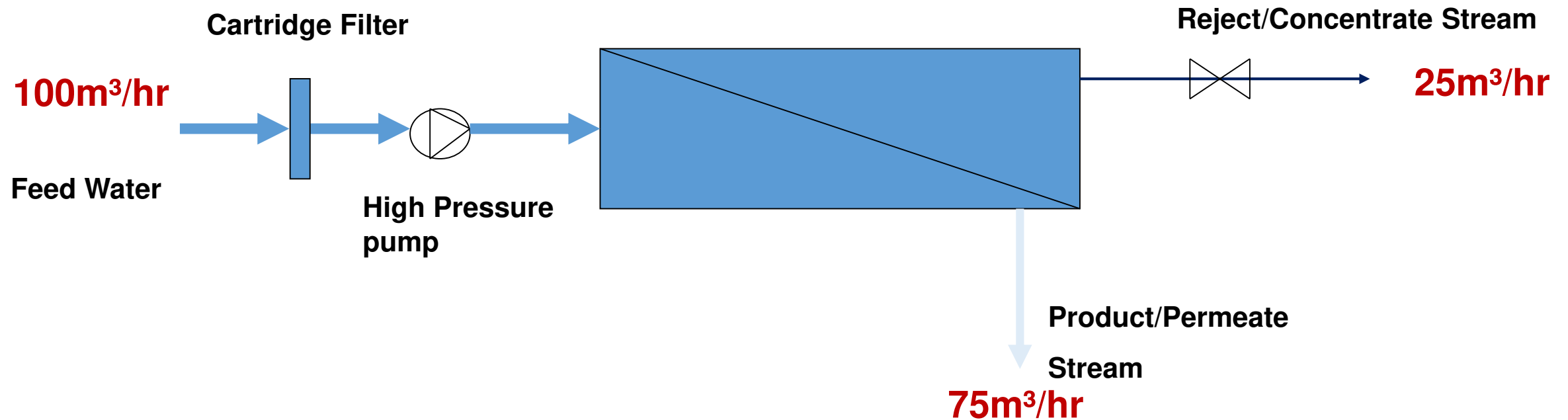
- **+2.5M membrane elements**
- **+15,000 plants**
- **Producing 130M m³/day**
- **Supply 300m people**



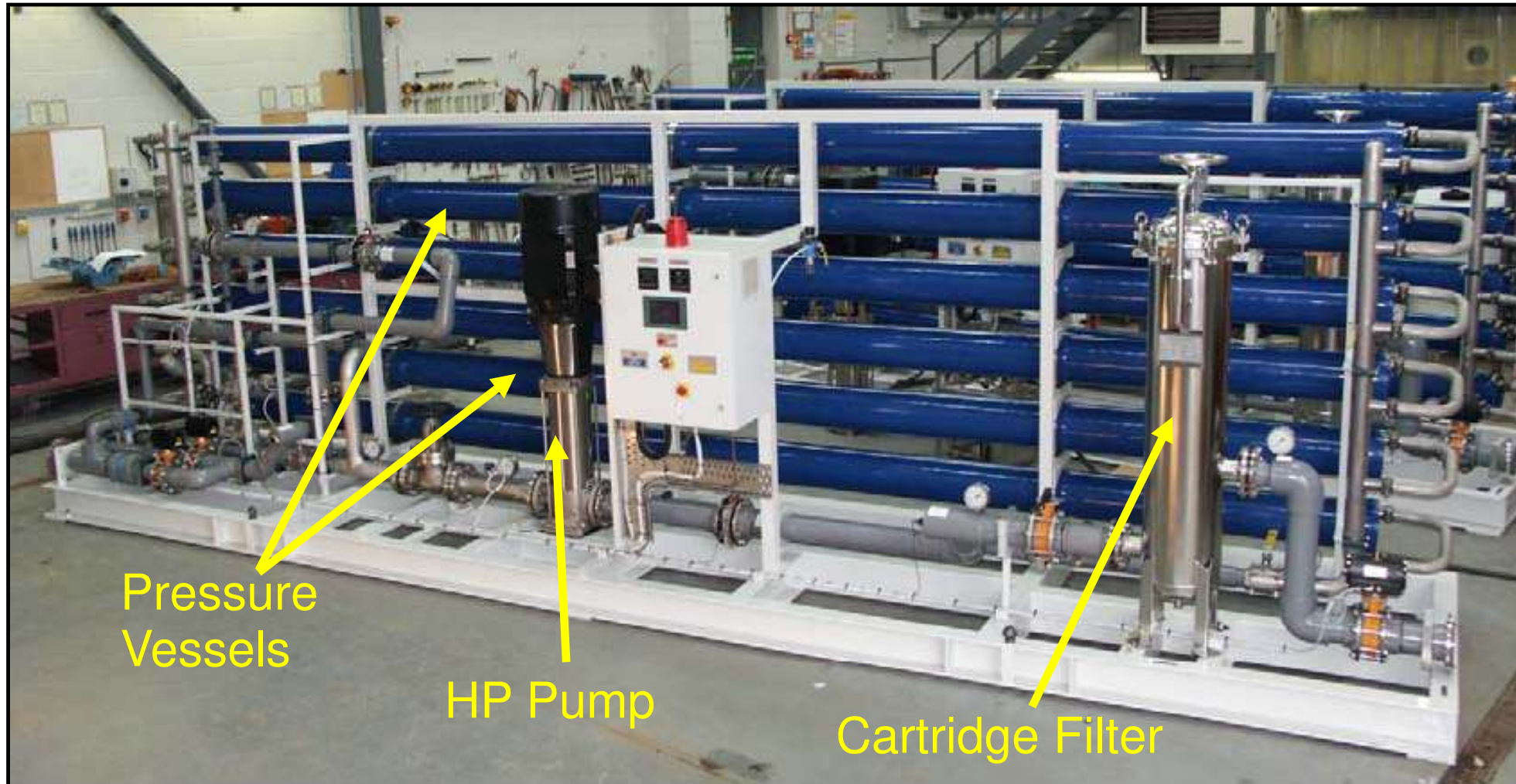
Source; Global water intelligence 2014

RO Membrane System

75% Recovery 4 cycles of concentration



Reverse Osmosis Installation



Membrane Filtration Spectrum

Reverse Osmosis (RO)

- Removes all suspended solids & 99% soluble cations & anions
- ~100 atomic mass unit (amu) molecular cut-off

Nano-filtration (NF)

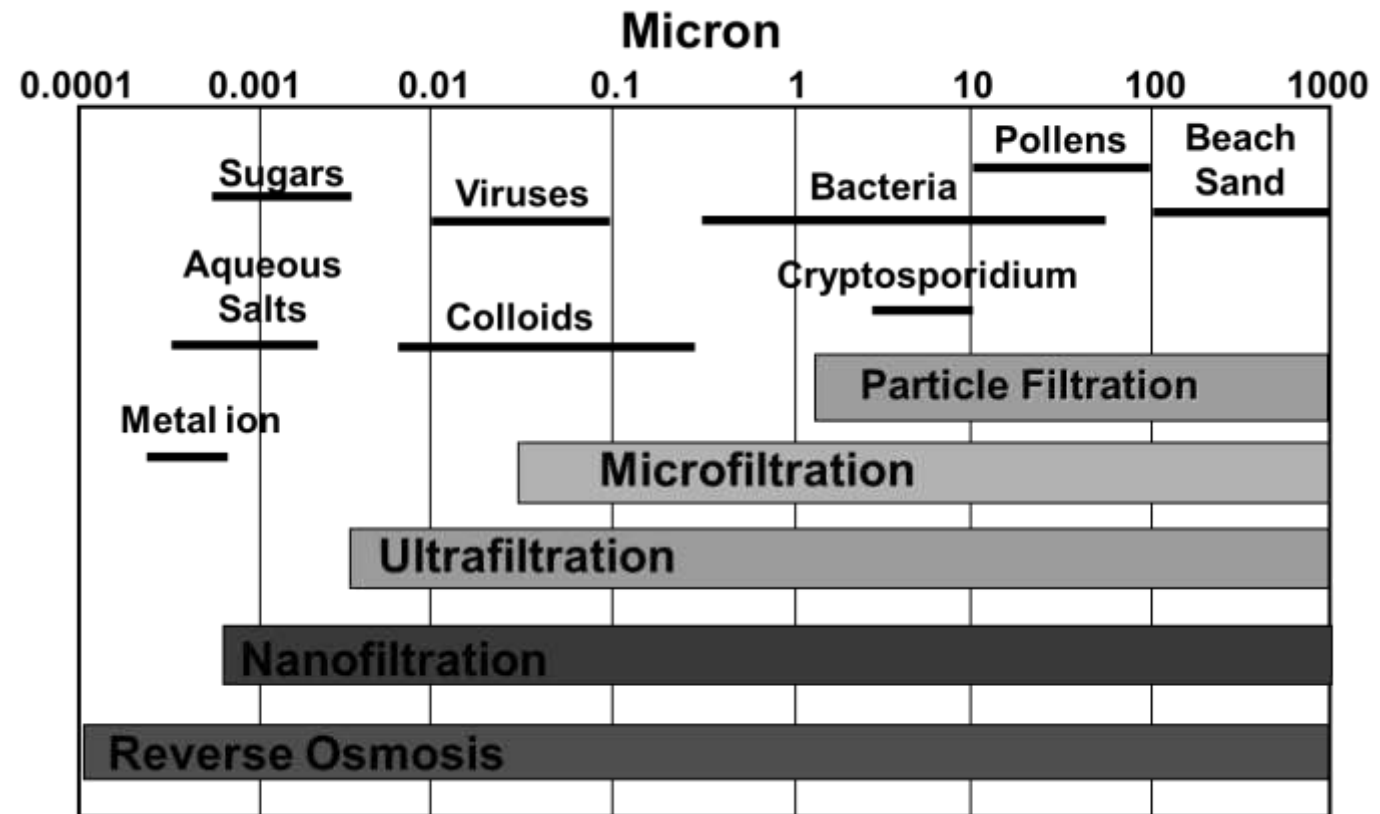
- Same as RO but membrane pores are larger
- Divalent ions rejected, monovalent pass through
- 200-400 (amu) molecular cut-off

Ultra-filtration (UF)

- Excludes particles 0.001-0.1 μ m
- Bacteria, viruses & colloids retained

Micro-filtration (MF)

- Excludes particles 0.1-10 μ m
- Separates microorganisms & suspended particles



Membrane use in Mines

Mining- 4th largest water consumer

Gold- 1,155,000 litres/kg

Copper- 18,000 litres/kg

Aluminium – 8,000 litres/kg

Coal – 6,000 litres/kg

>90% minewater reusable by applying RO & MF (*Szyplinska, 2012*)

Figure 1. Water intensity of key minerals and metals

Mineral/metal type	Water use
Coal 	
Copper 	
Diamond 	
Gold 	
Nickel 	
Iron ore 	
Platinum 	

Key:  High  Medium high  Medium low

Source: <http://www.waterworld.com/articles/wwi/print/volume-27/issue-1/regulars/creative-finance/thirsty-world-of-mining.html>

Membrane use in Mining

- Enhanced Metal recovery
- Leach solution recovery
- Acid Mine Drainwater clean up
- Lithium Brine concentration and divalent ion removal
- Zero liquid discharge
- Dewatering mines
- Man camp drinking water

Enhanced Metal Recovery

Yanacocha Gold Mine Peru

- 3,500-4,100m asl in Andes Mountains
- 30miles north of Cajamarca city



Enhanced Metal Recovery

Yanacocha Gold Mine Peru

- Lime blended, heap leached
- Free cyanide 30-50 mg/L
- Drip & spray Irrigation
- Excess rainwater dilutes the leachate



Enhanced Metal Recovery

Yanacocha Gold Mine Peru

- Barren pond storage prior to treatment and disposal



Enhanced Metal Recovery

Yanacocha Gold Mine Peru

- RO plant concentrates pregnant leach
- RO plant treats barren pond water
- First plant installed 2003



Enhanced Metal Recovery

Yanacocha Gold Mine Peru

Concentration of rain diluted pregnant liquor

7 plants @250 m³/hr each

- Dewater pregnant liquor for Merrill Crowe extraction process
- Remove excess cyanide for reuse
- Remove excess metals

Clean barren liquor

5 plants @500m³/hr each

- Treated for discharge to environment
- Additional gold recovered via carbon column
- Concentrate returned to heap leach pond

OPEX 70% less than that of a conventional precipitation plan

Source: MDS Membrane Separations & System Case Studies

Technologies and



Yanacocha RO plants

- Membrane autopsy
- Calcium sulphate scale
- Antiscalant lab test
- Using Genesys CAS
October 2013



Genesys Mining Research



UK Government Research grant for \$700k £500k

- Calcium sulphate scale research
- Threshold testing
- Develop new antiscalants & cleaners
- Application testing on different minewaters
- Minewater scaling prediction software

Research Project

Database identifying 800 mines

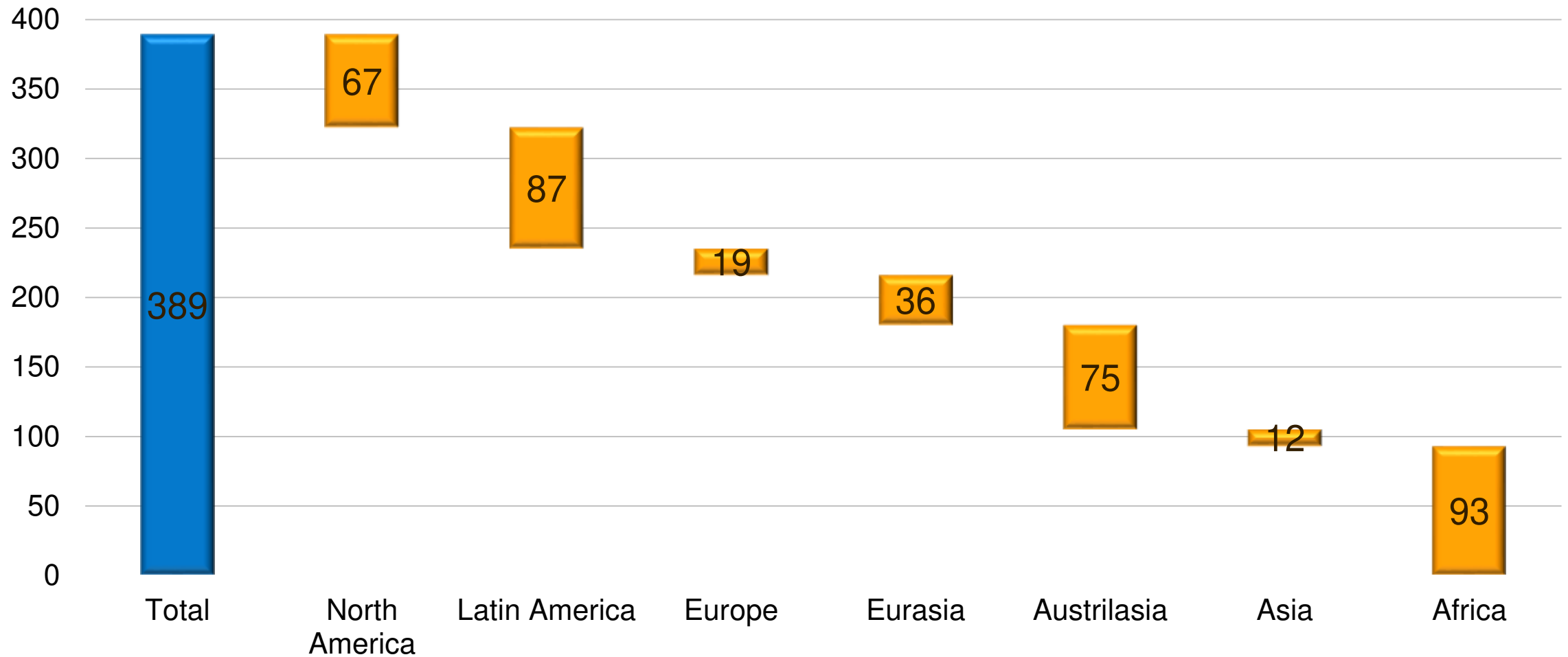
389 operational membrane plants

Main Adopters

- Glencore
- Barrick
- Anglo American
- Rio Tinto
- Newmont



of RO Plants by location



Africa

Over 1,000,000m³d⁻¹ treated by 87 plants across 15 nations.

Burkina Faso- Yaramoko

Company- Roxgold
Commodity- **Gold**
Membrane Process- **BWRO**
Capacity- **150m³ d⁻¹**

Ghana

Companies- **AGA, Asanko, GSR & Newmont**
Commodity- **Gold**
Membrane Process- **BWRO/GWRO**
Capacity- **81,400m³ d⁻¹**

Botswana- Orapa

Company- Debswana
Commodity- **Diamonds**
Membrane Process- **BWRO**
Capacity- **3,342m³ d⁻¹**

Egypt- Sukari

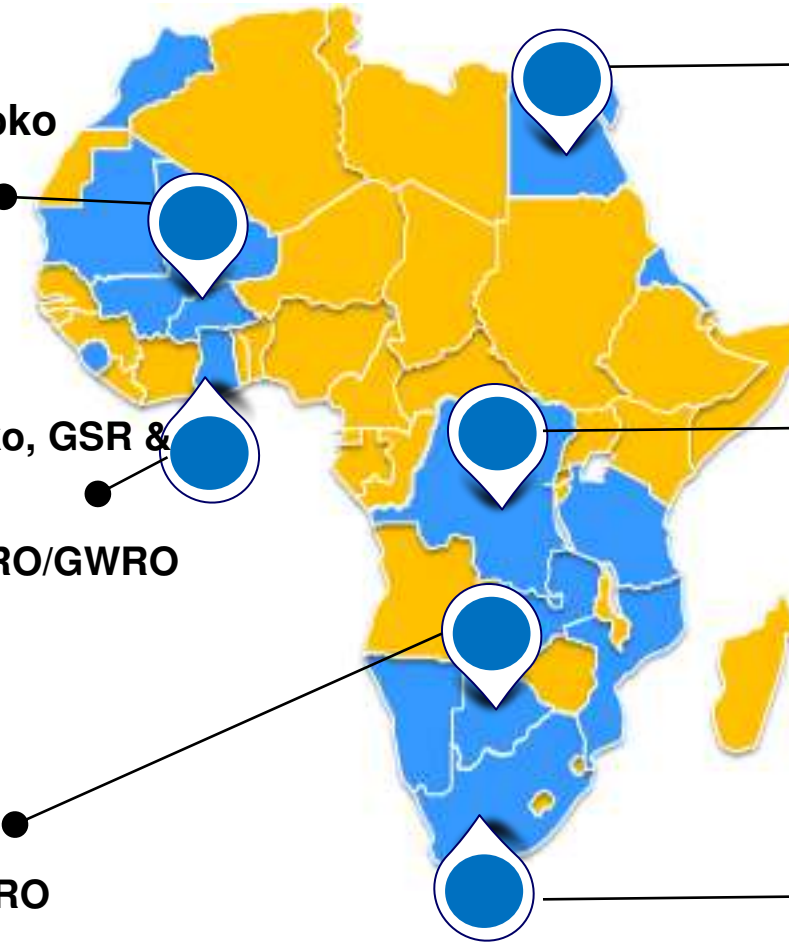
Company- Centamin
Commodity- **Gold**
Membrane Process- **SWRO**
Capacity- **15,250m³ d⁻¹**

DRC- Kibali

Company- Randgold
Commodity- **Gold**
Membrane Process- **UF x2**
Capacity- **240m³ d⁻¹**

South Africa

Companies- **AA, Exxaro, FRE, Glencore, Harmony Gold, RPH, Samancor, Sibayne-Stillwater, S32,**
Commodities- **Chrome, Coal, Diamonds, Gold**
Membrane Process- **UF, BWRO**
Capacity- **255,240m³ d⁻¹**



Latin America

Over 1,900,000m³d⁻¹ treated by 93 plants across 12 nations.

Peru

Companies- **Barrick, Buenaventura Chinalco, CMM, FMI, Glencore, Goldfields, MMG, Newmont, Shougang Hierro**

Commodity- **Copper, Gold, Iron**

Membrane Process- **NF, UF, SWRO/BWRO**

Capacity- min 304,954m³ d⁻¹

Chile

Companies- **Albermarle, Algorta Norte, AA, Antofagasta, Barrick, BHP, Codelco, ENAMI, Glencore, Lundin, Mantos, RT, SCM, TECK**

Commodity- **Copper, Gold, Lithium, Iron, Silver**

Membrane Process- **SWRO/ BWRO/ GWRO**

Capacity- min 1,475,676m³ d⁻¹

Argentina

Companies- **Barrick, Enirgi, Glencore, Int. Lithium Corp, Minera Triton, Orocobre, Yamana**

Commodities- **Gold, Lithium, Silver, Zinc**

Membrane Process- **UF, BWRO**

Capacity- min 9,352m³ d⁻¹



Australasia

Over 527,000m³d⁻¹ treated by 75 plants across 4 nations.

NT

Company- **Glencore, RT, Vista Gold**
Commodity- **Gold, Uranium, Zinc**
Membrane Process- **MF₃, BWRO**
Capacity- **min 24,280m³ d⁻¹**

QLD

Company- **AA, BHP, Carbine, Glencore, Metro Mining, RT**
Commodity- **Bauxite, Coal, Copper, Gold, Zinc**
Membrane Process- **NF₃, UF₃, BWRO**
Capacity- **min 12,550m³ d⁻¹**

NSW

Companies- **Aurelia Metals, Austar Coal, Bemax, Centennial Coal, Evolution, Glencore, S32, Peabody**
Commodities- **Coal, Copper, Gold, Minerals sands**
Membrane Process- **UF₃, RO**
Capacity- **min 28,848m³ d⁻¹**

VIC

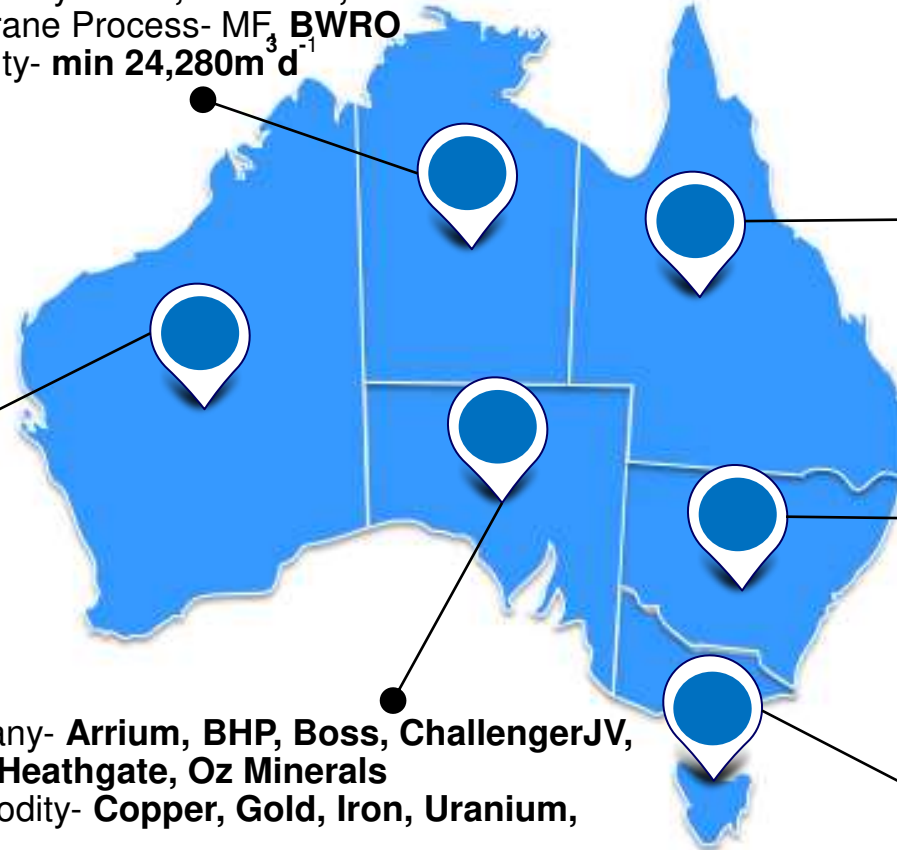
Companies- **Alcoa, Kirkland, Liongold, Mandalay, Nystar**
Commodities- **Aluminum, Gold, Zinc**
Membrane Process- **RO**
Capacity- **min 2,000m³ d⁻¹**

SA

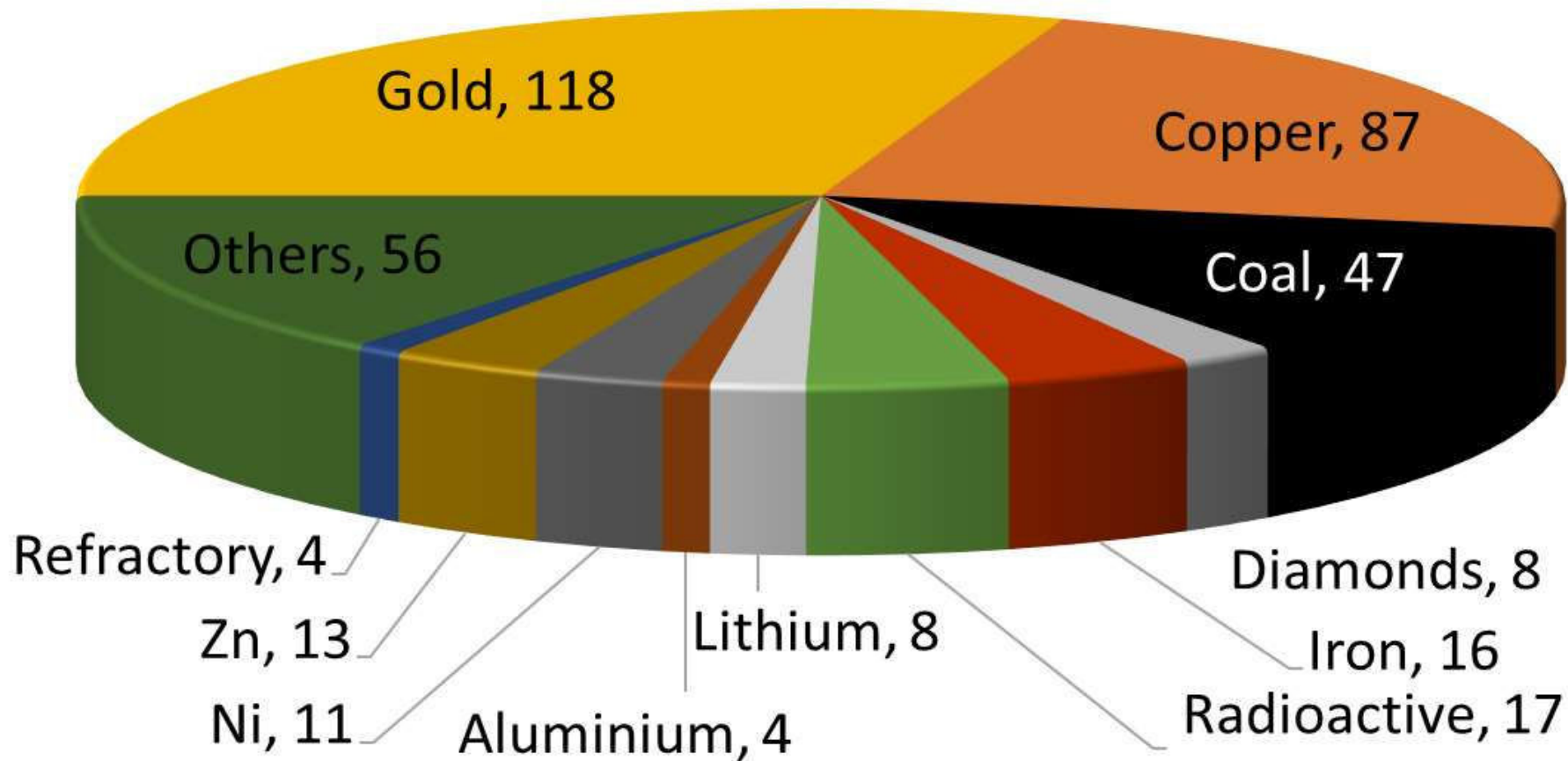
Company- **Arrium, BHP, Boss, ChallengerJV, Exco, Heathgate, Oz Minerals**
Commodity- **Copper, Gold, Iron, Uranium, Zinc,**
Membrane Process- **UF₃, SWRO/BWRO**
Capacity- **264,750m³ d⁻¹**

WA

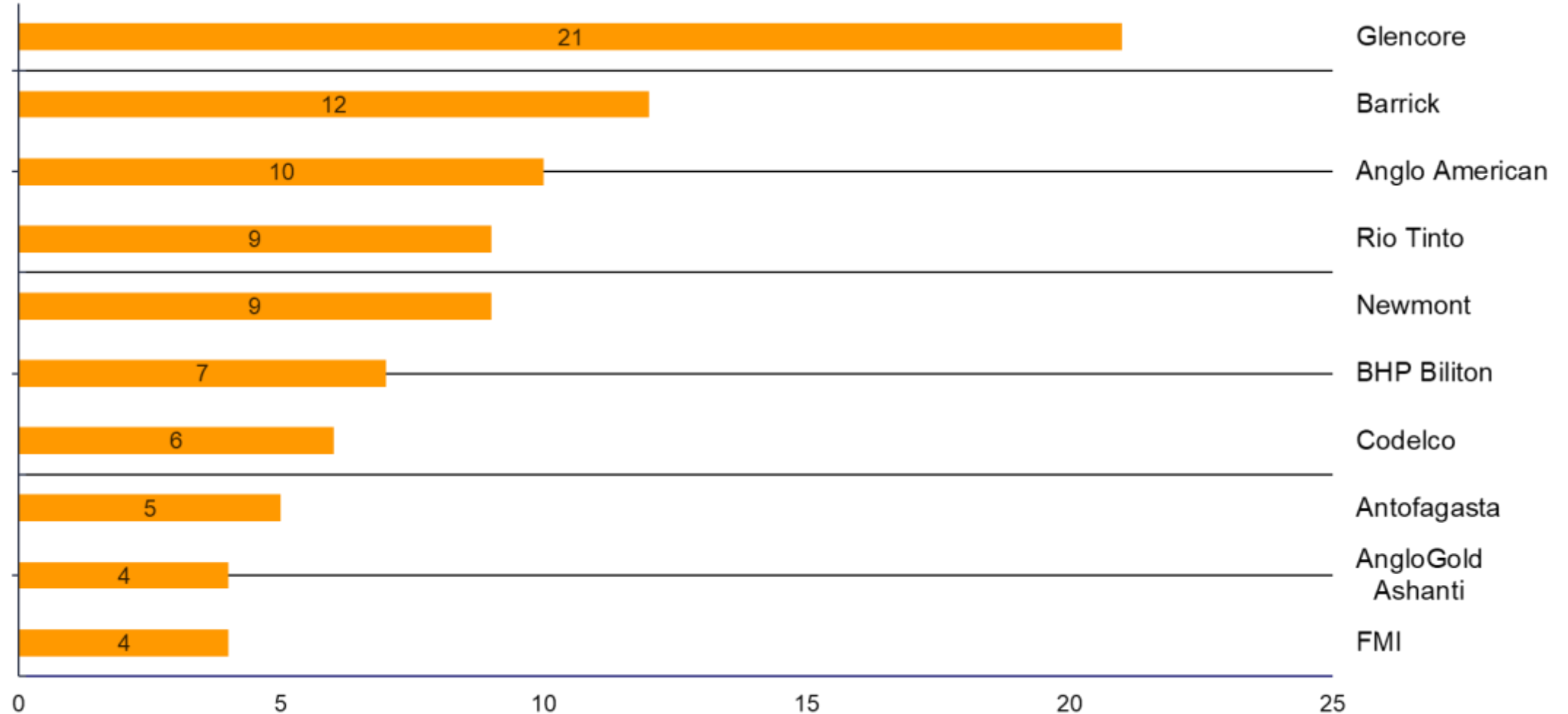
Companies- **Alcoa, AGA, Barrick, BHP, Cameco, Citic Pacific, CNR, FMG, Glencore, Goldfields, Lynas, MMG, Newmont, Norton GF, Panoramic, Red5, RT, RHH, Saracen, Silver Lake, St Barbara**
Commodity- **Gold, Iron, Nickel**
Membrane Process- **UF₃, NF₃, SWRO/BWRO**
Capacity- **min 185,206m³ d⁻¹**



of MST Plants by Commodity



Top 10 #plants by mining company



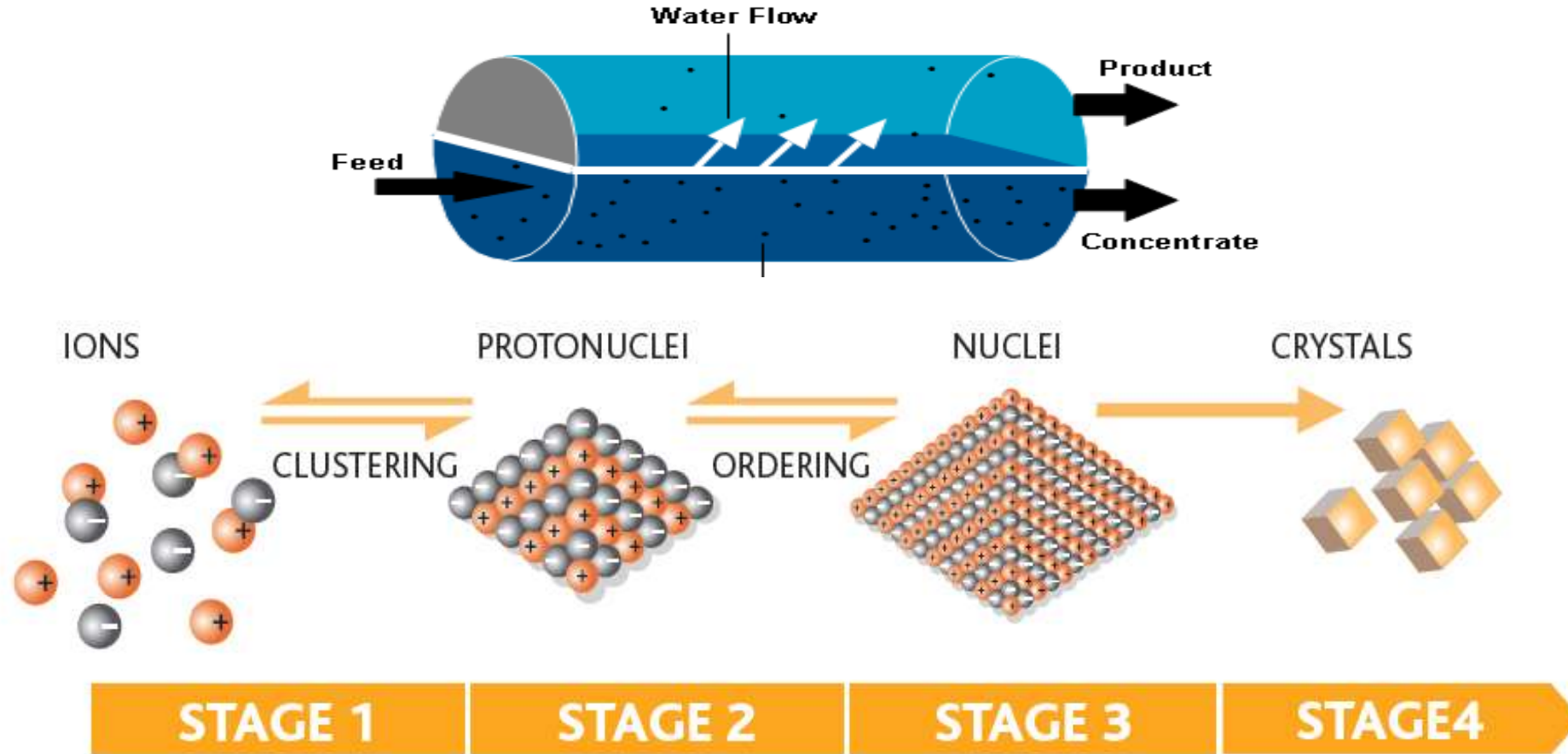
What can go wrong?

- **SCALING**
- **FOULING**
- **PHYSICAL
DAMAGE**
- **CHEMICAL
DAMAGE**

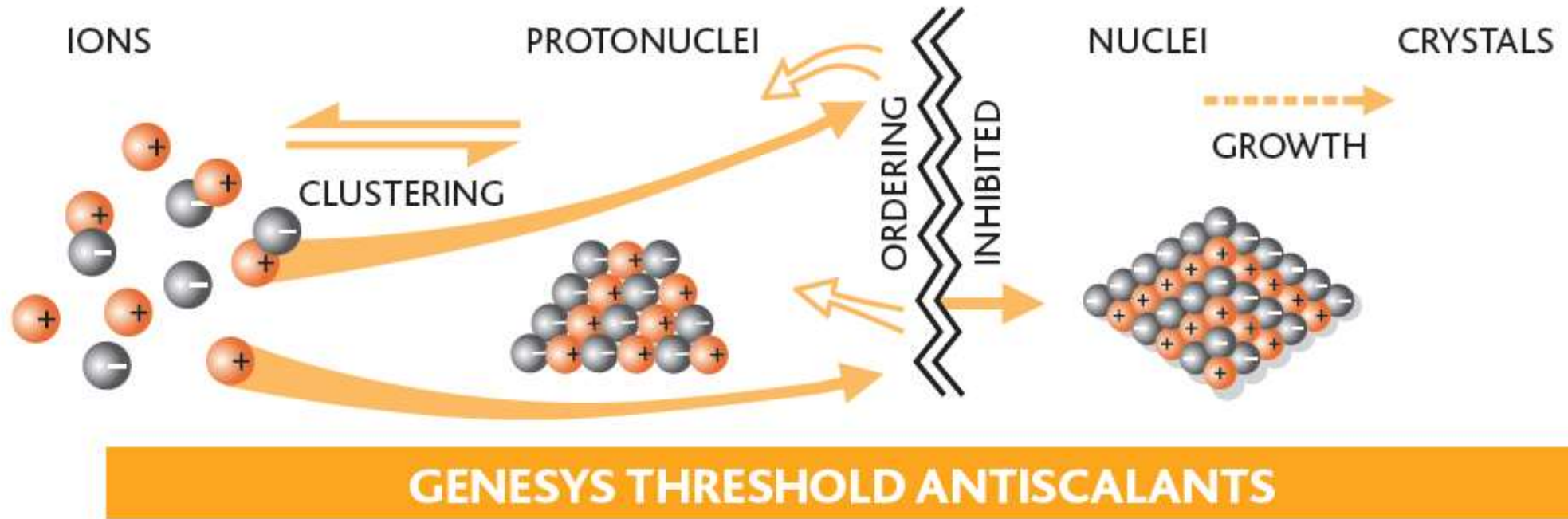


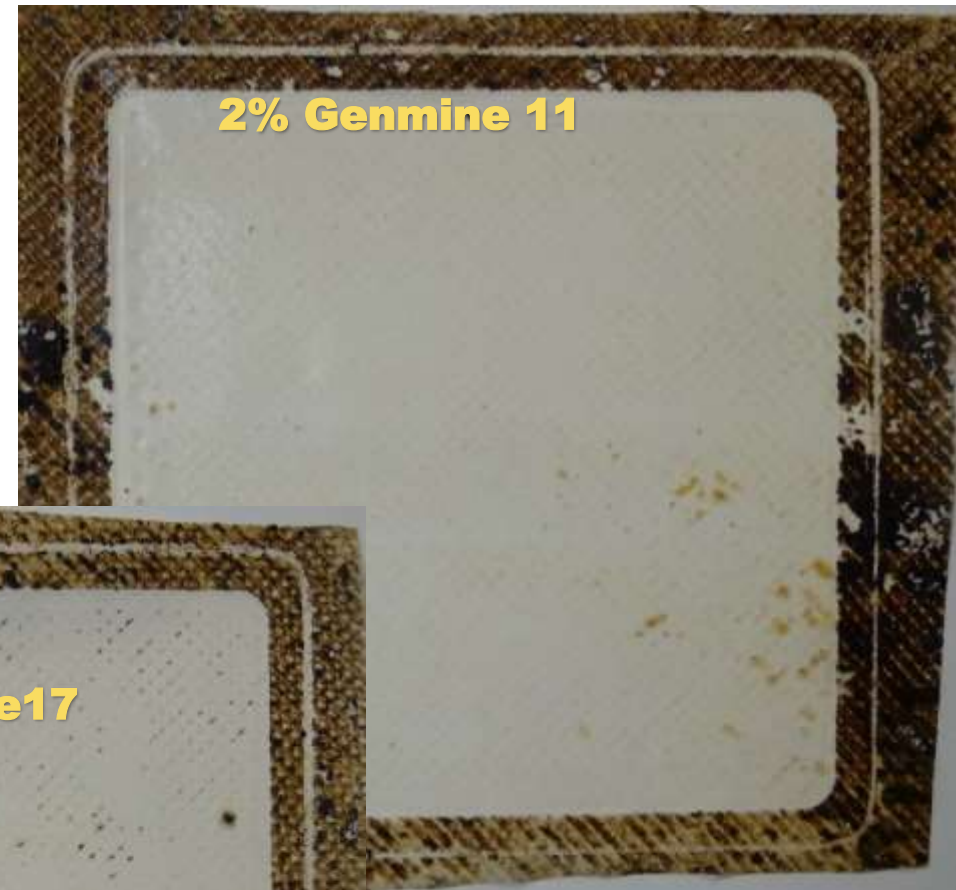
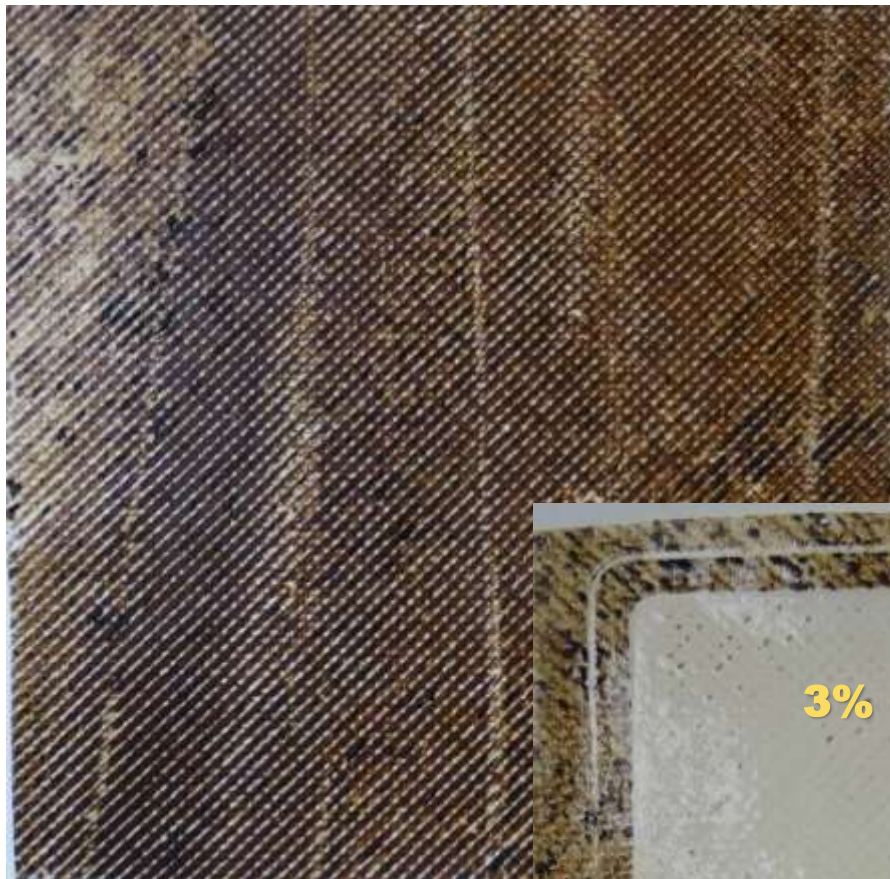
Membrane scaling & inhibition

Reverse Osmosis

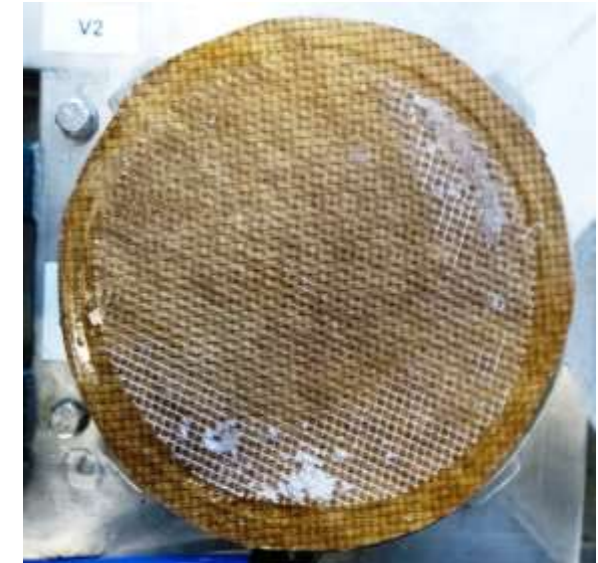
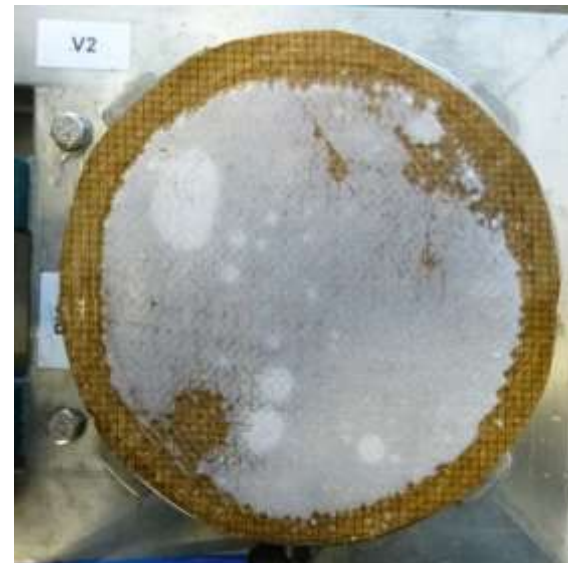


Antiscalants



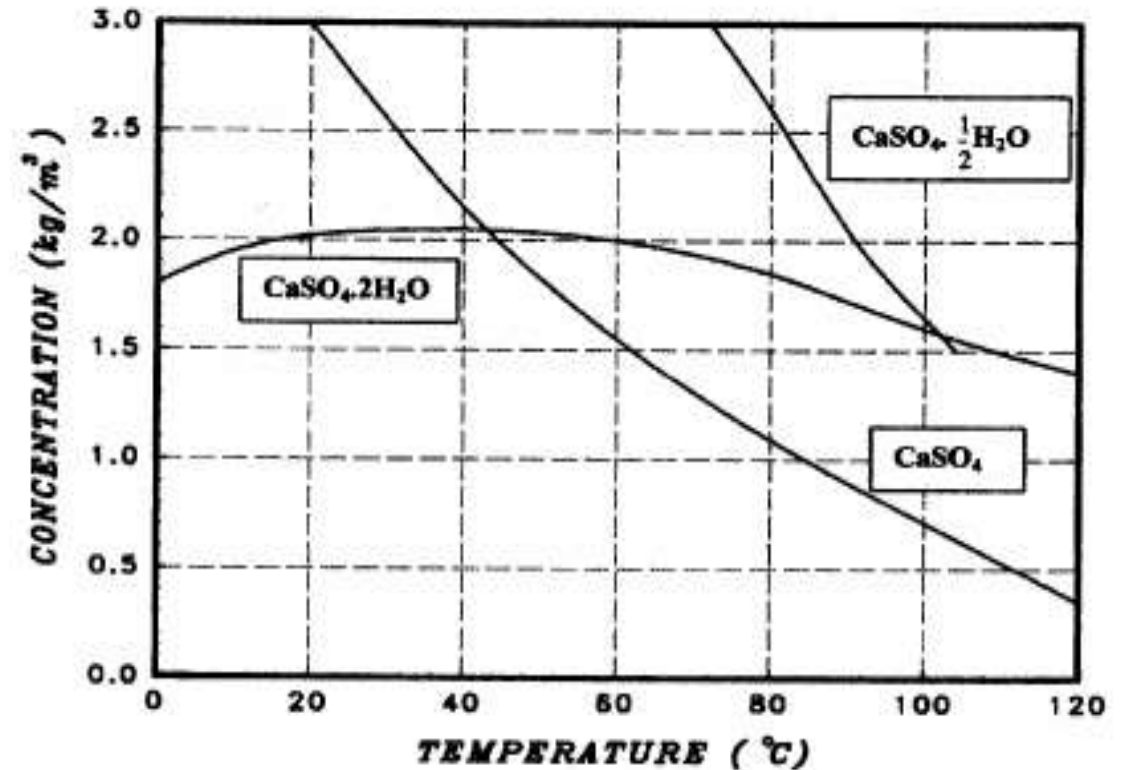


Cleaning Calcium Sulphate

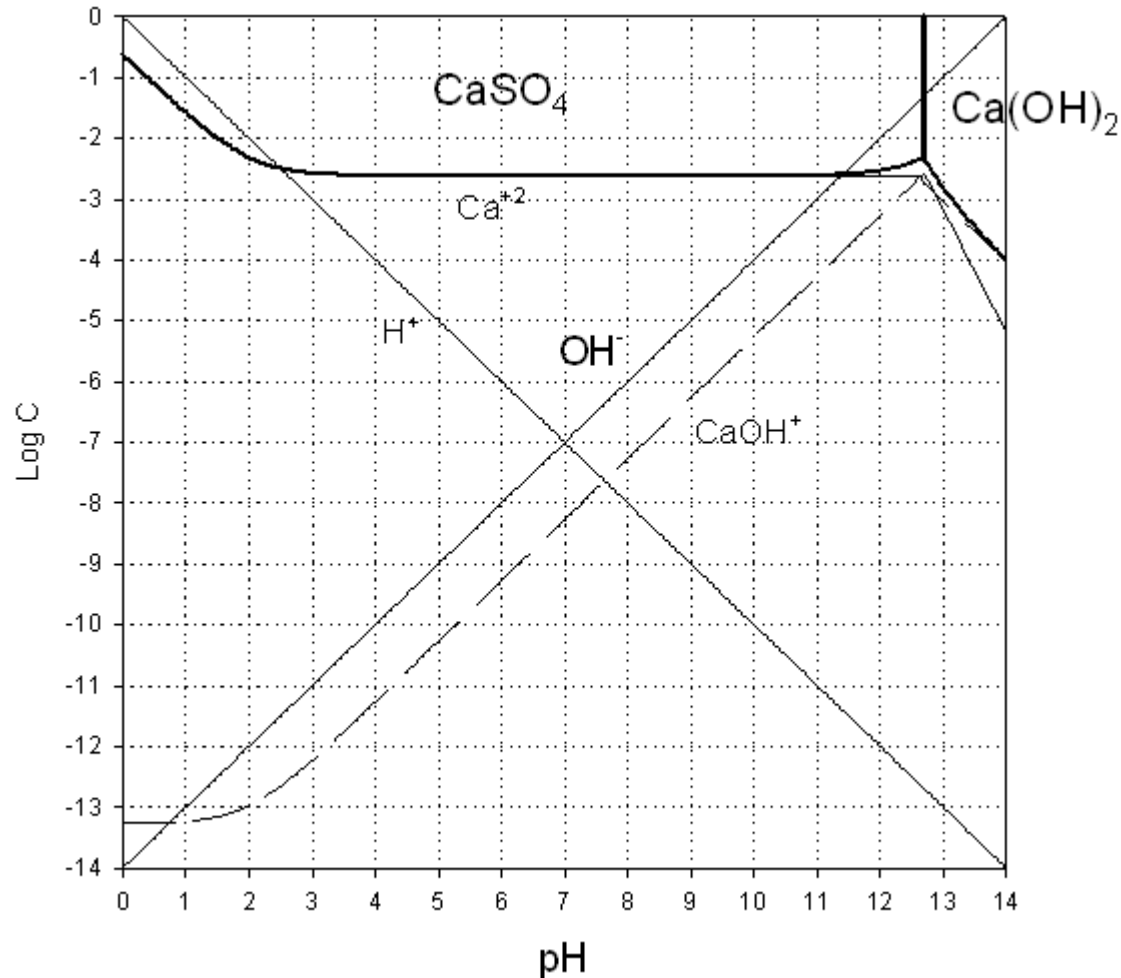


Membrane scaling & inhibition

- 3 Major forms of calcium sulphate
 - Hemihydrate $\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O}$
 - Dihydrate $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
 - Anhydrite CaSO_4
- 3 differing solubility isotherms
- Dihydrate form is gypsum
 - Solubility decreases with increasing temperature also with reducing temperature below 15°C
 - Calcium sulphate solubility decreases in acidic conditions



Calcium sulphate solubility



- **Saturation Point**
- **2,600mg/l of CaSO_4**
- **Decreased solubility**
 - **below pH 4**
 - **Below 20°C**

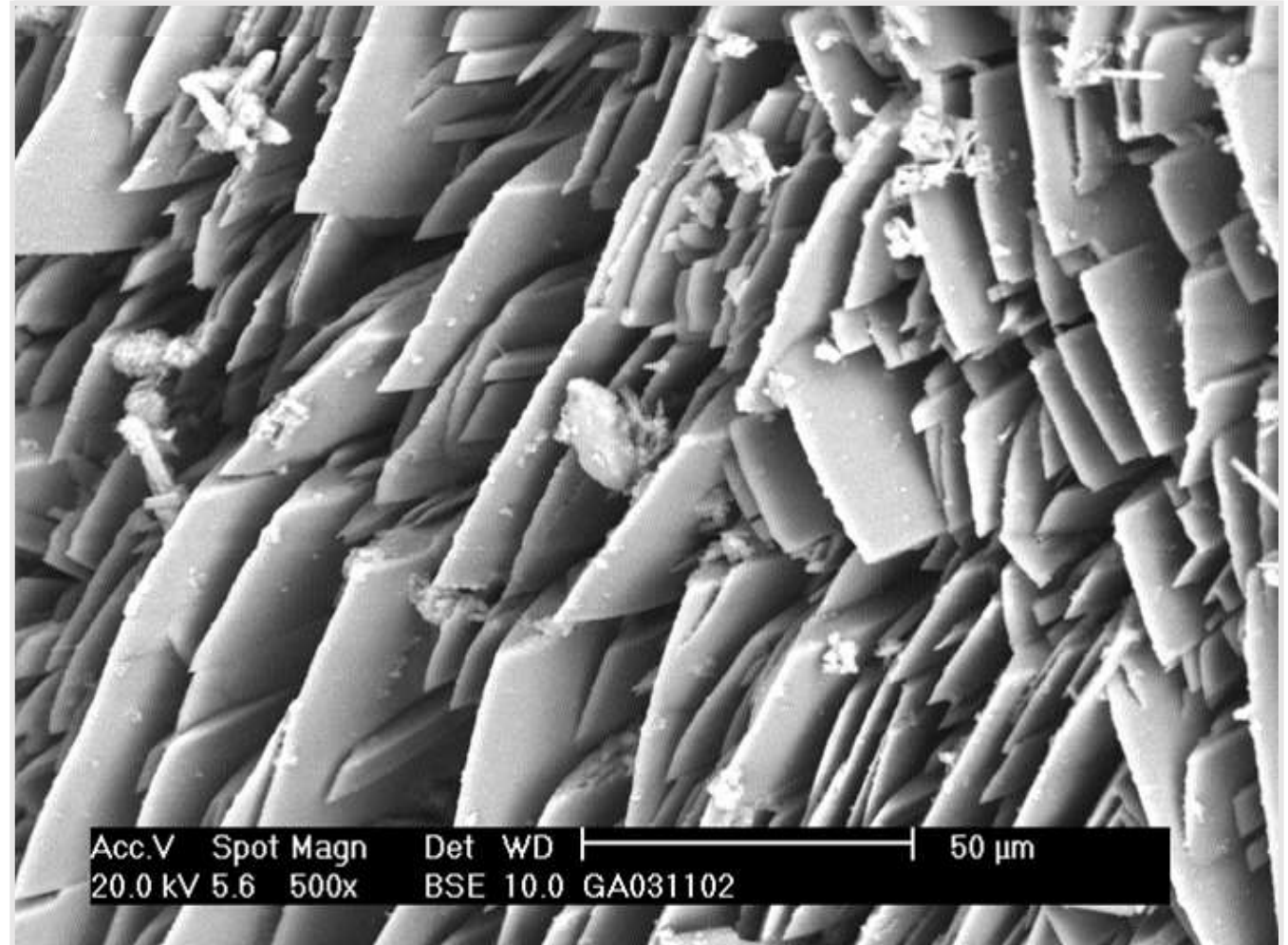
Membrane scaling & inhibition

Calcium sulphate (Gypsum) scale

- Crystal platelets form in low flow cross over points of feed spacer
- Clearly displayed when spacer removed during autopsy

Damaging to membrane

- Scale formation initially needle platelets & rosettes resulting in blades
- Chemical removal difficult



Threshold Tests

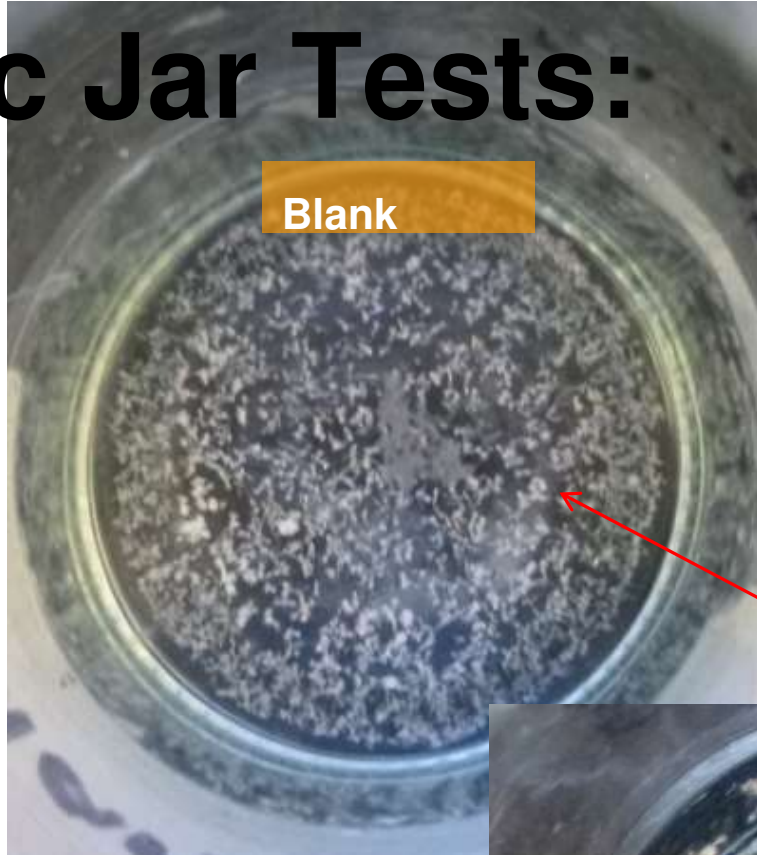
- **New formulation Genmine AS-26, designed specially for low pH mine waters for CaSO₄ scale control.**
- **Threshold jar tests conducted and performance compared to existing inhibitor Genesys CAS.**
- **Tests also conducted in the presence of various metals.**

Threshold tests carried out using AS-26 and G-CAS.

Test Conditions:

- 2000ppm Ca / 20000ppm SO₄,
- Metal ion levels: 0 to 300ppm
- Temp 20 C, pH 7, 24 hr
- CaSO₄ Sat Index = ~7x

Static Jar Tests:



Blank



4ppm Genesys G-CAS



2ppm Genesys CAS

Crystals

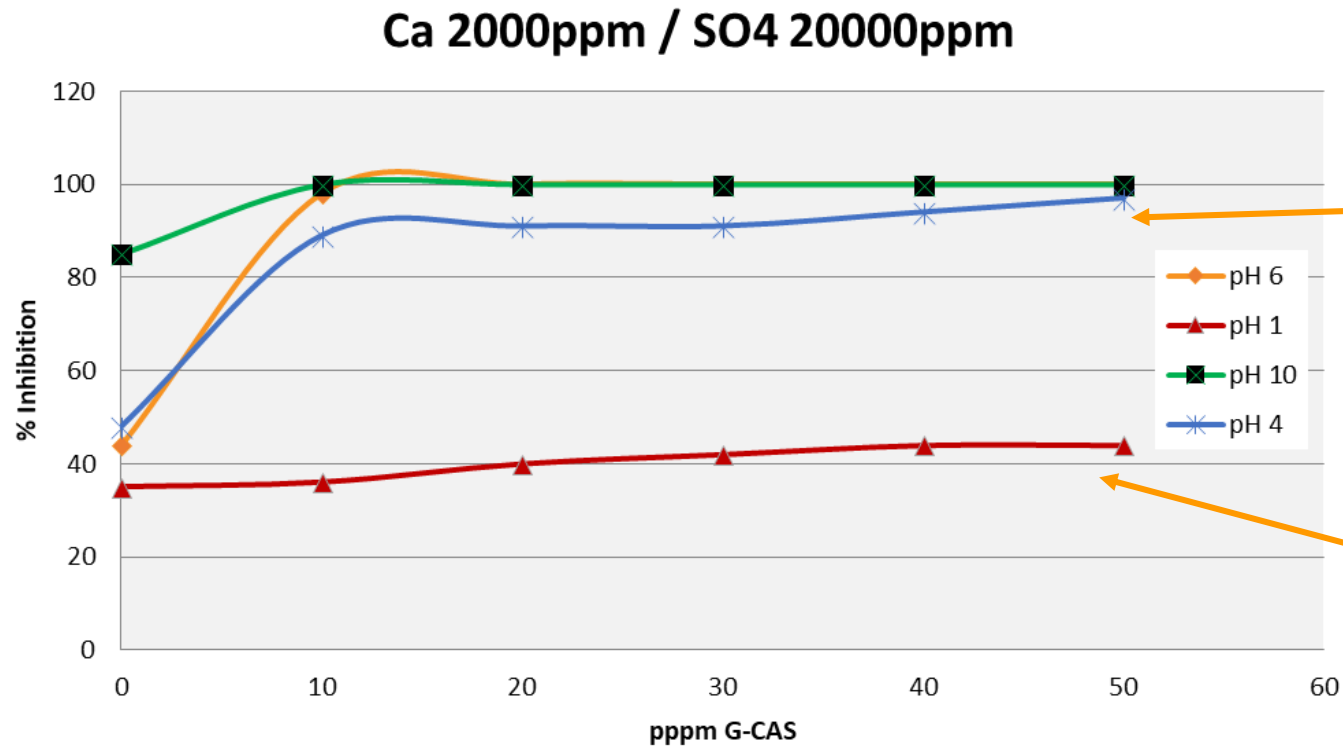
6ppm Genesys CAS



- 6ppm Genesys CAS gave ~90% Inhibition at pH 7 and presence of no metals

Static Jar Tests:

Genesys CAS Performance at various pH

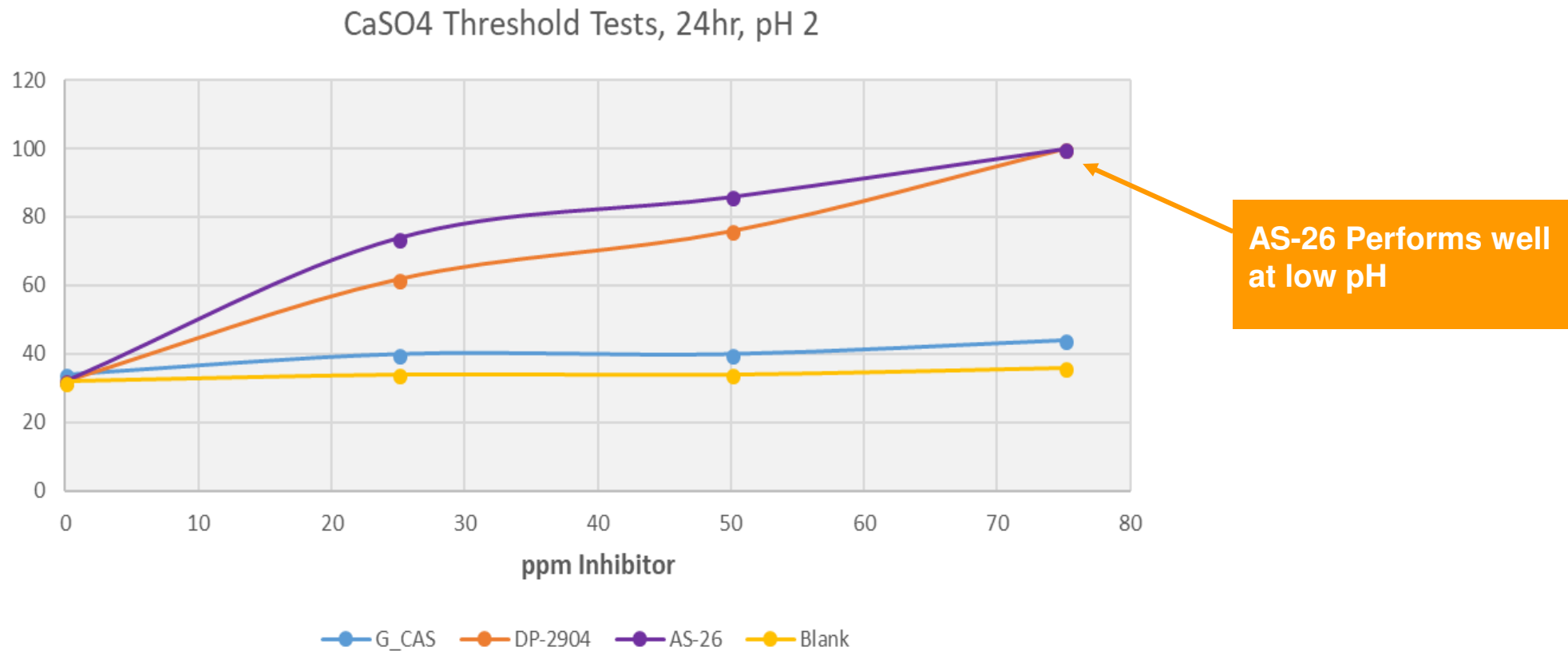


G-CAS Performs well at normal pH

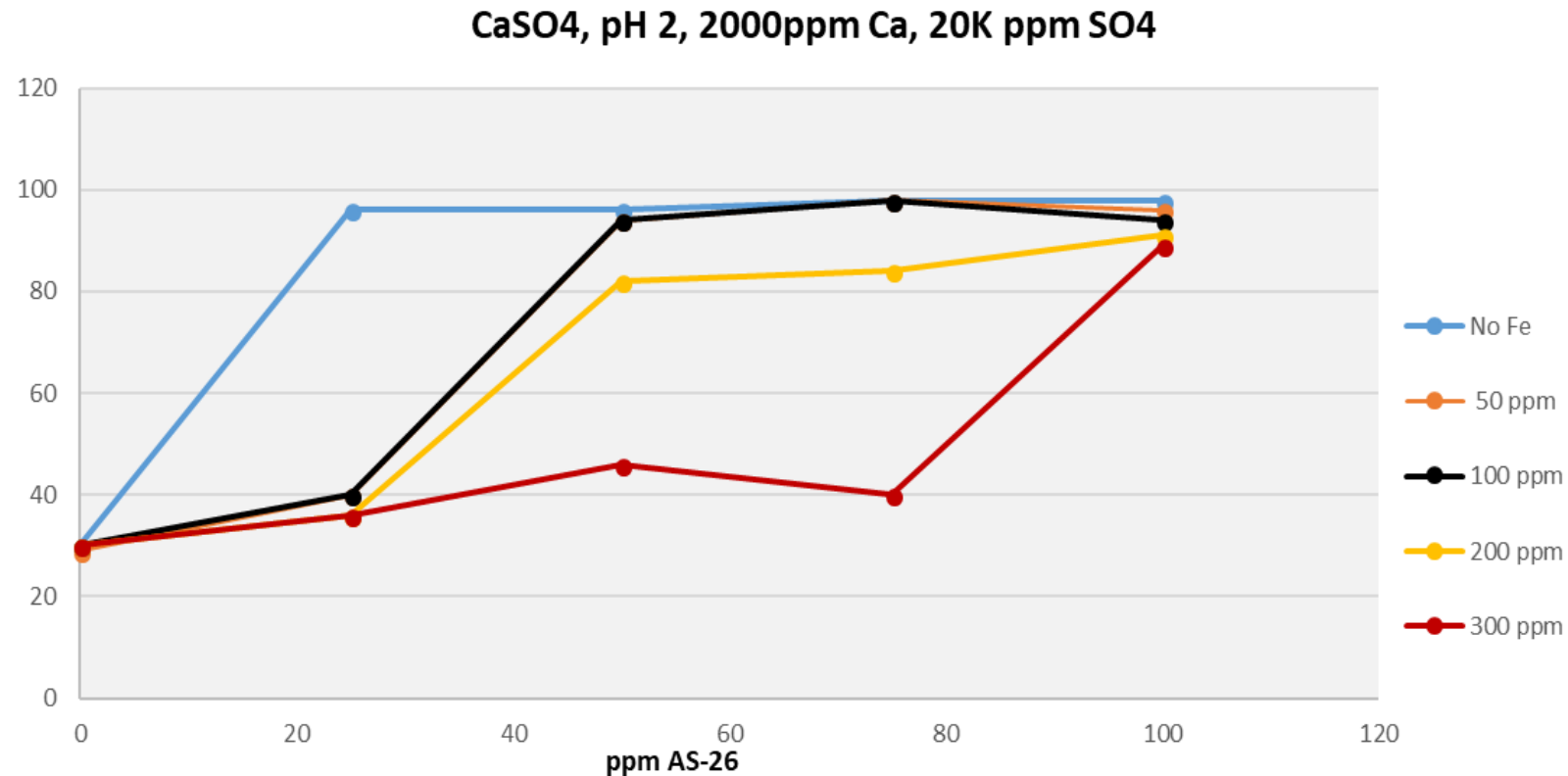
but poor at low pH

Genesys CAS and AS-26 performance at pH 2

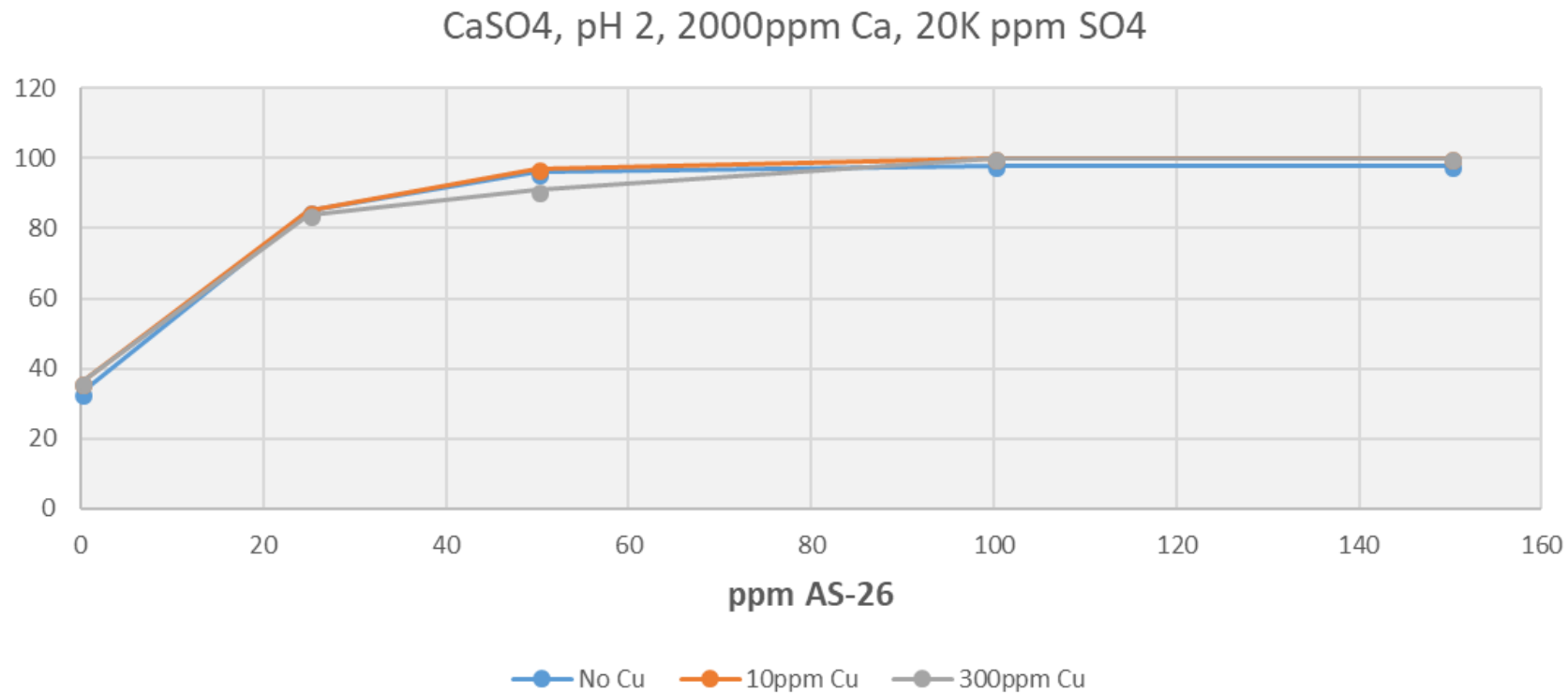
2000ppm ca and 20000ppm SO4



Static Jar Tests with Fe

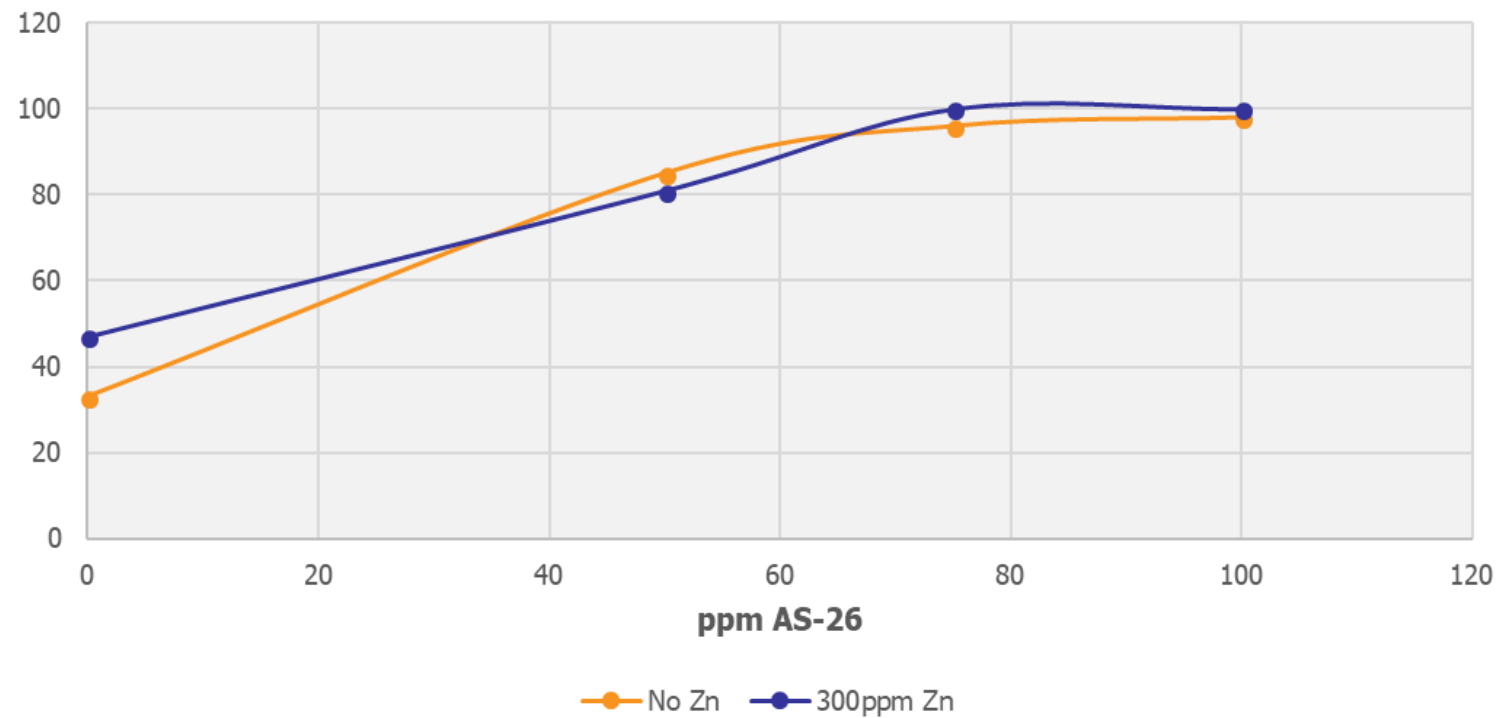


Static Jar Tests with Cu

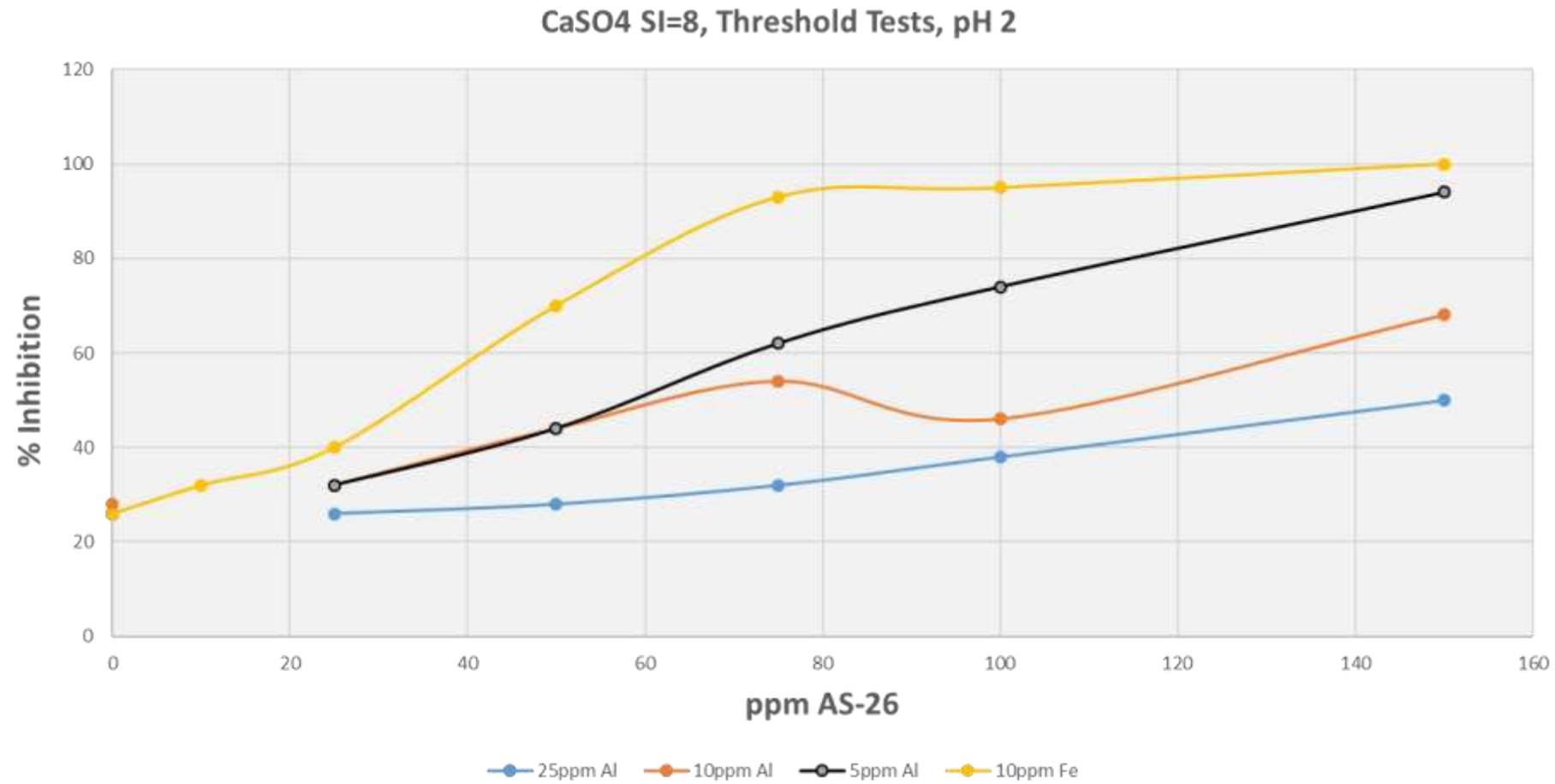


Static Jar Tests with Zn

CaSO4 Threshold Tests, pH 2.2, 2000ppm Ca, 20K ppm SO4



Static Jar Tests with Al



Conclusion:

Genmine AS-26 was very effective at preventing CaSO₄ precipitation in low pH waters.

It was also effective against CaSO₄ in the presence of high amounts of various metals. Requiring higher proportional dose rates with increasing levels of Fe and Al.

FTIR



2.5" Pilot Plant



Flat Sheet Rig



8" Pilot Plant



8" Pilot Plant



Flat Sheet CaSO₄ Cleans

Before Clean – CaSO₄ scaled membrane



After 5% Genmine C15 – 2hrs



Scaled Spacer

Before Clean – CaSO₄ scaled spacer



After 5% Genmione C15 – 2hrs



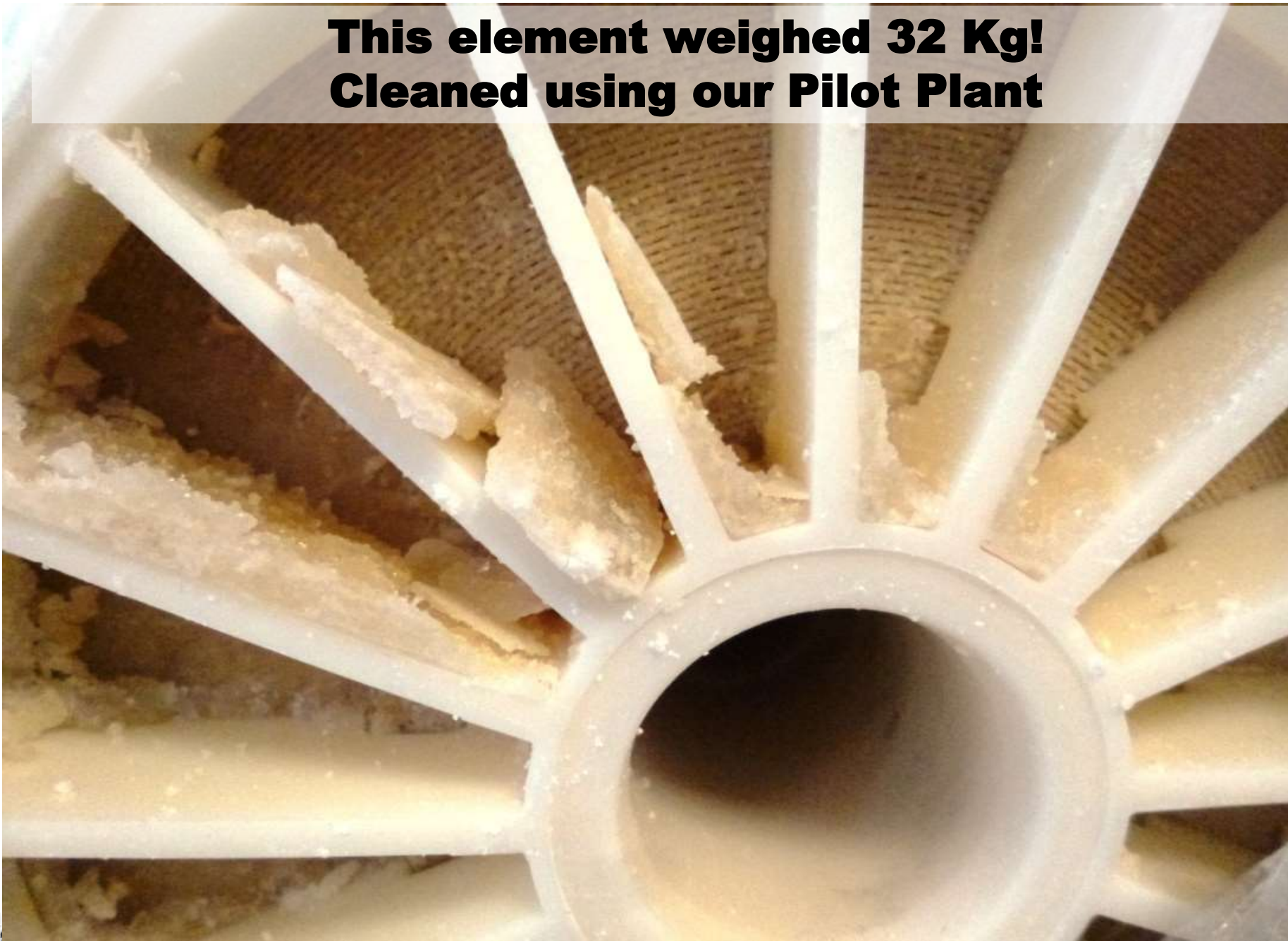
Before Clean – CaSO₄ scaled spacer



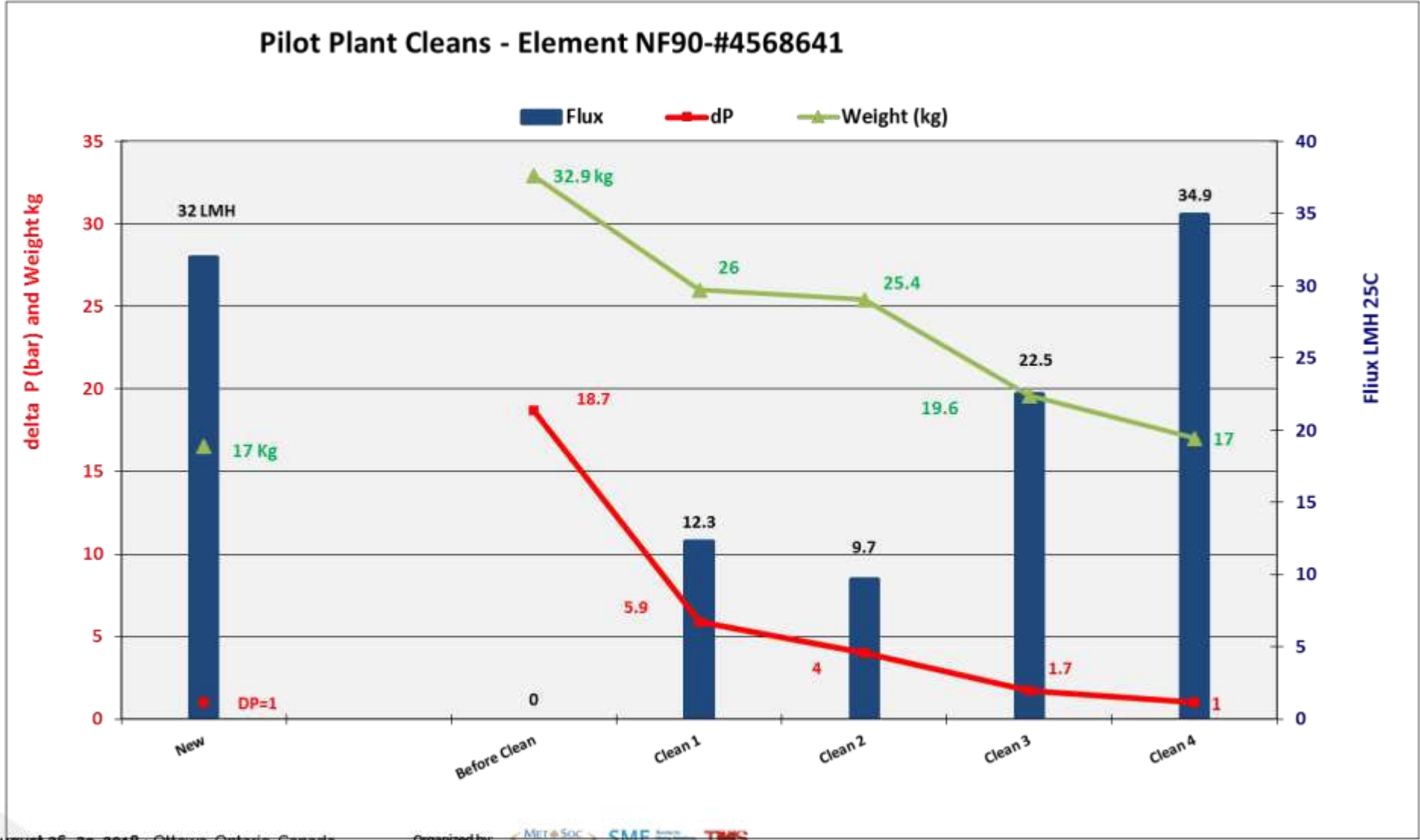
After 5% Genmine C17 – 2hrs



**This element weighed 32 Kg!
Cleaned using our Pilot Plant**



Results: Cleaning Heavily Scaled Element



Genesys Software

- **Membrane Master 4**
- **Membrane Minemaster**



New Product performance modelled in the software

Antiscalant product range

Antiscalant

Application

GENMINE AS26	calcium sulphate acidic minewaters
GENMINE AS34	barium and silica specific
GENMINE AS45	calcium carbonate and silica specific
GENMINE AS47	broad spectrum for neutral and alkaline minewater
GENMINE AS51	silica specific
GENMINE AS65	calcium sulphate specific neutral and alkaline minewater

New Product performance modelled in the software

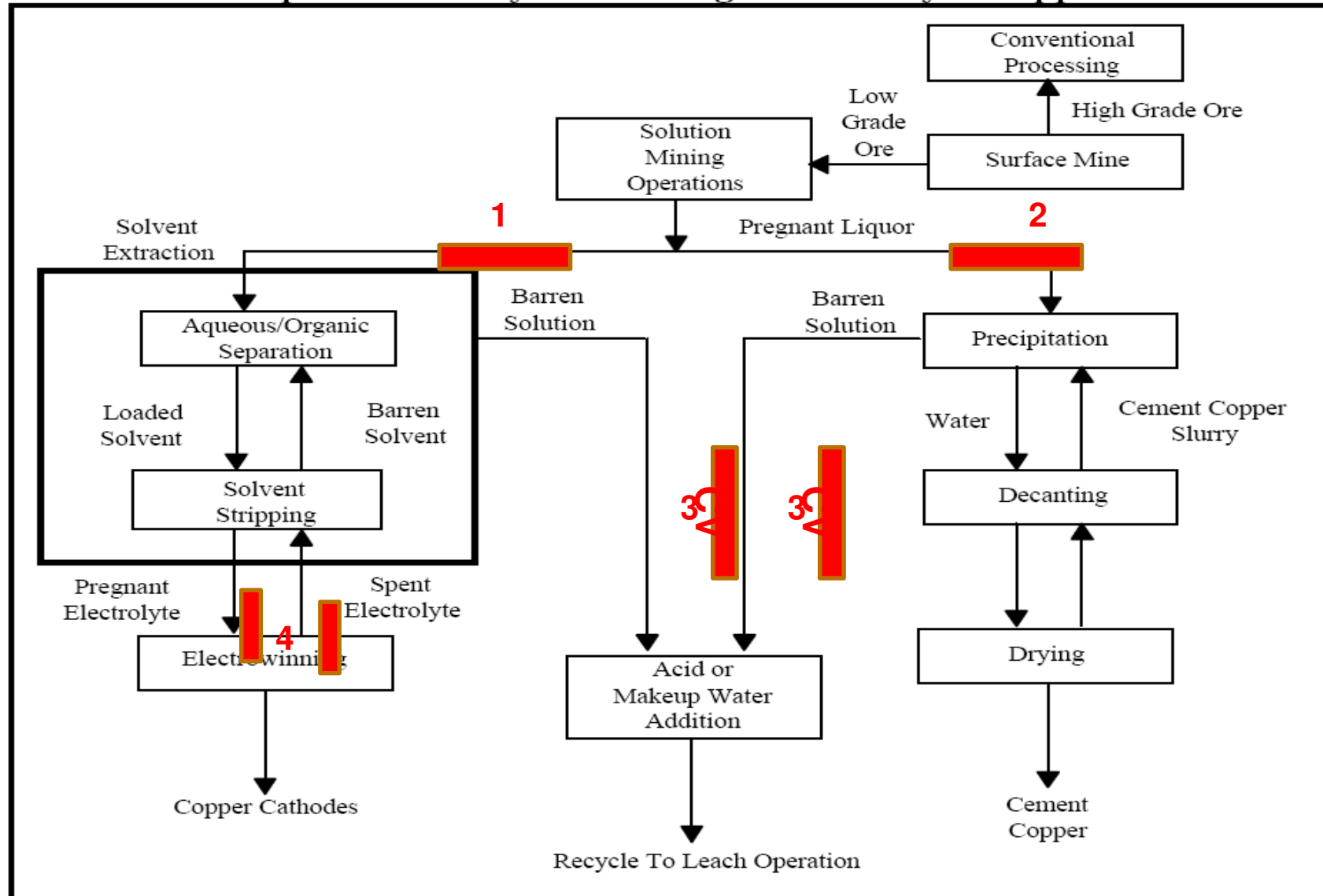
Cleaning product range

Cleaner

Application

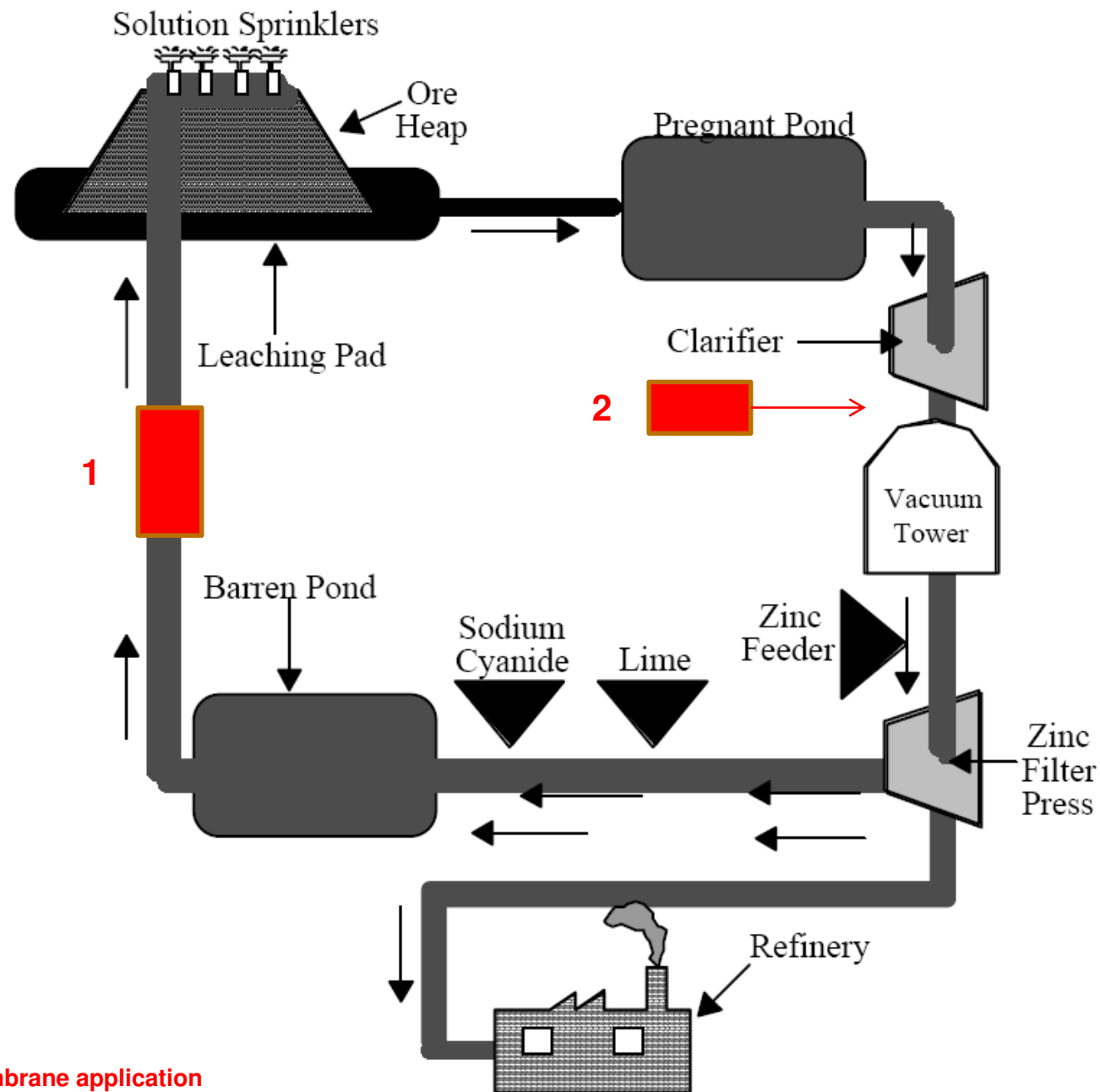
GENMINE C11	clay, organics, colloidal foulants, incorporates micro-bubbles
GENMINE C14	biofouling, clay
GENMINE C15	calcium sulphate, metals
GENMINE C17	complex deposits containing metals and calcium sulphate
GENMINE C18	metals, inorganic scale, incorporates micro-bubbles
GENMINE C20	inorganic scale, metals
GENMINE C21	inorganic scale, metals

Representative Hydrometallurgical Recovery of Copper



Source: *Technical Resource Document: Extraction and Beneficiation of Ores and Minerals, Volume 4, Copper, August 1994 U.S. EPA.*

Gold Heap Leaching Operation



Membrane application

August 26

Conclusions

- **Membrane plants already in use in 390 mines**
- **Double benefit in enhanced metal recovery and AMD clean up**
- **Specific antiscalants and cleaners required to keep membranes clean**
- **Security of operation will lead to more widespread use.**

Thank You Questions?