Water Pro Conference

National
Rural Water
Association

September 25-27,
2023

Gaylord at
the Rockies

6700 North
Gaylord Rockies
Blvd

Aurora Colorado
80019

Powell Water Micro Algae System (PWMAS)

Natures Way of Cleaning Water for Abundant Use

Powell Water

Electrocoagulation & Support Equipment

www.powellwater.com

Powell Water System, Inc.

Scott Powell, President

(303) 241-2489

Design, Build and Operation

Lagoon Logistics, LLC

Jeff Couch

President

(970) 231-9937

Sundine Enterprises

Microalgae Microbe Assemblages

Sundine Enterprises, Inc.

Judd Sundine, Horticulturist

(720) 363-0548

United States Patent Number 10358361 B2 & 11407660 B2. System and Method for Remediation of Wastewater Including Aerobic, Anaerobic and Electrocoagulation Technology. This patent is wholly licensed by Powell Water Systems, Inc.

Powell Water Micro Algae System

Biological and Electrical Treatment Advantages
Broad Spectrum Treatment

- PFOA/PFOS (Removal in Both Water and Solids)
- Solid Removal with Biological Conversion
- Arsenic Removal Below Detectable Limits
- Lead & Copper Removal
- Cadmium & Zinc ions
- Effective Disinfection
- Nutrient Removal
- Lower Initial Investment
- Lower Operating Costs

Proposed New Discharge Limits

Colorado

- **PFOA PFOS PFAS – 0.004 ug/l**
- **Lead – 0.015 mg/l Action Level**
- **Copper – 1.3 mg/l Action Level**
- **Arsenic – 0.02 ug/l**
- **Phosphate – 0.025 mg/l**

Missouri

- **Ammonia – 0.60 mg/l**
- **Phosphorus – 0.50 mg/l**

Virtually all EPA wastewater discharge permits will have more restrictive effluent standards between now and 2027.

Powell Water Micro Algae Systems

Innovative Lagoon and Electrocoagulation

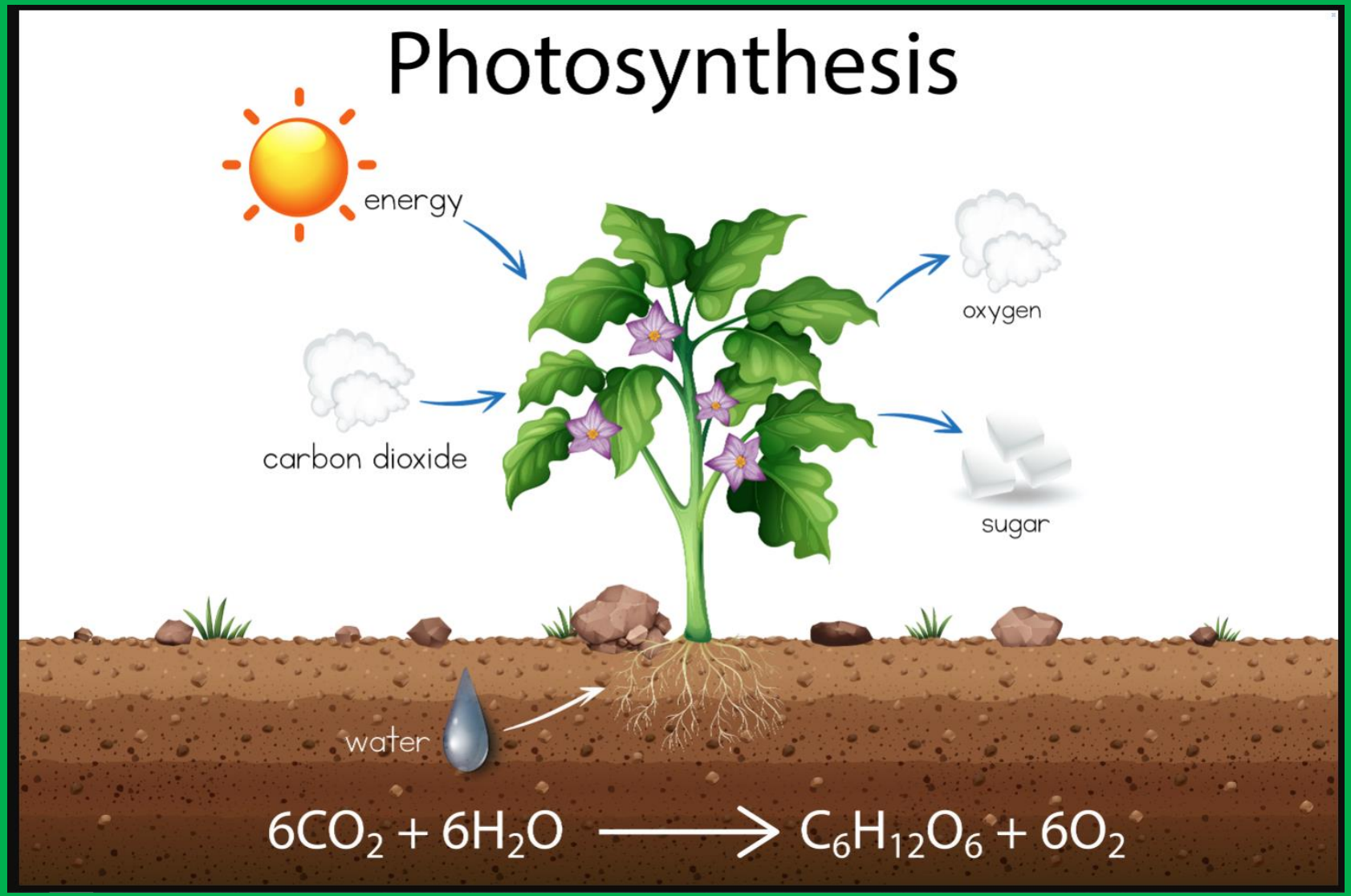
90% reduction in electrical aeration costs.
90% reduction in accumulated lagoon solids.
90% reduction in carbon dioxide creation.
50% reduction in disinfection costs.

Primary Treatment

Tertiary Treatment

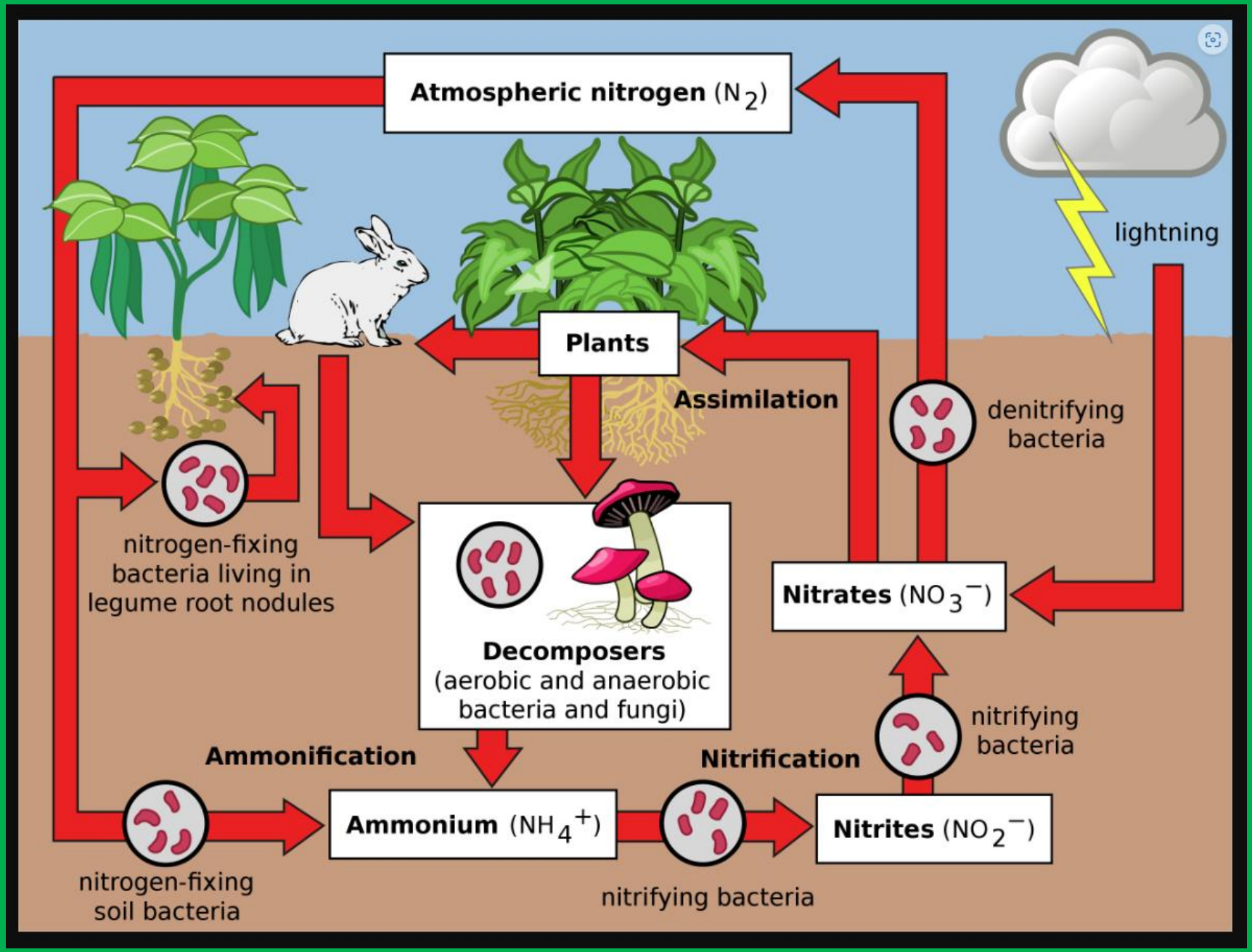
Powell Water Microalgae System (PWMAS) Patent No: US 10,358,361 B2 & 11407660 B2

Micro Algae Converts Carbon Dioxide to Oxygen
1.4 pounds of Carbon Dioxide to make 1 pound of Oxygen



2.5 pounds of carbon dioxide per pound of BOD
6.4 pounds Carbon Dioxide per pound of ammonia.

Microbes convert ammonia to nitrogen gas.



Cultivated Micro Algae and Microbes

Eliminate mechanical aeration

Eliminate Odor

Reduce aeration electricity cost by 90%

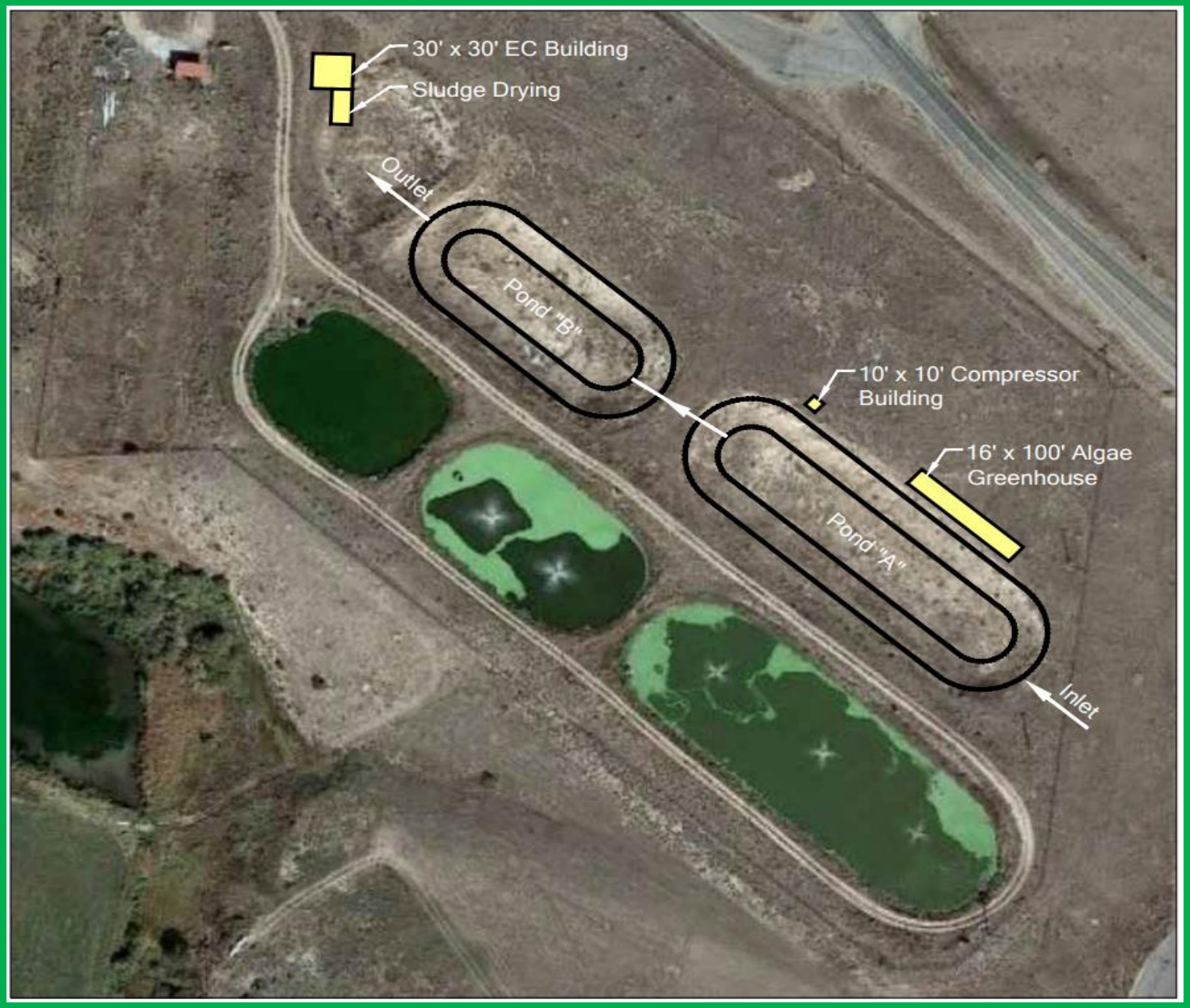
Organics are Consumed in the Lagoons Drying Bed for Inorganics

Electric Coagulated solids repel water

Reduced sludge volume for disposal

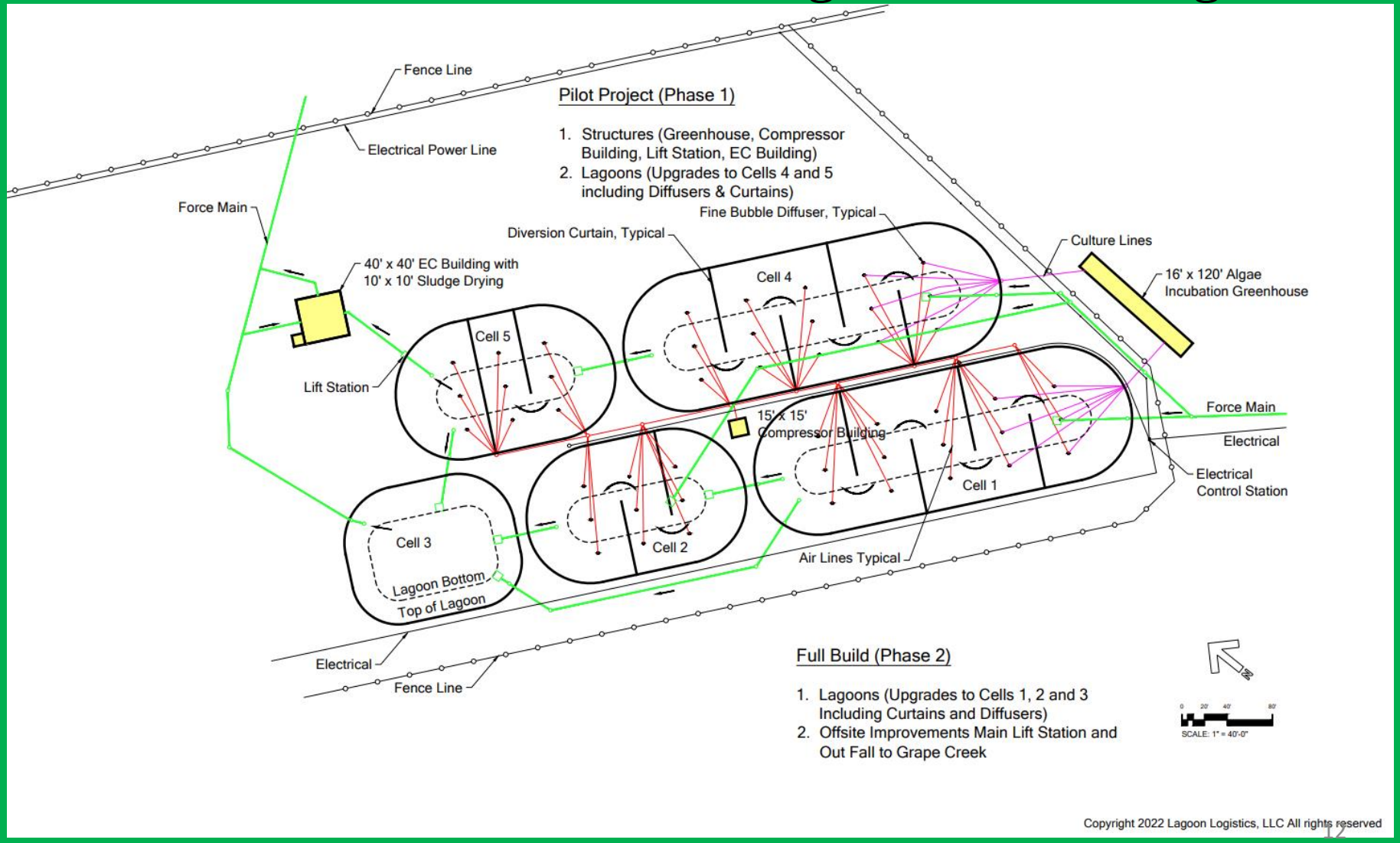
Solids dry completely

Enhance Existing Lagoon System



PWMAS Modification Details

Greenhouse and Electrocoagulation Buildings



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Economic Reasons for PWMAS

Colorado Sanitation District:

1,100 people

700 taps

$40,000 annual median household income

	SBR UV	**PWMAS**
Capital	$14,100,000	$4,400,000
Personnel	8 hours/day	2 hours/day
2027 EPA Regs	No	Yes
CO_2 Reduction	No	Yes

Prices shown in 2017 United States Dollars.

Cadmium Copper Lead Zinc

The Doe Run Company Brushy Creek Mine

Storm Water Run Off

	Cadmium	Copper	Lead	Zinc
Raw water ppb	**36**	23	**1,285**	**6,675**
Powell EC ppb	0.29	0.38	0.76	18
% Reduction	99.19%	98.35%	99.94%	99.73%
Action Level	**5**	1,300	**150**	**5,000**

Cadmium Copper Lead Zinc

Berkeley Pit, Butte Montana, Horseshoe Bend Mine Acid Mine Drainage

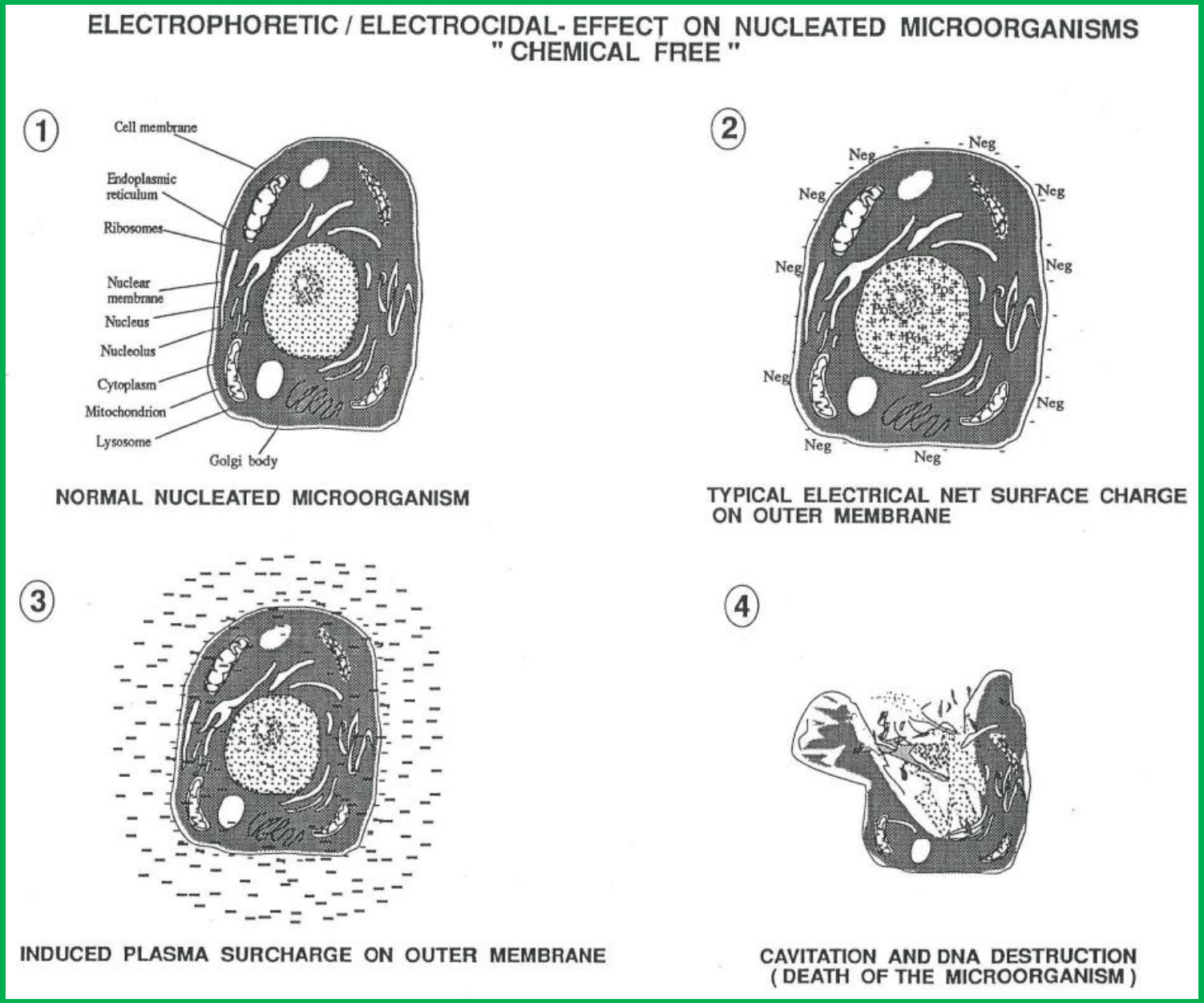
	Cadmium	Copper	Lead	Zinc
Raw water ppb	**1,014.65**	**30,983.5**	3.08	**260,050**
Powell EC ppb	4.61	6.860	< 0.6	29
% Reduction	99.55%	99.98%	>80.5%	99.99%
Action Level	**5**	**1,300**	150	**5,000**

Bacterial Components

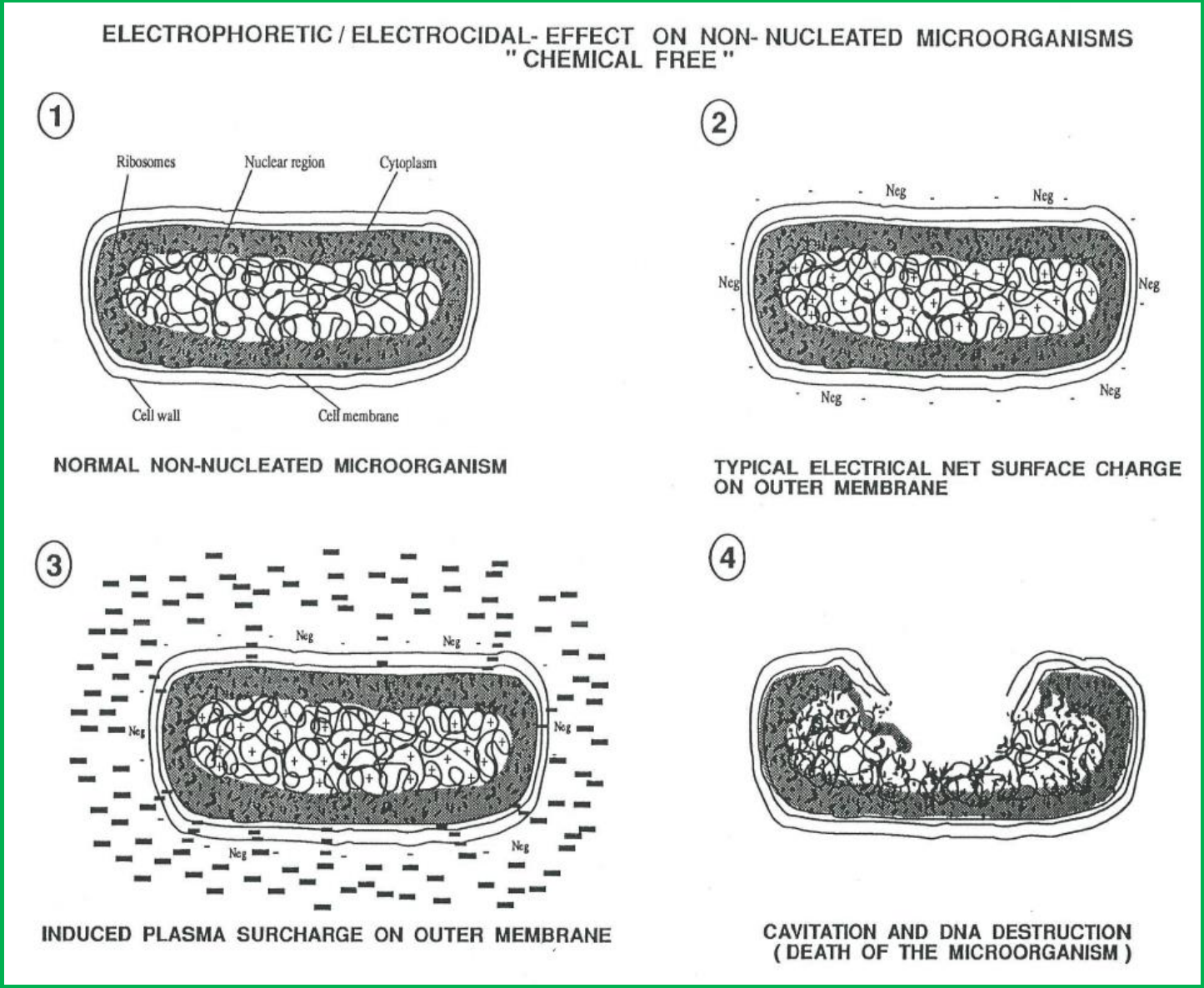
	Fecal Coliforms (CFU/ml)	Enterococci (CFU/ml)
Before EC	**1,000,000**	**1,000,000**
After EC	**ND**	**ND**

Data Source: Rosario and Adkinson

Bacteria Cell Walls are Broken



Cell Contents are Denatured



50 gpm

Cyanobacteria and Toxins Destruction

Celina, Ohio Grand Lake Drinking Water

Mono Species of Planktatherix (Neurotoxic Species) Cyanobacteria

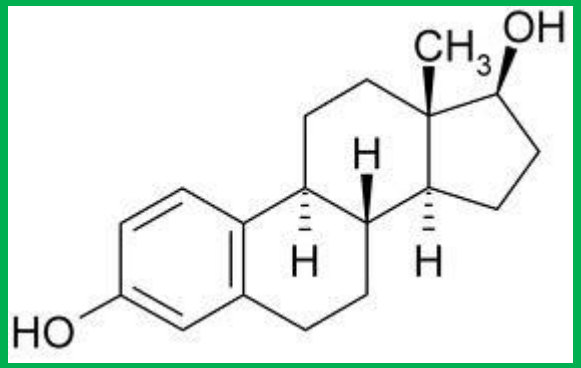
Raw Lake Water **97.1 ug/l was reduced to 0.001 ug/l** with Powell EC

Virus Destruction

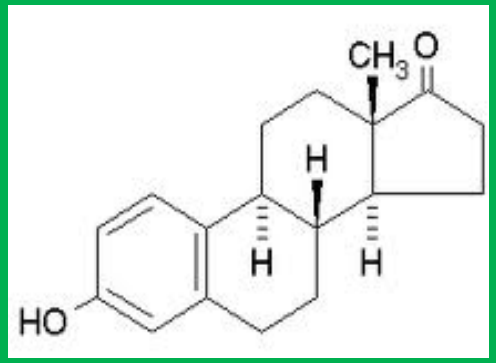
	Phage, *E. coli* (Pfu/ml)	**Phage, *B. subtilis* (Pfu/ml)**	**PMMoV (copies/ml)**	**HPyV (copies/ml)**
Before EC	**12,800**	**2,220**	**60,100**	**100,000**
After EC	ND	ND	ND	ND

Data Source: Rosario and Adkinson

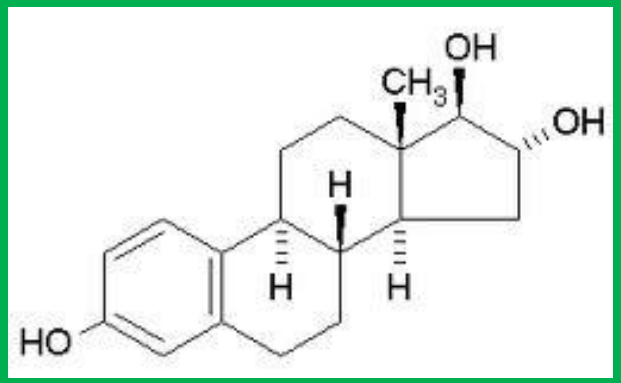
Estrogenic Endocrine Disruptors



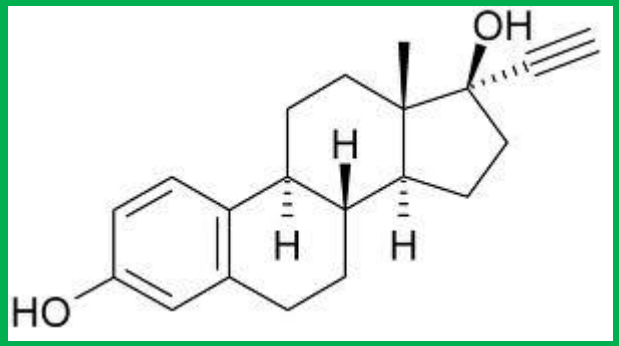
Estradiol



Estrone



Estriol



Ethinyl Estradiol

Deformed white sucker fish with both male and female sex tissue have been discovered near Colorado wastewater treatment plants on the South Platte River and Boulder Creek. Female fish far outnumber the male fish near the plants.

https://www.chron.com/news/nation-world/article/Discovery-of-deformed-fish-scares-scientists-1679259.php

Swine Production Facility

A 5,000 head Swine Facility uses 6,000,000 gallons of water per year (16,438 gpd).

Swine lagoon water is an excellent fertilizer

Total Nitrogen	0.617%	6,170	mg/l
Organic Nitrogen	0.166%	1,660	mg/l
Ammonium Nitrogen	0.450%	4,500	mg/l
Nitrate Nitrogen	<0.001%		
Phosphorus	0.089%	890	mg/l
Phosphorus as P2O5	0.204%	2,040	mg/l
Potassium	0.365%	3,650	mg/l
Potassium as K2O	0.438%	4,380	mg/l
Moisture	93.000%	930,000	mg/l
Total Solids	7.000%	70,000	mg/l
Organic Matter	5.500%	55,000	mg/l
Ash	1.500%	15,000	mg/l

Problems using Swine Lagoon fertilizer

Crop growing season limits the time lagoon water can be applied to the ground. **One year holding time in the lagoons.**

Limits on nitrogen and phosphate allowed per acre by government regulation. **Purchase additional land with pipeline for irrigation.**

Weather events that overflow the lagoon causing environment concerns down stream. **Put a roof over the lagoon.**

Odor associated with lagoons. **Spray Rose Oil to mask the lagoon odor.**

Powell Water Micro Algae System Solution

Reduction of nitrogen and phosphate **without water reuse**.

Constituent	gal / day	Reduction
Water to Land	15,288	7.00%
Organic Nitrogen	0	100.00%
Ammonium Nitrogen	0.15	99.45%
Phosphorus	0.15	99.80%
Potassium	55	0.00%
Ash insoluble	0	

99% reduction in the amount of land required for lagoon water disposal. Water disposal reduced by 1,150 gpd.

Powell Water Micro Algae System Solution

Reduction of nitrogen and phosphate **wash water reuse**.

Constituent	gal / day	Reduction
Water	2,137	87.00%
Organic Nitrogen	0	100.00%
Ammonium Nitrogen	0.15	99.97%
Phosphorus	0.15	99.97%
Potassium	55	87.00%
Ash insoluble	0	

99% reduction in the amount of land required for lagoon water disposal. Water disposal reduced by 14,300 gpd.

Covered lagoon under floor

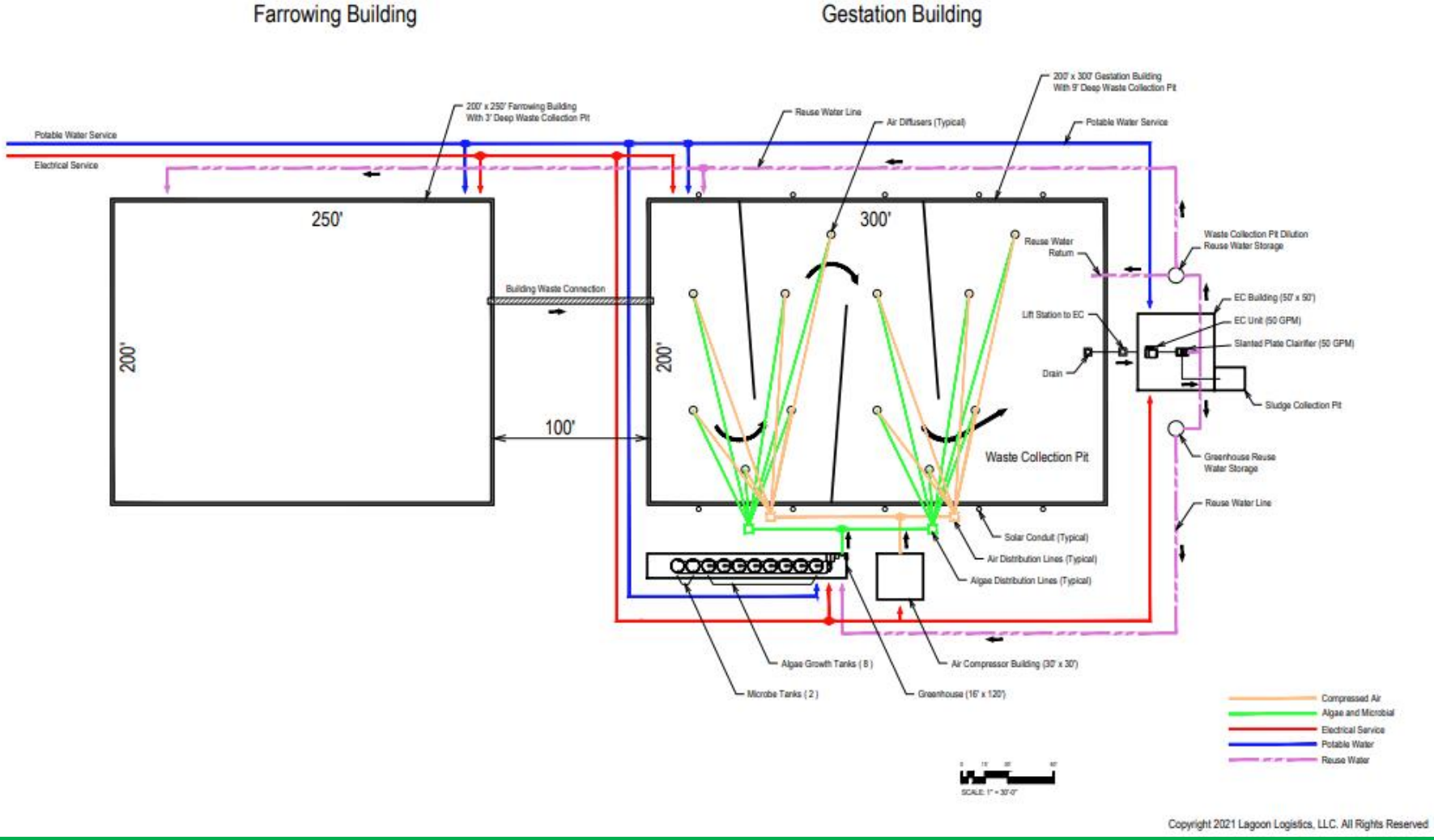
Slated Floor to Drain Water from Swine

One Year Liquid Storage Under the Floor

One Year Liquid Storage Under the Floor

Fans to pull air into the facility and expel toxic fume buildup under the floor

PWMAS Under The Existing Building



PWMAS Advantage

Oxygen Gas replaces toxic Methane, Ammonia, Carbon Dioxide and Hydrogen Sulfide under the floor.

Odor is eliminated because oxygen is up to 20 mg/l.

Land irrigations needs is reduced because of nitrogen and phosphate reduction by PWMAS.

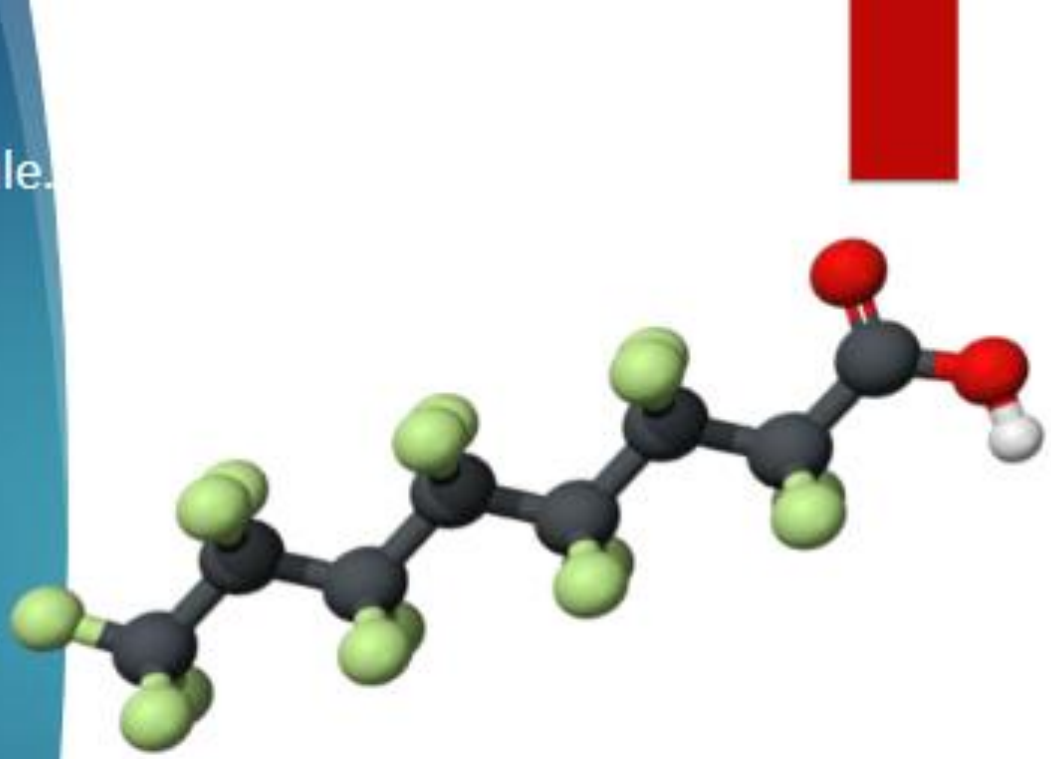
Capital cost of the PWMAS is less than land purchase price savings.

Operating cost is reduced by solids disposal Savings.

This 3D model of a PFO**A** (perfluorooctanoic **acid**) molecule.

This is the acid form of PFOS.

- Gray spheres represent *carbon atoms* linked together in a chain; there are eight of them, so "octane" is used in the name.
- Green spheres represent *fluorine atoms* bonded to carbon atoms.
- Red spheres represent *oxygen atoms.*



PFOA PFOS PFAS

Oil and Water Repellency, Temperature Resistance, Friction Reduction

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Wastewater Technician/Trainer
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Tallahassee, FL 32309
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PFOA PFOS

Powell Water	PFOA Liquid ng/l (ppt)	% Removal Liquid	PFOA Solids ng/l (ppt)	PFOS Liquid ng/l (ppt)	% Removed Liquid	PFOS Solids ng/l (ppt)
Landfill Leachate as Received	1,540			421		
Electrocoagulation + H_2O_2	< 3.97	99.74%	70	< 2.36	99.44%	20

Powell Water Systems not only separates the PFAS from the water, but also destroys the PFAS in the coagulate solids. US Patent No. 8,048,279

Fluoride Carbon Bond Destruction in the Solids- One of the Strongest Single Bonds in Chemistry

Powell Water	PFOA Liquid ng/l (ppt)	% Removal Liquid	PFOA Solids ng/kg (ppt)	PFOS Liquid ng/l (ppt)	% Removal Liquid	PFOS Solids ng/kg (ppt)
Landfill Leachate as received	**1,540**			**421**		
Electrocoagulation Aluminum Blades	**193**	**87.47%**	**31,900**	**11.1**	**97.36%**	**8,230**
Electrocoagulation Iron and Aluminum	**284**	**81.56**	**12,600**	**11.6**	**97.24%**	**3,390**
Electrocoagulation Iron H2O2	**< 3.97**	**99.74%**	**70**	**< 2.36**	**99.44%**	**20**

EPA Proposed Regulation Limit for PFOA & PFOS is 4 ng/l (ppt)

Fluoride Carbon Bond Destruction Bureau of Reclamation

Bureau of Reclamation owns and operates (BGNDRF) in Alamogordo, NM

Four groundwater wells used for supply of brackish water to desal research trains and three evaporation ponds to store spent brine

Salinity of these wells range from 1,000 to 6,000 mg/L total dissolved solids (TDS)

2 of the 4 wells are contaminated with PFAS and were bench tested by Garver on 7/27/22. Well 2 and Evaporation Pond (EP)

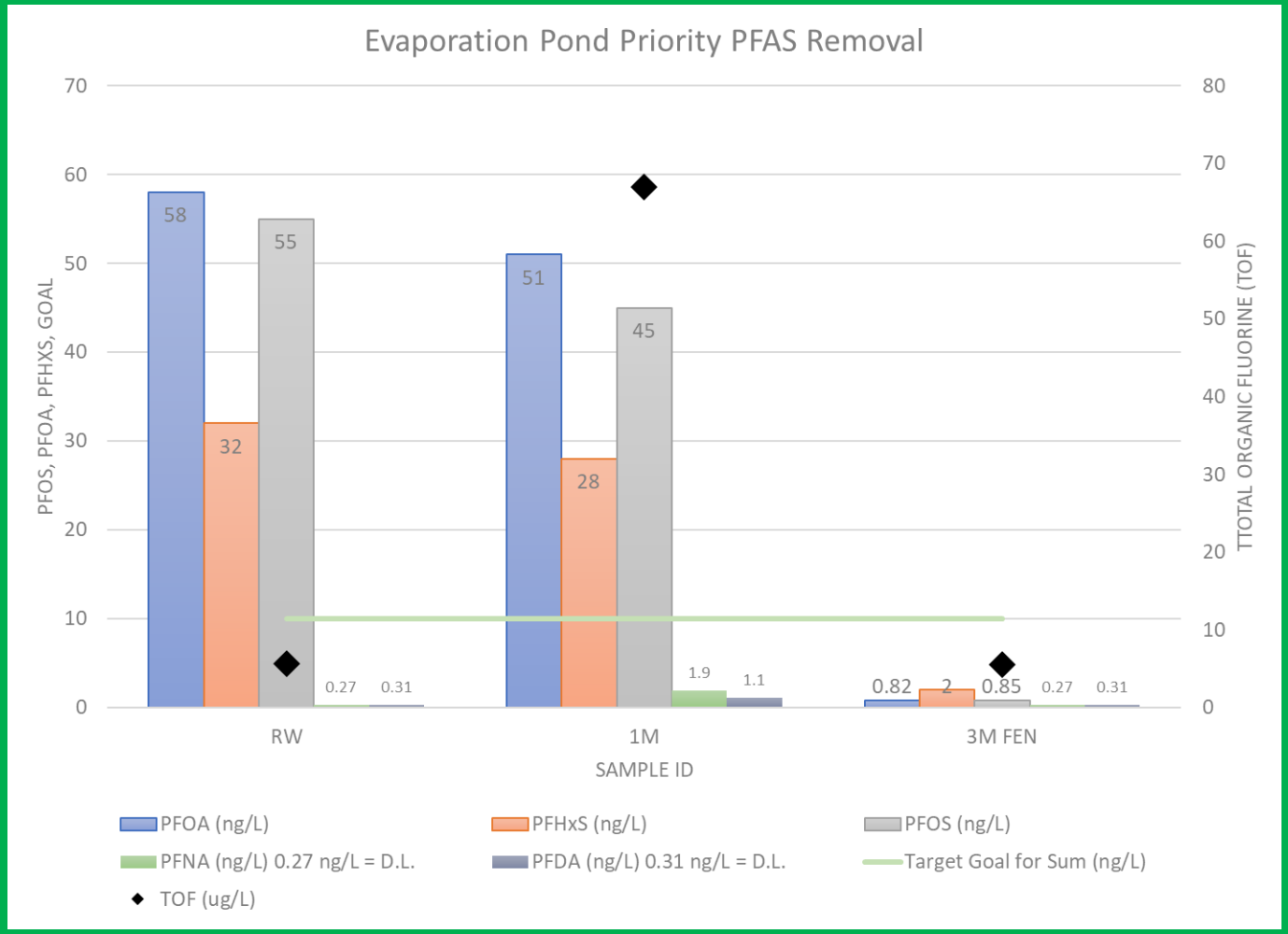
Problem

Due to NM regulations the facility's discharge permit no longer allows any water with PFAS to enter the sewer adding stress to the evaporation ponds capacity

BUREAU OF RECLAMATION

EP – Lab Data

- **Longer, E-Fenton run time resulted in better removal for PFOA, PFOS, PFHxS, PFDA and PFNA**
- **1M FEN led to 255% to 600% increase in PFDA and PFNA**
- **3M FEN brought PFNA and PFDA back to ND**
- **TOF increase in 1M Centrate samples may be indicator of C-F destruction**



BUREAU OF RECLAMATION

Eric Dole @ Garver 602 881 0186

EPA Proposed Regulation PFOS PFOA is less than 4 ppt

PFAS Destruction on a Commercial Scale

Costs for electrocoagulation treatment meeting MCL-TCLP criteria are less than comparable treatments which only capture PFAS for final expensive destruction through incineration, encapsulation, of deep well injection.

The Powell electrocoagulation system can be permanently installed, or skid mounted trailers for treating water on a short-term basis.

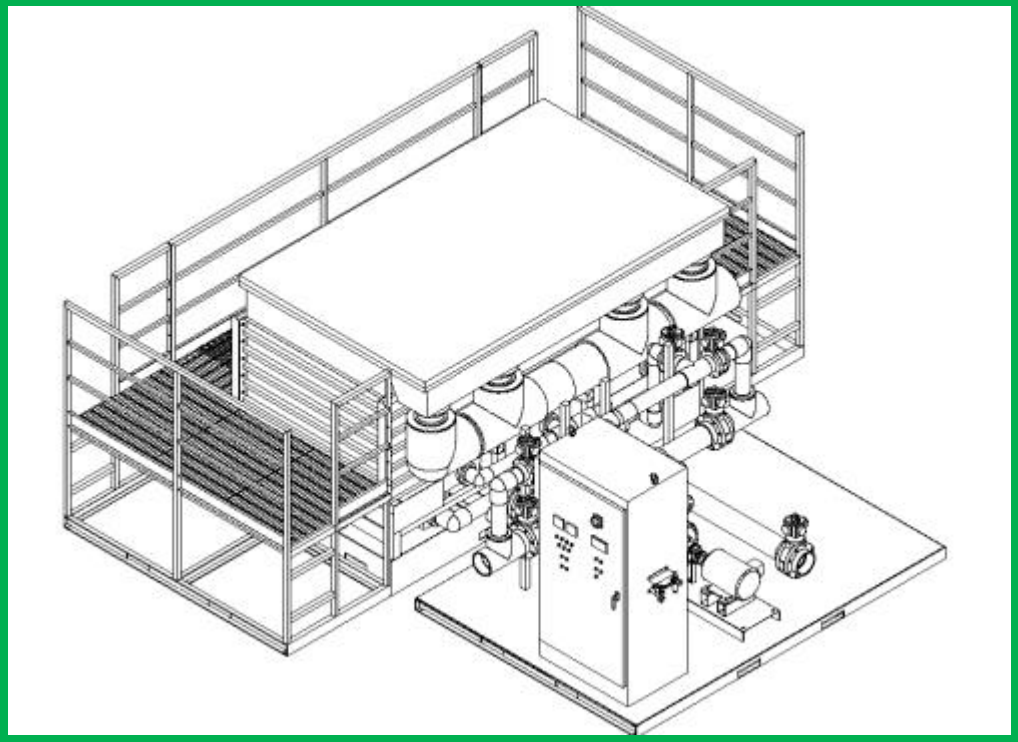
Powell Water Systems Inc systems are operating in the United States and many countries around the world.

Chemical Lime Softening Compared to Powell Electrocoagulation for Steam Assisted Heavy Crude Oil Extraction.

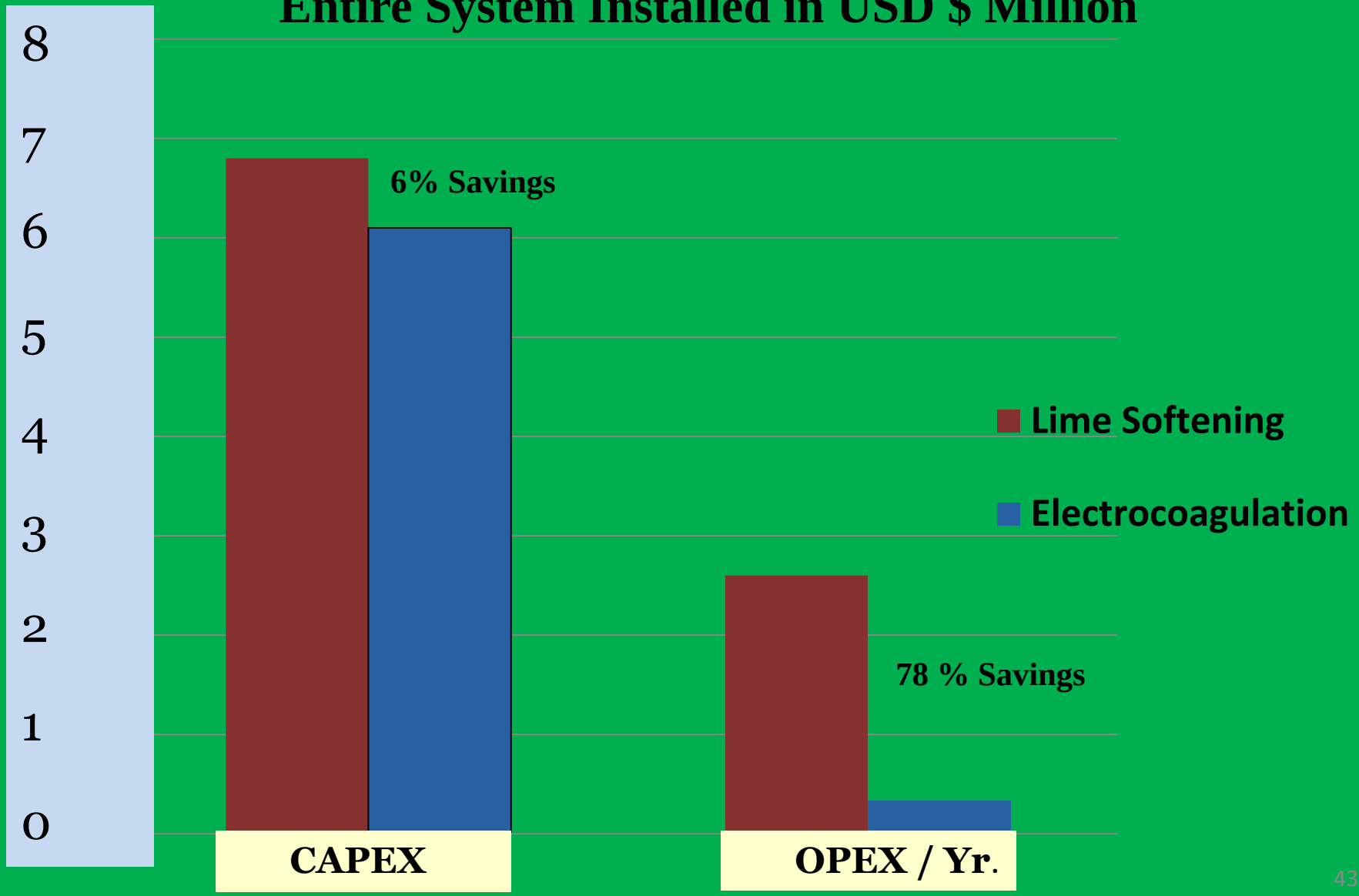
As a practical mater the most difficult aspect of Lime Softening is the truck traffic flow to haul in the lime and haul away the coagulated solids.

If you do not add contaminates to the water, you do not need to remove them from the water.

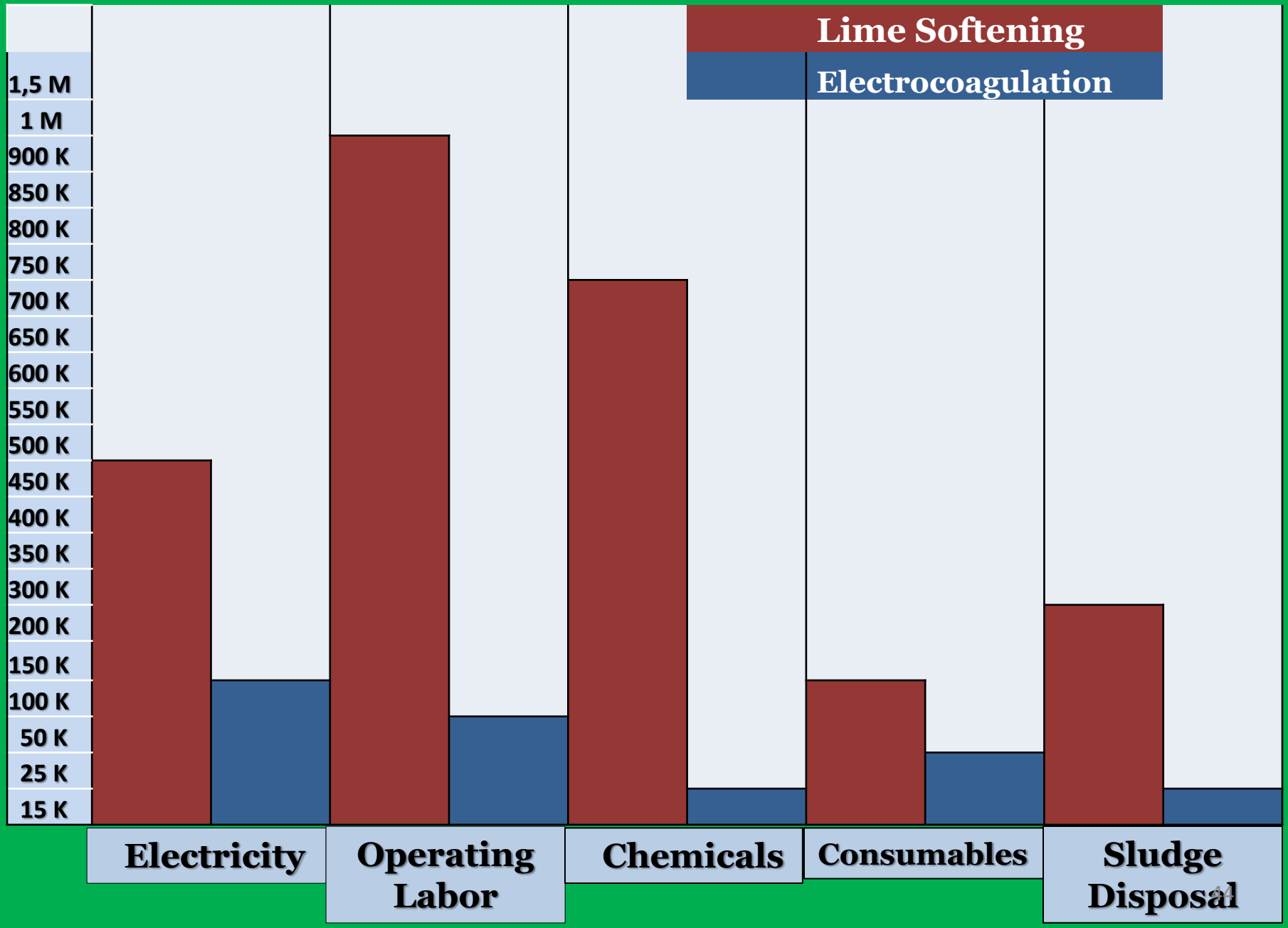
Powell 500 gpm EC Assembled skid is 18 ft by 17 ft, 7 ft tall



500 GPM Lime Softening vs. Electrocoagulation
CAPITAL EXPENSE – OPERATING EXPENSE
Entire System Installed in USD $ Million



Operating Expense /Yr. (OPEX)



We need to change the way we approach water softening treatment

Traditionally: we try to solve one water treatment problem at a time, and we ignore the overall consequences of the traditional water treatment step.

For example: Hard water in out homes block our pipes, makes our skin uncomfortable after bathing, and makes washing our clothes more difficult.

Traditional Solution: Ion exchange water softening removes calcium, magnesium, and hardness from the water used in the house.

Unintended problem: The added Total Dissolved Solids (TDS) being discharged back into the river makes it more difficult for the cites down stream to make drinking water! The problem is compounded in each city.

Innovative Solution: Municipal Electrocoagulation, at the well head before potable water distribution, will remove calcium, magnesium, and hardness, in a solid form, with clean electricity, eliminating the need for in home ion exchange water softening.

Overall Benefit: Soft Water in every home in the city. Less cleaning product TDS added to sewer. Cleaner softer drinking water for the city downstream.

Well Water Eastern Colorado City

Table 1: Summary of Potable Water Quality (all wells combined, samples collected between January and March 2020)			
Parameter	Unit	Average	Maximum
TDS	mg/L	268	295
pH	s.u.	7.5	8.0
Alkalinity	mg/L as CaCO3	141	157
Calcium	mg/L	105	121
Magnesium	mg/L	35	50
Hardness	mg/L as CaCO3	407	506
Sulfate	mg/L	11	14
Chloride	mg/L	10	12

Hardness Classification as Calcium Carbonate in mg/l

Soft water	less than 17	Hard water	121 to 180
Slightly hard	17 to 60	**Very hard**	**above 181**
Moderately hard	61 to 120	**This city**	**407 mg/l**

City Wastewater Entering the Sewer

Table 2: Summary of Influent Wastewater Quality (samples collected between January and March 2020)			
Parameter	Unit	Average	Maximum
TDS	mg/L	553	611
pH	s.u.	8.0	8.6
Alkalinity	mg/L as CaCO3	300	348
Calcium	mg/L	135	229
Magnesium	mg/L	38	60
Hardness	mg/L as CaCO3	493	819
Sulfate	mg/L	13	27
Chloride	mg/L	95	135

Environmental Protection Agency (EPA) **National Secondary Drinking Water Regulations for Total Dissolved Solids (TDS) is 500 mg/l**

TDS Increases From Wells to Sewer

TDS increase	285 mg/l	**106%**
Calcium increase	30 mg/l	29%
Magnesium increase	3 mg/l	9%
Sulfate increase	2 mg/l	18%
Chloride increase	85 mg/l	**850%**

Colorado Department of Public Health and Environment (CDPHE) would like a Total Dissolved Solids (TDS) reduction of 150 to 200 mg/l

Home Water Softeners Add TDS

Ion exchange water softeners add two Sodium ions and two chloride ions into the home water for each Calcium ion removed from the water.

To regenerate the ion exchange resin, saturated sodium chloride is used. The sodium, chloride, magnesium, calcium, and hardness is returned to the water going to the sewer plant.

In home water softeners added 85 mg/l chloride & 55 mg/l sodium, or **140 mg/l TDS** to the well water entering the home creating sewer water leaving the home.

Softening Well Water with Electricity

Calcium removal at 90% of 105 mg/l	94 mg/l
Magnesium removal at 90% of 35 mg/l	32 mg/l
Total TDS removed as solids	126 mg/l
Sodium Chloride that was not added	140 mg/l
Effective reduction of TDS at sewer	266 mg/l

CDPHE TDS desired reduction is 150 to 200 mg/l

If you do not add the Sodium Chloride to the water in the home, you do not need to take it out at the sewer.

Every Home benefits from Soft Water.

The Towns Down Stream receive Soft Water.

Evaporative Cooling

When water changes from a liquid to vapor 967 BTU / pound is required.

We naturally cool our bodies as our skin produces water droplets that evaporate.

As the water vapor evaporates solids in the liquid water concentrates.

Cooling Towers evaporate water vapor to cool the remaining water liquid.

This works great until the solids concentrated in the water plate out on the cooling tower.

The problematic solids include Silica, Phosphates, and Dust.

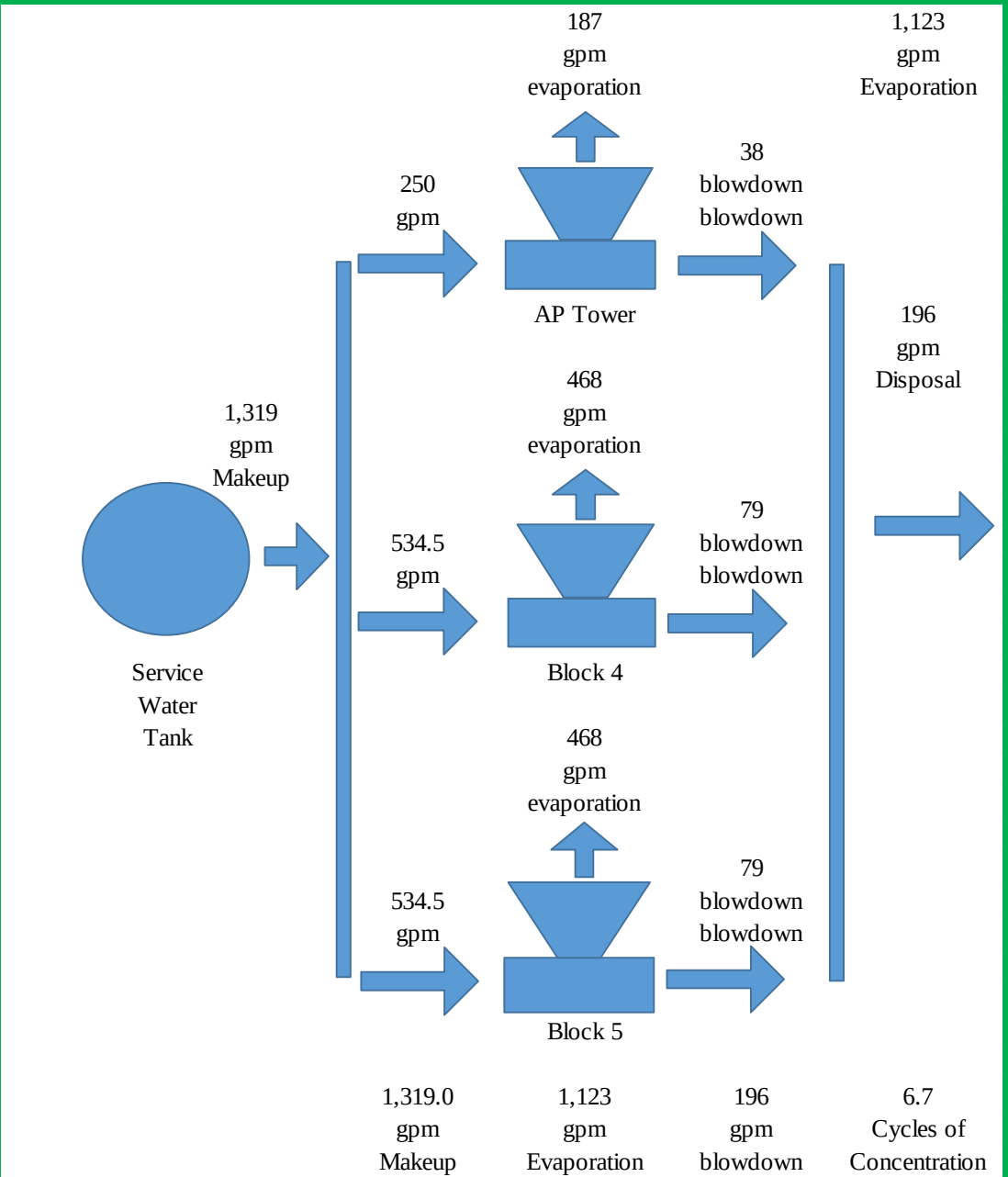
The annoying solids include Calcium, Magnesium, and Hardness.

The lease offensives include Sodium and Chloride.

BTU = British Thermal Unit: The amount of heat required to raise 1 pound of water 1 degree Fahrenheit (F).

1 Ton of cooling = 12,000 BTU/hour

Cooling Towers



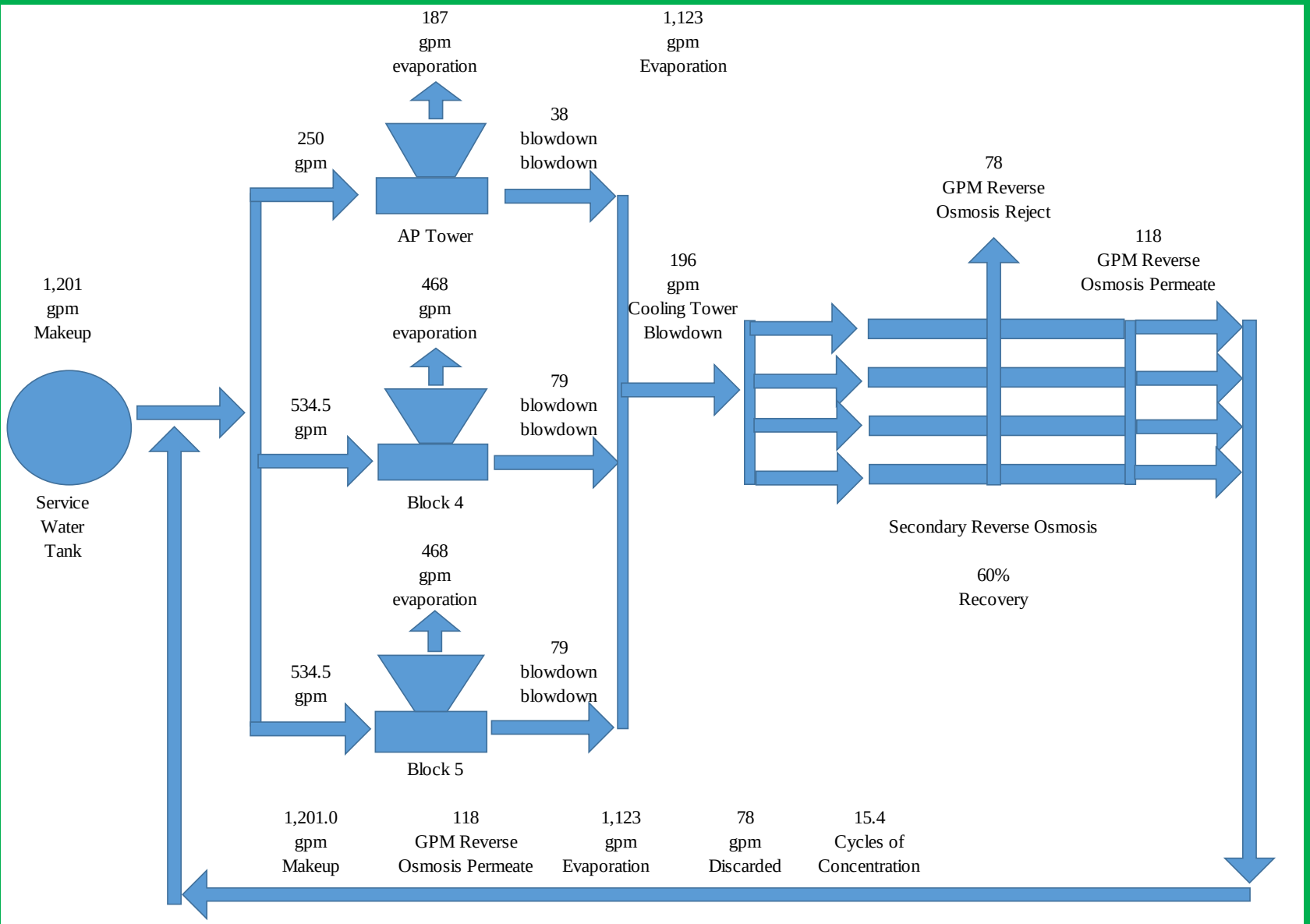
Natural Gas Electrical Generation Facility

	GPM	Percent
Service Water	1,319	100.00%
Cooling Process	1,123	85.14%
Discarded Water	196	14.86%

Zero Liquid Discharge

196 GPM Evaporation Ponds

6.7 Cycles



Cooling Tower with Reverse Osmosis

15 Cycles

Reverse Osmosis benefit:
118 gpm recovery for evaporation
78 gpm as disposal water

Zero Liquid Discharge
78 GPM Evaporation Ponds

Sparingly Soluble Salts Removed as Solids

Remove the **Silica, Phosphate**, and Dust from the cooling tower blowdown water between the cooling tower and reverse osmosis.

This allows a higher Reverse Osmosis Permeate percentage.

This reduces the amount of Reverse Osmosis Reject going to the evaporation disposal pond allowing Zero Liquid Discharge

Powell Electrocoagulation removes the silica and phosphate after cooling tower concentration and before ultra filtration.

Silica reduced from **110 to 1.4 mg/l** with EC

95% Recovery

Two 500 gpm EC Systems in Parallel

Electrocoagulated, Ultra Filtration Reject Water is Pulled into a Vacuum Tower

Coagulated solids are pumped into a dumpster at 23% solids by weight.

The solids continue to dewater over time.

Solids Handling

"When compared with alum treatment, electrocoagulation provided approximately **83% less sludge** volume and a **76% improvement in filtration rate."**

***EPA** / 540 / S-937504 September 1993 Emerging Technology*
Summary, Superfund Innovative Technology Evaluation

Innovative Alternative

- Remove the **Silica and Phosphate by 95%** from the service water.
- Remove the **Calcium, Magnesium, and Hardness by 90%** from the service water.
- After evaporating the water in the cooling tower by 90%, return the remaining 10% with the concentrated solids to be blended with the service water for Powell Electrocoagulation and coagulated solids separation.

Service Water to Cooling Tower

Gas Fired Electrical Generation	Water quality on 2/27/2020				
	Raw		Blowdown		Concentration
	Service		EQ		difference
Metals	Water		Tank		EQ / Service
Calcium (Ca) mg/l	40.6		250.3		6.17
Calcium (CaCO3) mg/l	**101.5**		**625.8**		**6.17**
Magnesium (Mg) mg/l	10.1		61.5		6.09
Magnesium (MgCO3) mg/l	41.6		253.4		6.09
Sodium (Na) mg/l	14.7		148.1		10.07
Potassium (K) mg/l	8.0		20.8		2.60
Silica (Si) mg/l	2.7		18.1		6.70
Silica (SiO2) mg/l	**5.8**		**38.7**		**6.67**
Phosphate (P) mg/l	0.0		4.3		
Iron (Fe) mg/l	0.0		0.1		
Boron (B) mg/l	0.0		0.3		
Anions					
Fluoride (F-) mg/l	0.7		5.0		7.14
Chloride (Cl-) mg/l	11.7		131.4		11.23
Nitrite (NO2) mg/l	0.7		0.0		0.00
Sulfate (SO4) mg/l	**78.6**		**975.5**		**12.41**
Bromide (Br) mg/l	0.0		0.0		
Nitrate (NO3) mg/l	3.2		20.0		6.25

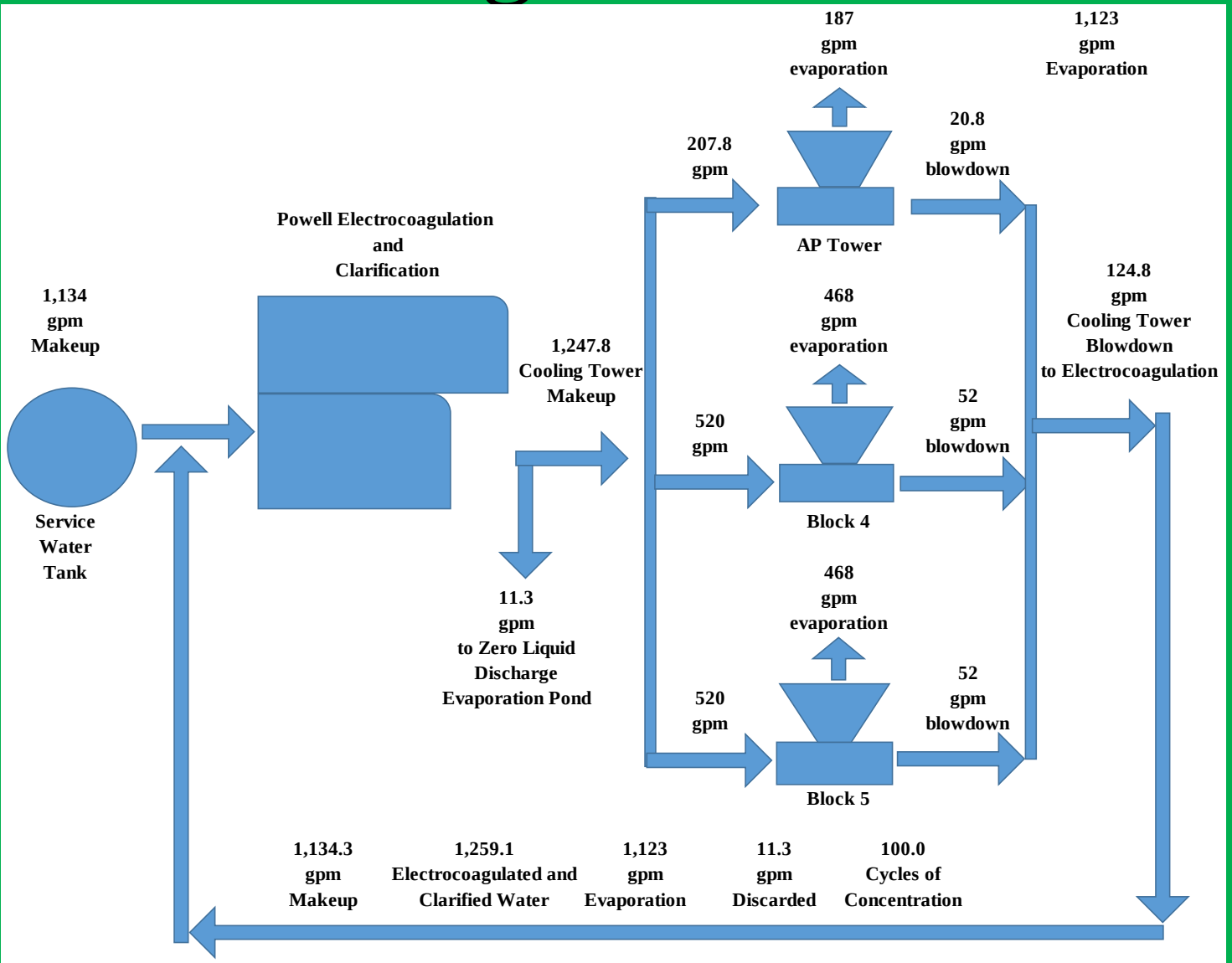
Cooling Tower chemical addition is required to keep the calcium and magnesium from plating out on the cooling tower.

The added sulfate is more than the calcium.

Silica increased by evaporation by 6.7 times.

Sulfate increased 12.41 times because of chemical addition.

Service Water to Powell Electrocoagulation to Cooling tower



Zero Liquid Discharge **11.3 GPM** Evaporation Ponds.

100 Cycles of Concentration

Blowdown Water after 100 Cycles

Gas Fired Electrical Generation	Raw Service		100 Cycles Blowdown		% in Raw Service
Metals	Water		11th pass		Water
Calcium (Ca) mg/l	40.6		40.6		100%
Calcium (CaCO3) mg/l	101.5		101.5		100%
Magnesium (Mg) mg/l	10.1		10.1		100%
Magnesium (MgCO3) mg/l	41.6		41.6		100%
Sodium (Na) mg/l	14.7		1,584.0		10776%
Potassium (K) mg/l	8		728.0		9100%
Silica (Si) mg/l	2.7		1.9		72%
Silica (SiO2) mg/l	5.8		3.9		67%
Phosphate (P) mg/l	0		0.0		
Iron (Fe) mg/l	0		0.0		
Boron (B) mg/l	0		0.0		
Anions					
Fluoride (F-) mg/l	0.7		70.0		10000%
Chloride (Cl-) mg/l	11.7		1,170.0		10000%
Nitrite (NO2) mg/l	0.7		31.0		4424%
Sulfate (SO4) mg/l	78.6		1,302.9		1658%
Bromide (Br) mg/l	0		0.0		
Nitrate (NO3) mg/l	3.2		19.2		600%

Problematic Ions like **Silica and Phosphate** are less than Raw Service Water

Annoying Ions like **Calcium, Magnesium, and Hardness** remained the same.

Infinity Soluble ions like Sodium and **Chloride increased 100 times.**

The 100 Cycle TDS of 5,052 mg/l could be increased to 70,000 mg/l with the existing metallurgy.

Economics Reasons for Raw Service Water Treatment with Blowdown

The **operating cost** for the Powell EC system **is less than cooling tower chemical cost**.

The **capital cost** for the Powell EC system **is less than the reduction in evaporation pond construction savings.**

The existing evaporation pond is twice the salinity of sea water and sooner or later those solids will turn into a Jell.

Replacement evaporation ponds for 78 gpm, 2.3 gpm evaporation per acre, and $500,000 per acre is $17,000,000.

Powell electrocoagulation, clarification and 11.3 gpm evaporation pond is $10,000,000.

Water savings is 35,000,000 gallons per year

Red Rocks Community College

- Water Quality Management (WQM) classes start at 6pm, and meet once per week
- Varied schedules- online, remote, in-person, accelerated, etcetera
- Prior Learning Assessment- turn experience into college credit
- All courses have Training Units

RED ROCKS COMMUNITY COLLEGE
WATER QUALITY MANAGEMENT

- Certificates
- Associates of Applied Science (2 years)
- Bachelors of Applied Science (4 years)
- Chelsea Campbell; Faculty Chelsea.Campbell@rrcc.edu

Bureau of Reclamation

GARVER

For more information on this project, please contact Eric Dole.

EJDole@GarverUSA.com
303.721.6932

PROJECT PARTNERS

Desalination and Water Purification Research Program
Pitch to Pilot for Fiscal Year 2019 NO. BOR-DO-19-F017

RED ROCKS COMMUNITY COLLEGE

MICKLEY & ASSOCIATES
INTEGRATING SCIENCE AND ENGINEERING

Powell Water

LYONS FILTER company


RED ROCKS
COMMUNITY COLLEGE


MADE IN
AMERICA
17
VOLTS
AMPS
VALVE CONTROL
AUTO CONTROL
POWER CONTROL
AIR CONTROL
Powell Water
303-627-0320 • WWW.POWELLWATER.COM


the salt miner

Consistent High Quality Permeate Without Irreversible Fouling

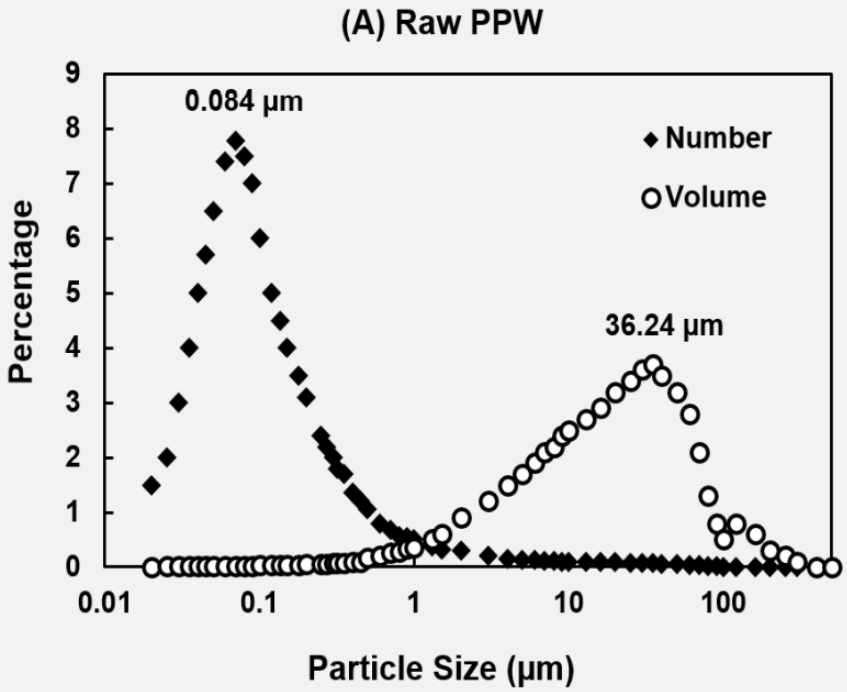
TARGET CONSTITUENT	10th Percentile			Average			90th Percentile		
	Raw Water	Filtered EC Supernatant	Permeate	Raw Water	Filtered EC Supernatant	Permeate	Raw Water	Filtered EC Supernatant	Permeate
TH as CaCO3 (mg/L)	699.7	174.3	0.1	743.38	428.68	1.38	810.4	723.4	4.86
pH	8.1	7.9	7.1	8.3	8.8	8.8	8.7	9.3	9.9
TDS (mg/L)	1683	1515	5	2848.7	1686.2	11.4	1992	1966	21.2
Silica (mg/L)	15.61	0.30	0.3	17.7	1.39	0.3	19.4	3.24	0.3
TSS (mg/L)	5.0	5	5	5.3	12.5	5	5.3	17.8	5
Total Phosphate (mg/L)	0.11	0.05	0.05	0.16	0.06	0.05	0.19	0.05	0.05
TOC (mg/L)	5.79	4.84	0.5	6.38	5.18	0.51	7.34	5.46	0.5
*ORP (mV)	180	-141.8	-182.9	194.00	-112.40	-124.60	211	-70	-61.2
*Temperature (^{o}C)	15.86	13.19	12.86	18.09	16.99	16.96	19.94	21.23	21.33
Total Coli (mpn/100 mL)	1.0	1.0	1.0	1.18	1.67	1.0	1.0	1.0	1.0
OPERATING PARAMETER	10th Percentile			Average			90th Percentile		
Energy Intensity (kWh/kgal)	39.6			44.9			51.4		
Pressure (psi)	312			346			386		
Permeat Flow (gpm)	0.72			0.80			0.86		
Perm Flux (gfd)	11.9			13.2			14.3		
Concentrate Flow (gpm)	0.80			0.88			0.97		
% Recovery 3-stg RO	43%			48%			52%		
**% Recovery Overall	49%			54%			59%		

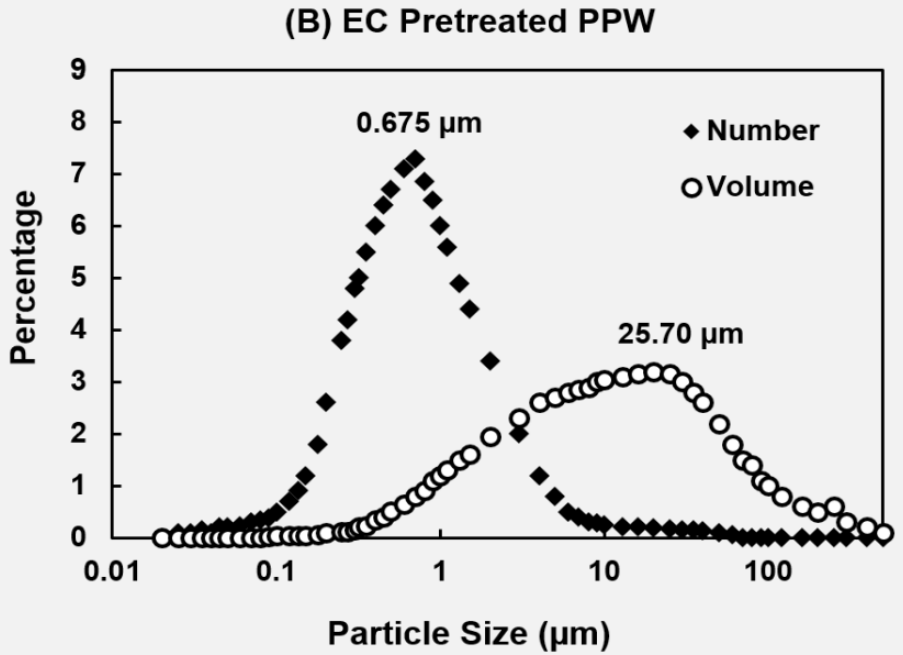
*As trended through in-line analyzers

**@ 400 ppm TDS w/ Blend

98% EC RO water recovery with implementation of recommended modifications from original test parameters

Particle Size Distribution
larger particles stay on top of the membrane

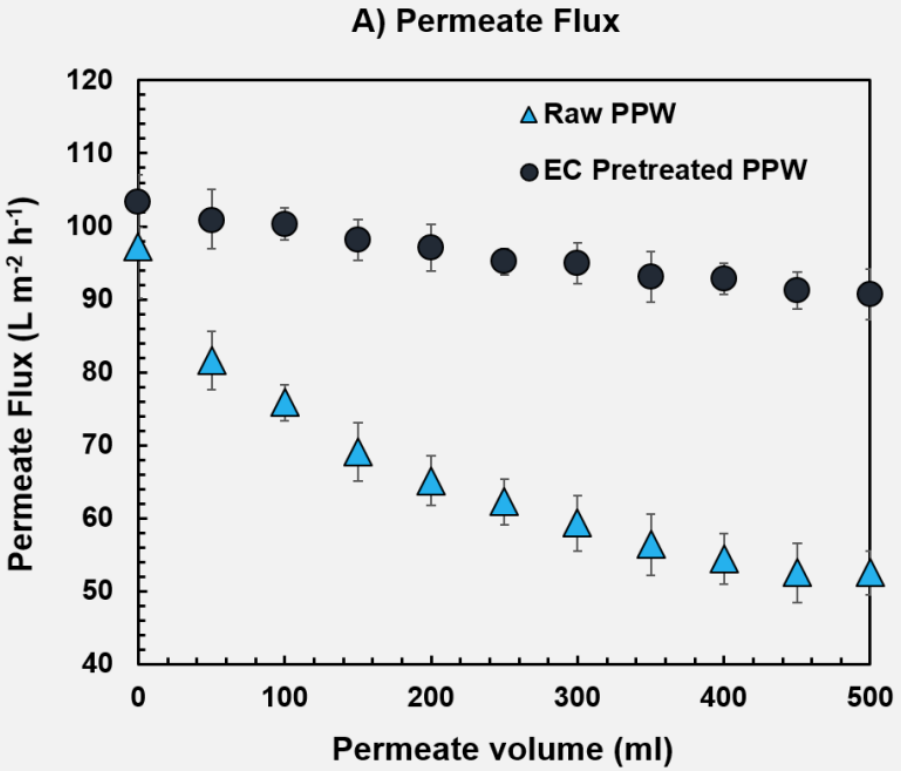


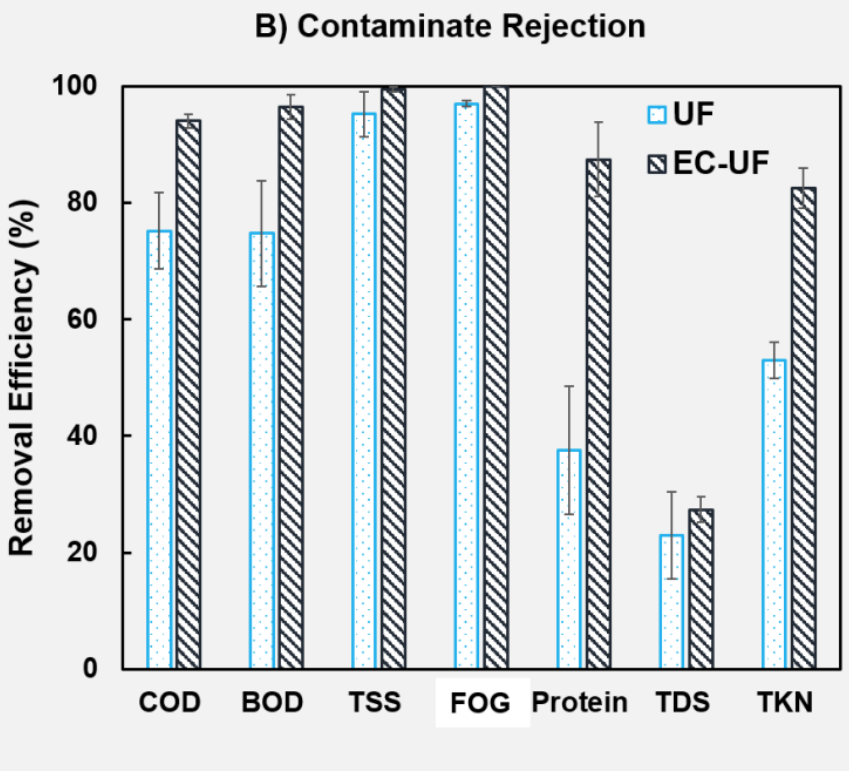


UF Membrane

UF Membrane

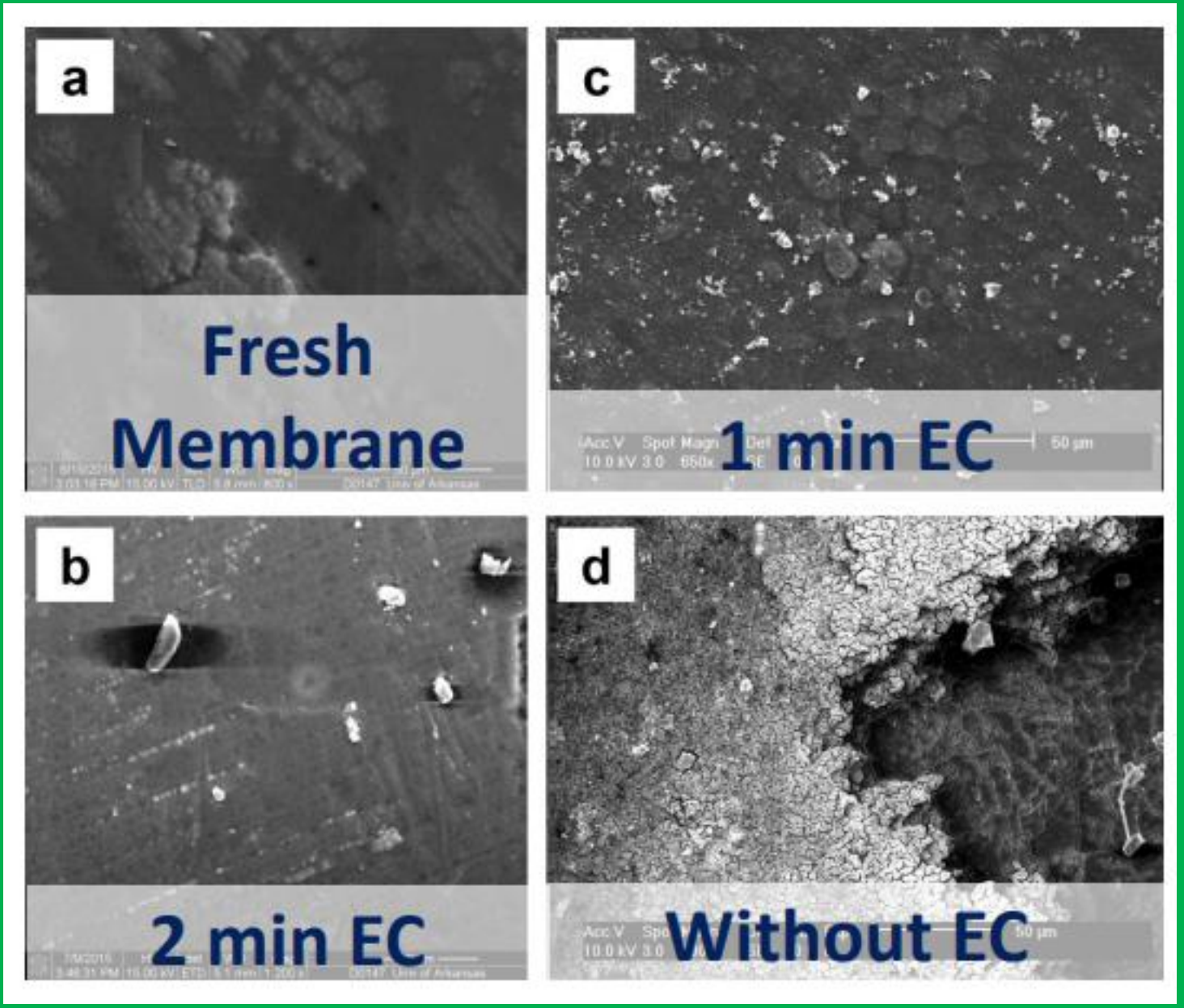
Ultra - Filtration Performance Significantly Improved With EC Pretreatment





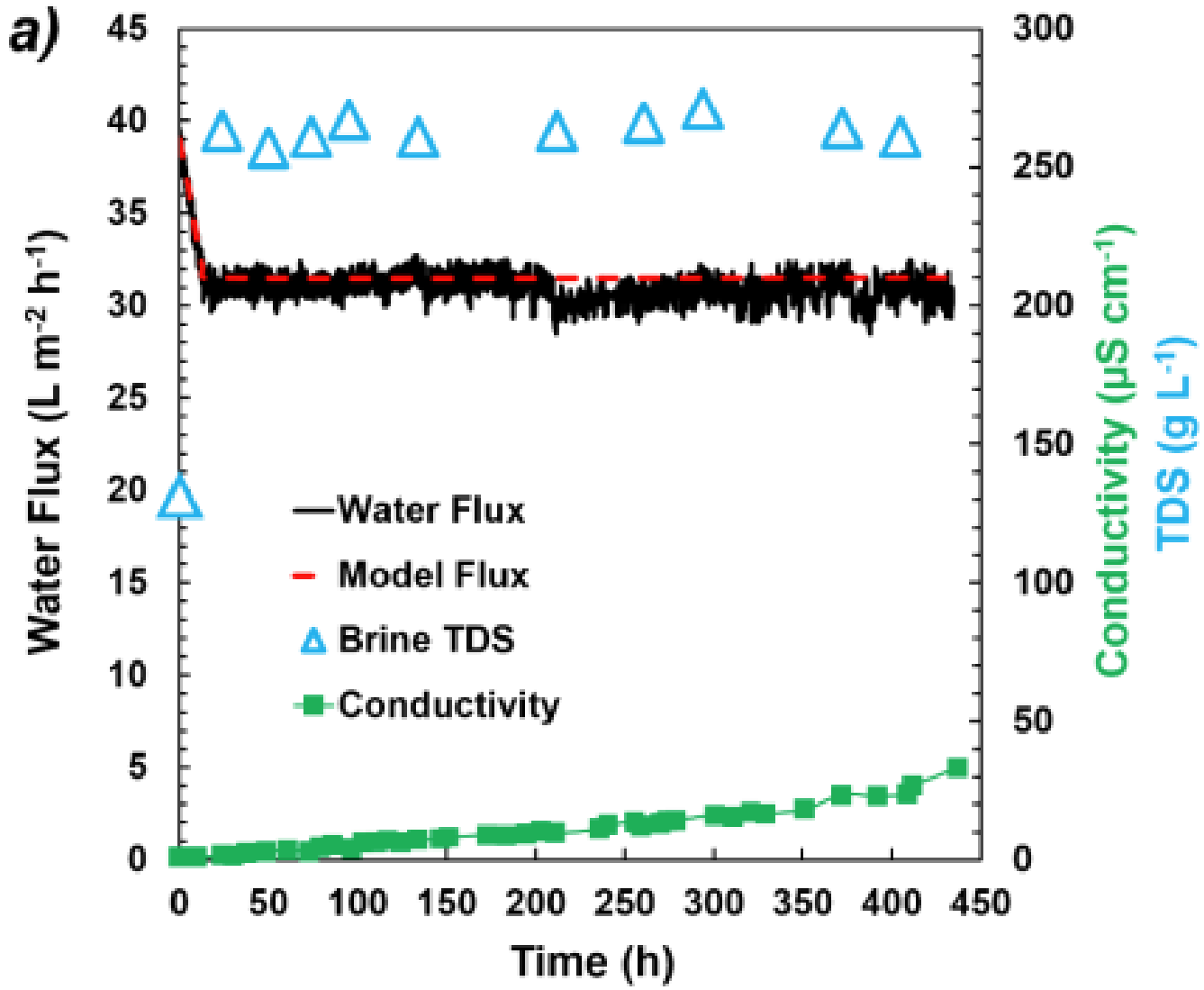
35% increase in permeate flow rate with Powell EC pretreatment

Scanning Electron Microscopy Imaging Shows Reduced Fouling via EC Pretreatment

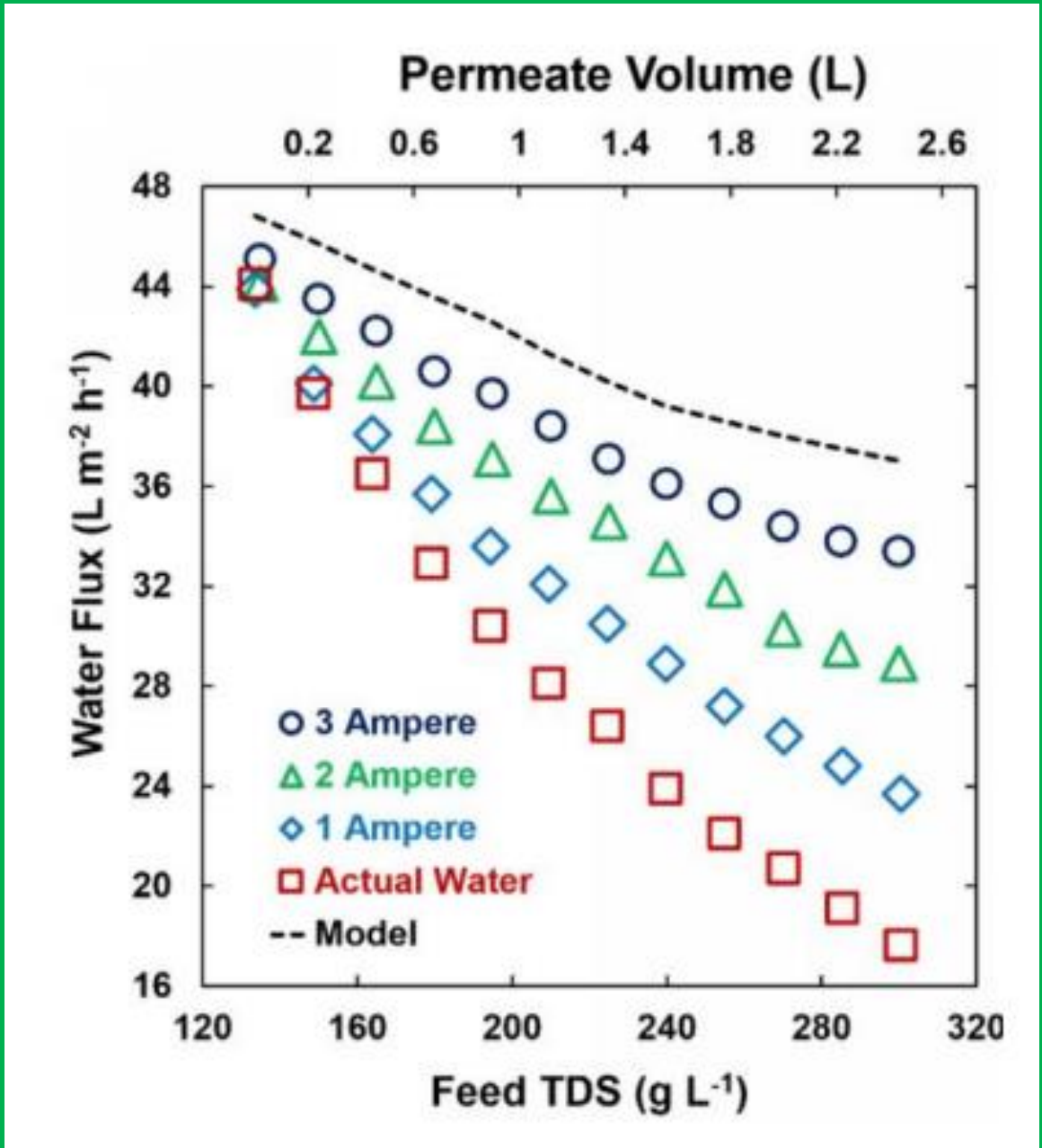


Electrocoagulated water cleans fresh membranes

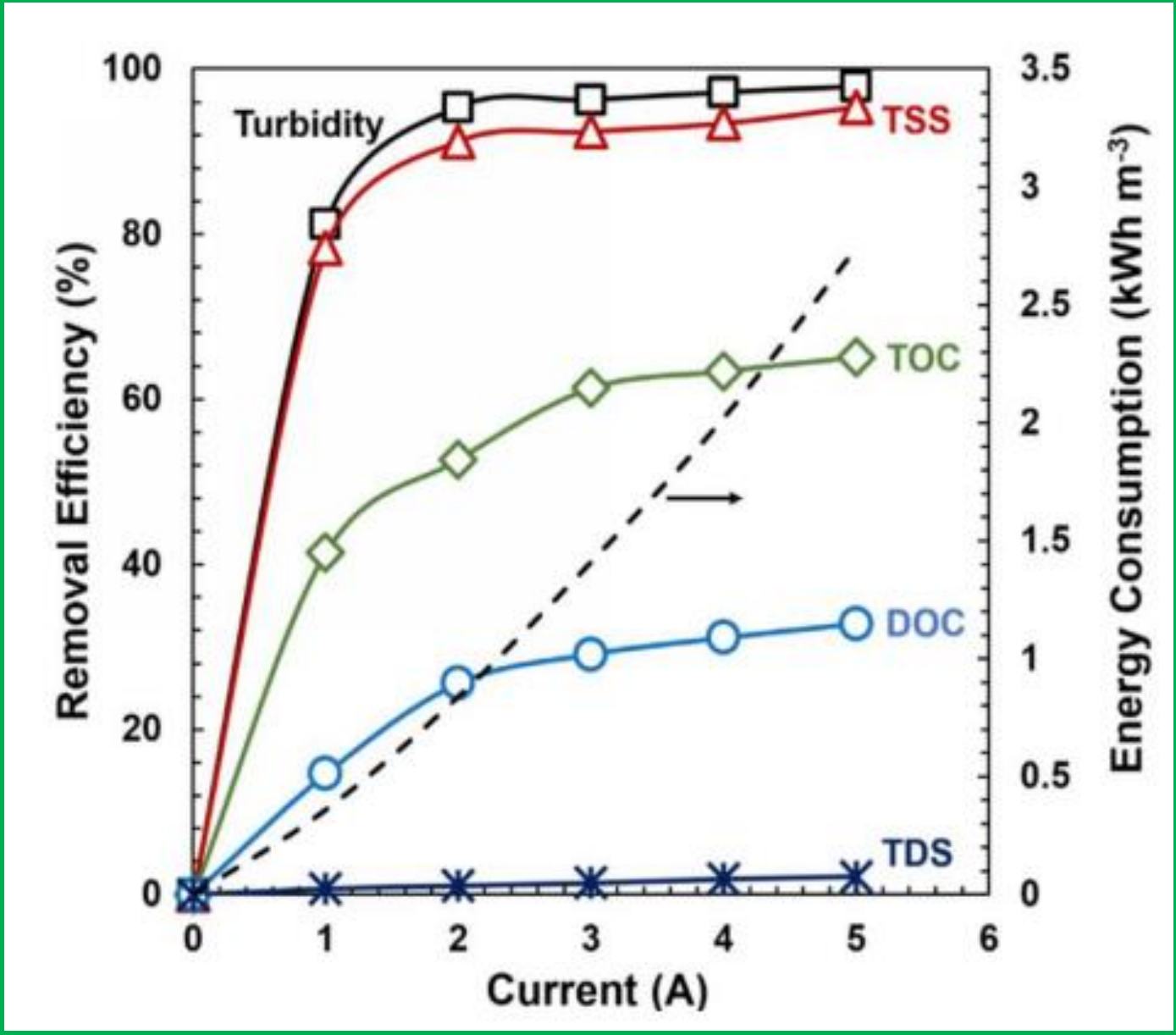
400 + Hours With No Reduction in Water Flux



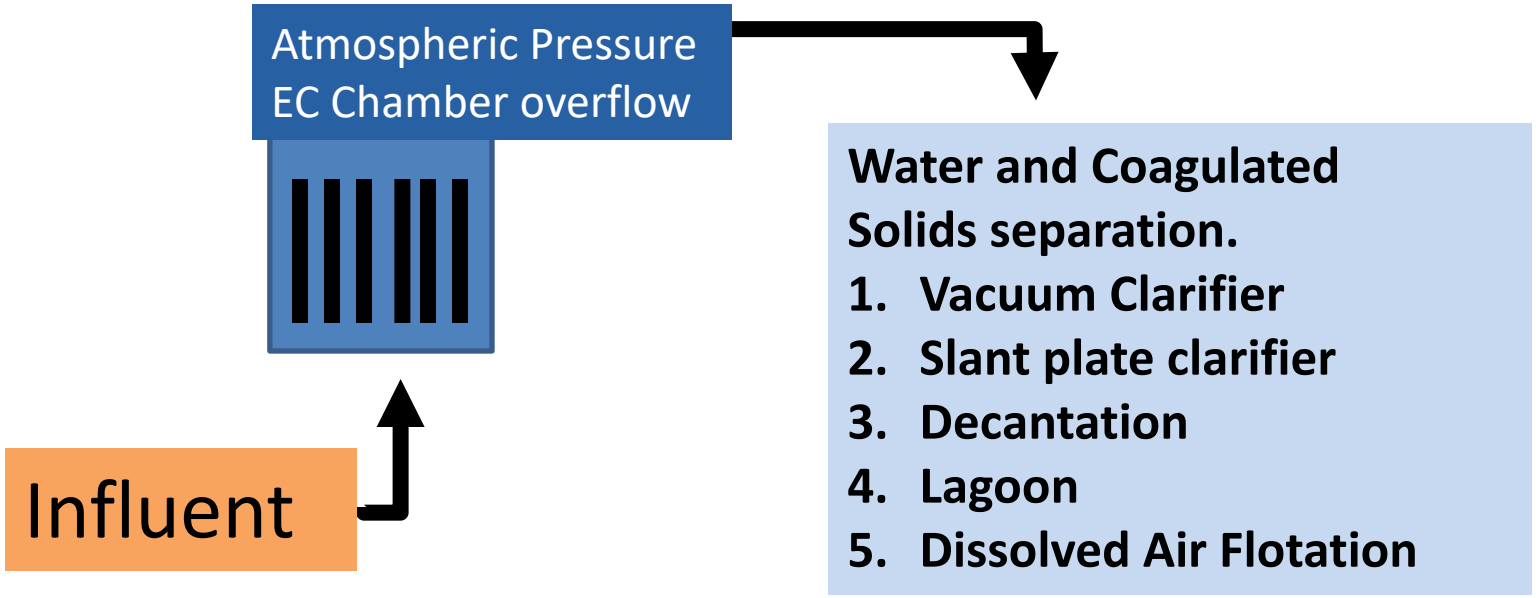
Amperage vs Flux Decline



Removal Efficiency vs Amperage



Powell Electrocoagulation Typical Flow Diagram



Atmospheric Pressure Electrocoagulation Chamber
Off the shelf dissolvable electrocoagulation blades

Powell Water Electrocoagulation

uses electricity and sacrificial metal blades/plates to coagulate solids

50 gpm Tertiary Treatment
Oklahoma WWTP

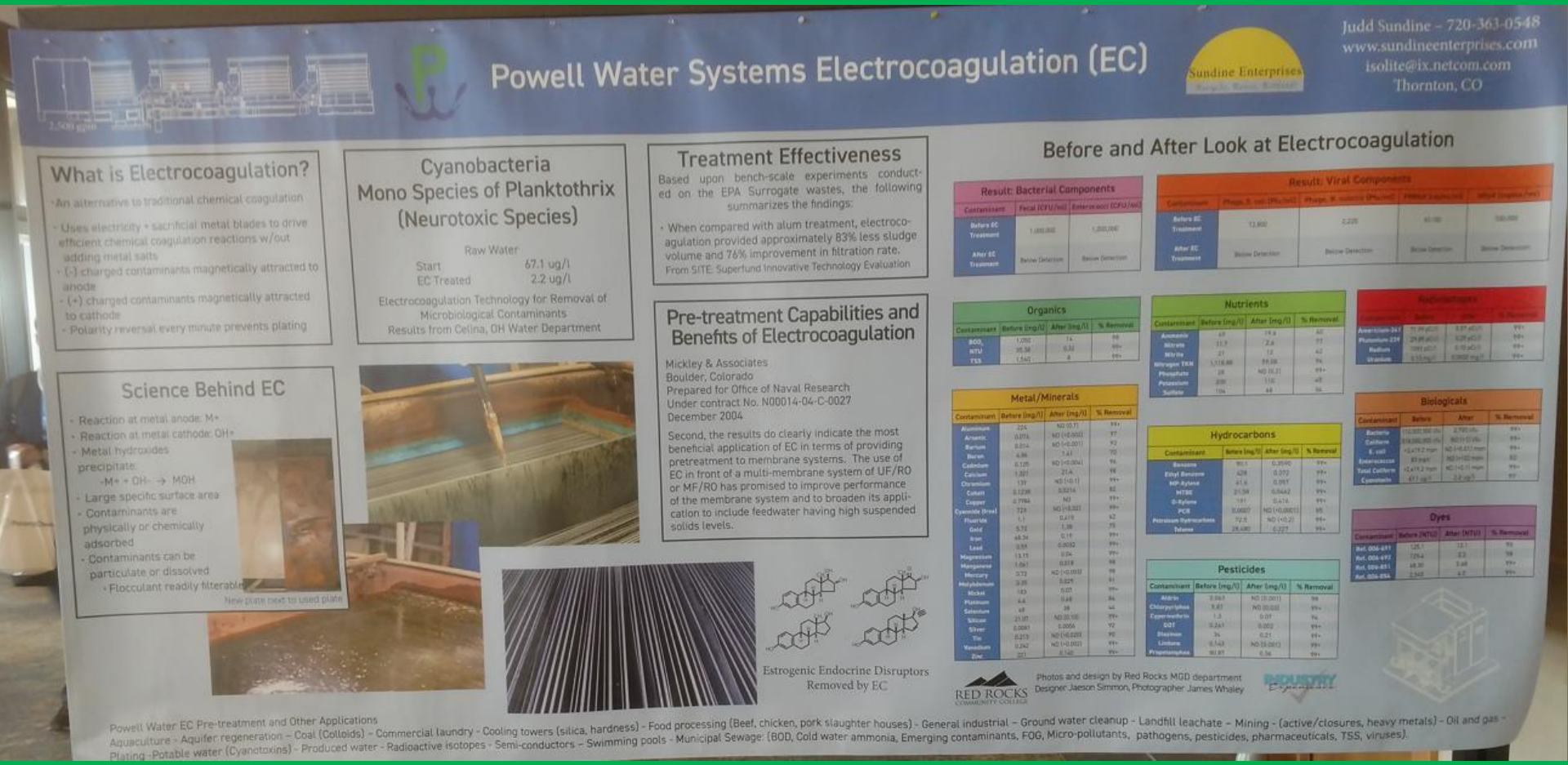
Courtesy: University of AZ Presentation "Electrocoagulation and Water Sustainability: Silica and Hardness Control" | June 26, 2008 | James C. Baygents and James Farrell

Electro-Coagulation vs. Chemical Coagulation

	Potassium Alum $KAl(SO4)_2 \cdot 12(H2O)$	Ferric Chloride $FeCl3 \cdot 6(H2O)$	Electro-coagulation Fe2+ or Al3+
Alum and ferric chloride cause salinity increase b/c of salt counter-ions	Potassium K = 39.10 Aluminum Al = 26.98 Sulfur S = 32.06 Oxygen O = 16.00 Hydrogen H = 1.01 KAl(SO4)2*12(H2) = 474.44	Iron Fe = 55.85 Chlorine Cl = 35.45 Hydrogen H = 1.01 Oxygen O = 16.00 FeCl3*6(H2O) = 270.32	Metal Sheet
Total Dissolved Solids reduction in place of TDS increase	17.6 to 1 5.7% Al	4.8 to 1 20.66% Fe	1 to 1 100%

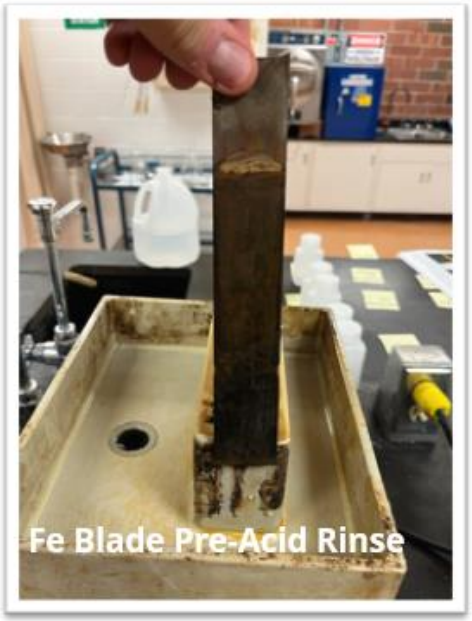
"When compared with alum treatment, electrocoagulation provided approximately **83% less sludge** volume and a **76% improvement in filtration rate."** (***EPA** / 540 / S-937504 September 1993 Emerging Technology)*

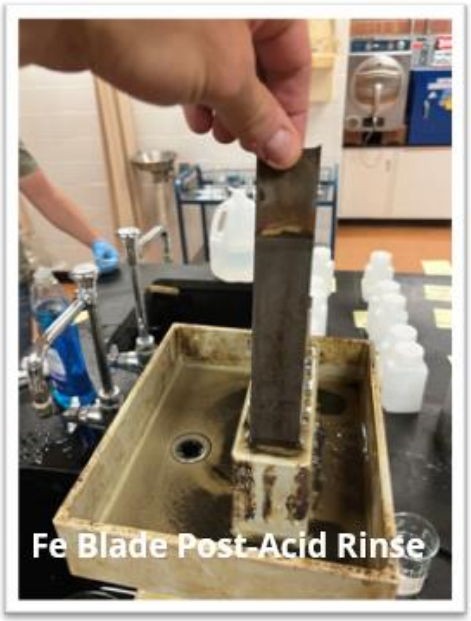
Blade Maintenance

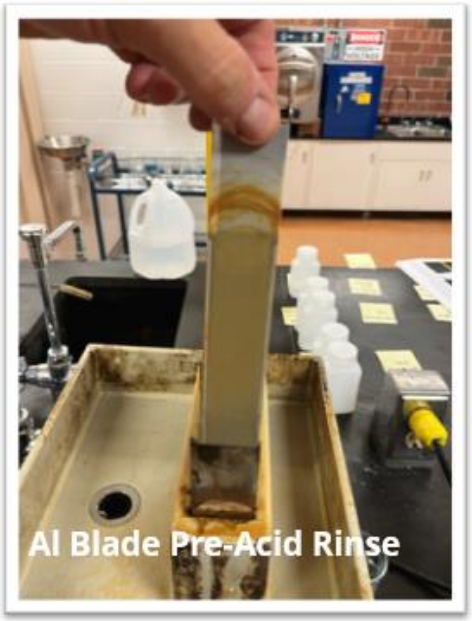


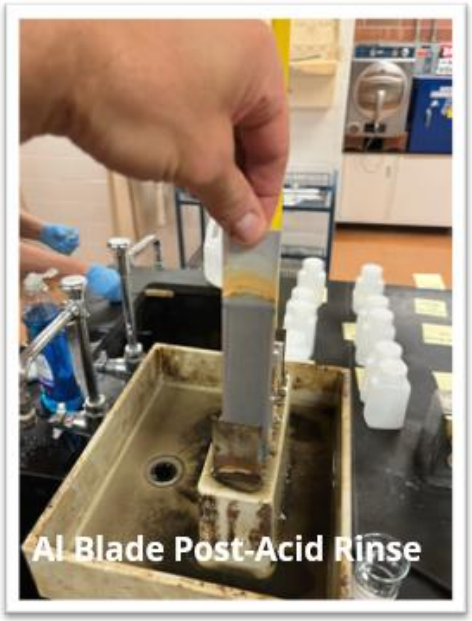
Change out 0 to 6 blades per day

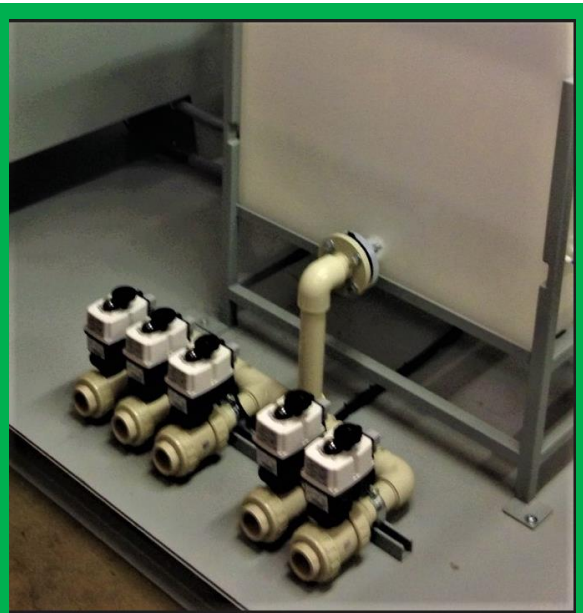
Sulfuric Acid Blade Cleaning CIP











1. Influent Supply feed
2. Clean in Place feed
3. City Water feed
4. Clean in Place return
5. Influent Supply return

- **Plates are placed vertically within the patented reaction chamber**
- **Direct current is applied to the first and last blade**
- **Untreated water is introduced into the bottom of the chamber**
- **Water is dispersed evenly as it moves upward through the blades**
- **Water conducts electricity throughout the chamber**

Samsung 600 gpm unit South Korea

- **Metal blades change from a solids to an ion when electrons pass through.**
- **Electron flooded water neutralizes charged particles, Van der Waals force, making them separable (precipitate) from the water**
- **Treated water overflows to secondary separation such as ponds, clarifiers, filters, or etcetera.**

Central Wastewater Treatment Facility (CWT)
50 gpm, Denver, Colorado

- **Heavy metals precipitate into acid-resistant oxide sludge that passes the Toxic Classification Leaching Procedure (TCLP), making the sludge non-hazardous**

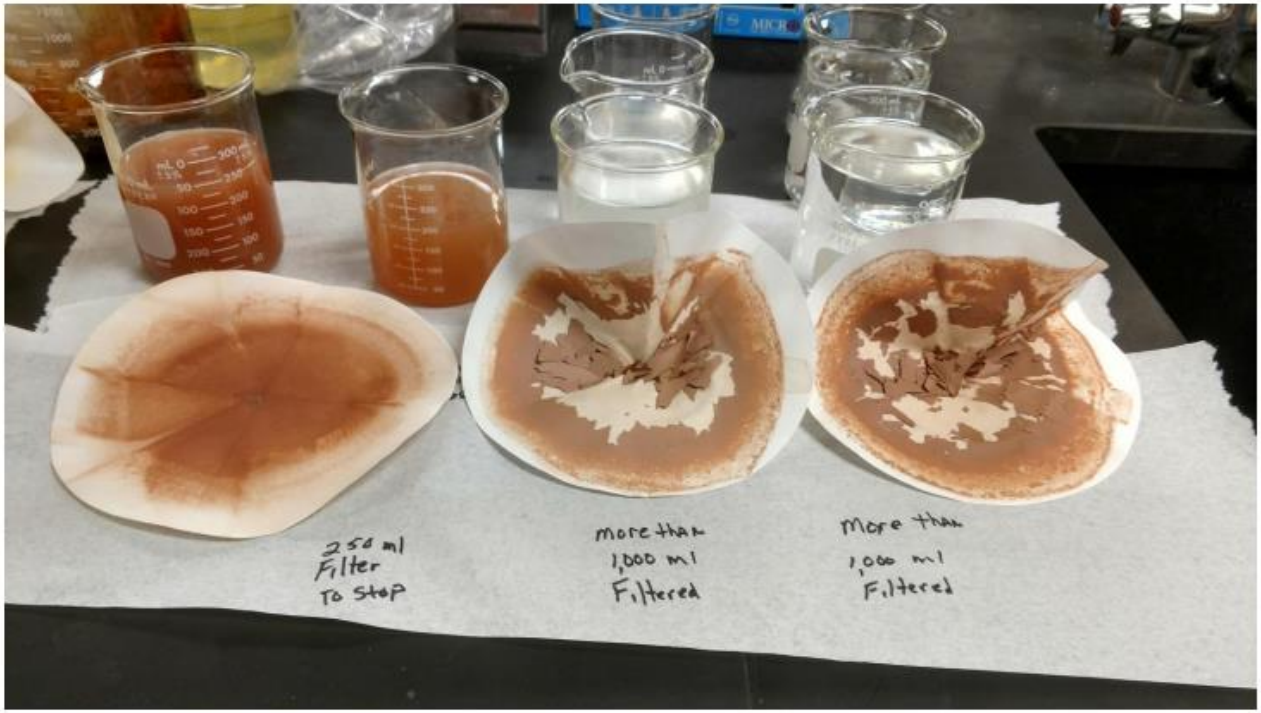
The Powell Electrocoagulation Process is Scalable to accommodate larger flow rates. 600 gpm is the manufacturing economy of scale and then parallel units can be used to treat any size flow rate.

500 gpm
1,866,240 square inch
Wet blade surface area

50 gpm
186,624 square inch
Wet blade surface

EC Solids Dry in the Oxide Form

Coal Mine Surface Run Off Water
Powell Electrocoagulated Solids



Sludge from EC:

- Solids dewater completely
- **Metals** are non-hazardous as **oxides**
- Does **not leach** at ambient landfill pH
- **Passes EPA TCLP** and California Title 22 **STLC and TTLC** leach tests

Canadian Oil Tar Sands Mature Fine Tails

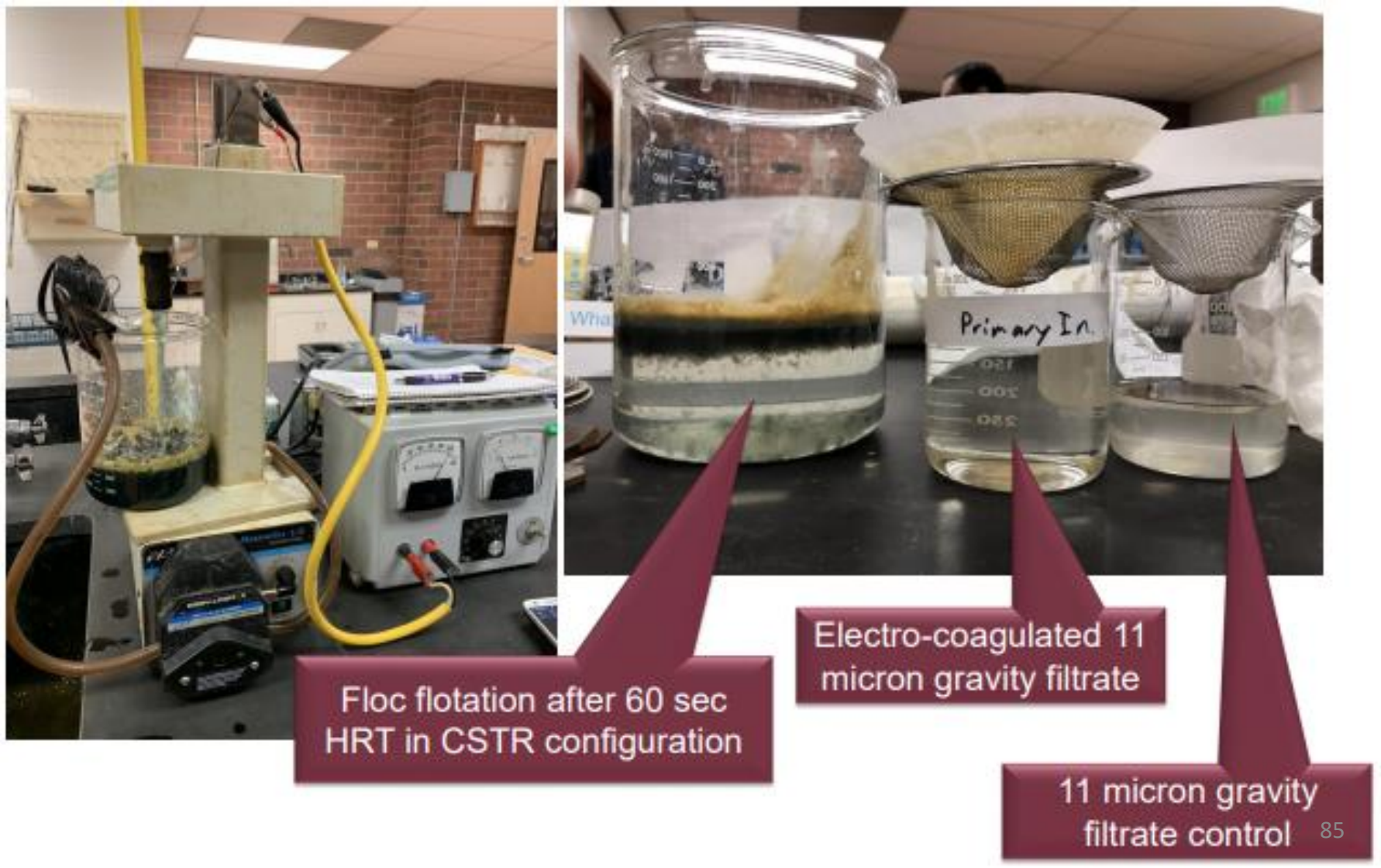
Filtered Solids after 10 days			
Moisture in filtered solids	0.20%		Wt% moisture
Compressive Strength	47.6		Kilopascal (kPa)
Compressive Strength	6.9		lbs/sq in (psi)
Specific Gravity	2.222		
Mature Fine Tails	**Sample 100819 - 1 As Received**		
pH	7.2		pH Units
Fluid Ratio - oil	0.50%		Vol%
Fluid Ratio - Water	74.50%		Vol%
Fluid Ration - Sediment	25%		Vol%

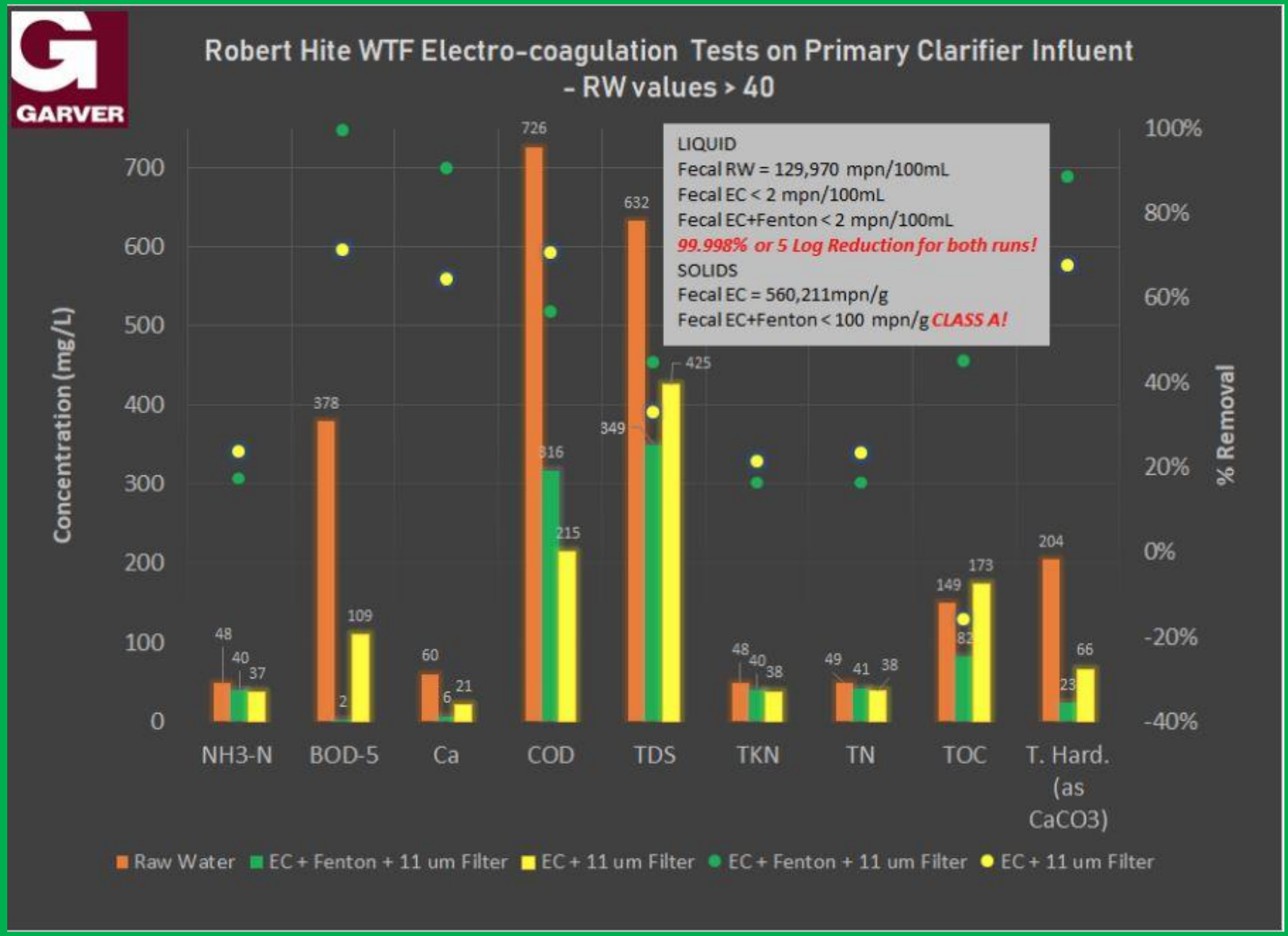
Solids concentration of 25% after 40 years went to 99.8% in 10 days, By adding the electro mode of force to drive the normal reaction in nature.

Post Powell EC-Filter Press

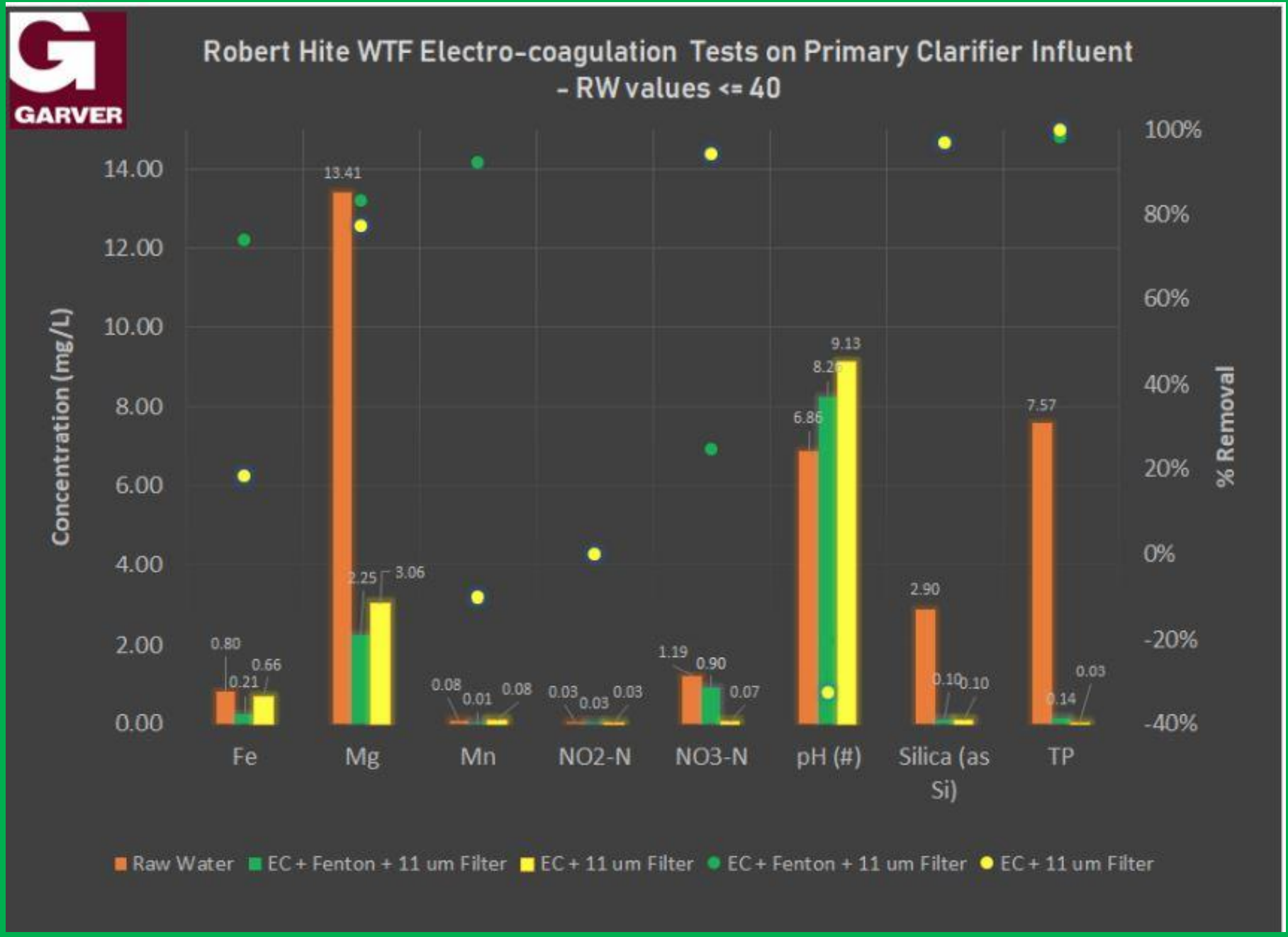
Denver Central Wastewater Treatment (CWT)

Primary Clarifier Influent, Robert Hite Water Reuse Facility Denver Colorado





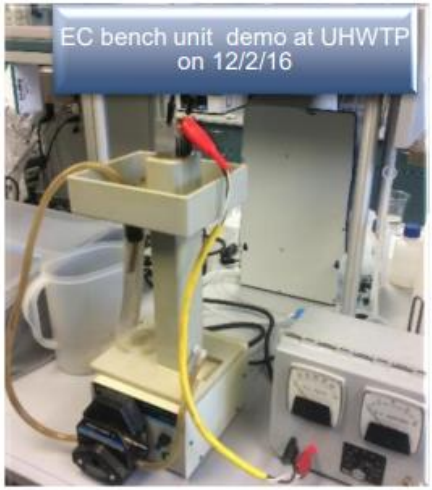
Henry Fenton's reagent is the addition of hydrogen peroxide (H_2O_2) with ferrous iron

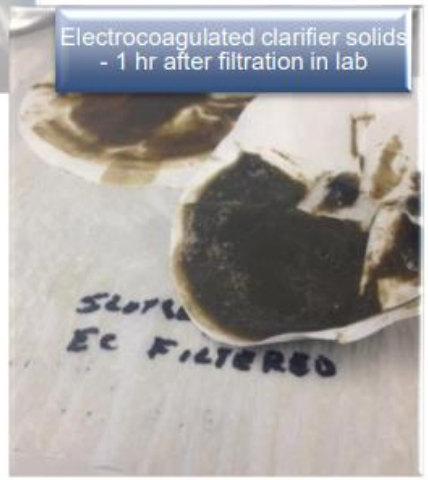


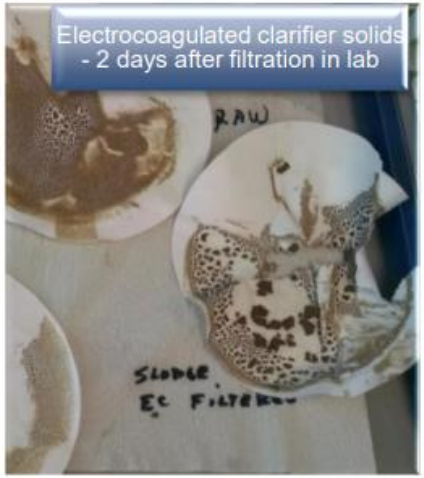
Henry Fenton's reagent is the addition of hydrogen peroxide (H_2O_2) with ferrous iron

EC Field Demo on Ultrafiltration Plant Solids

Maple Grove UF WTP, Lakewood CO







Hazen

Vector Attraction Reduction- fecal coliforms in sewage sludge must be less than 1,000 Most Probable Number (MPN) / gram of total solids on a dry mater bases.

EPA/600/R-22/194 | January 2023 | www.epa.gov/research.

Class "B" With Respect to Pathogens

- Geometric Mean <2,000,000 MPN/g fecal coliforms OR
- Use one of five PSRPs
  (Processes to Significantly Reduce Pathogens)
  - Aerobic Digestion
  - Air Drying
  - Anaerobic Digestion
  - Composting
  - Lime Stabilization
  - Other as approved by EPA Region 8

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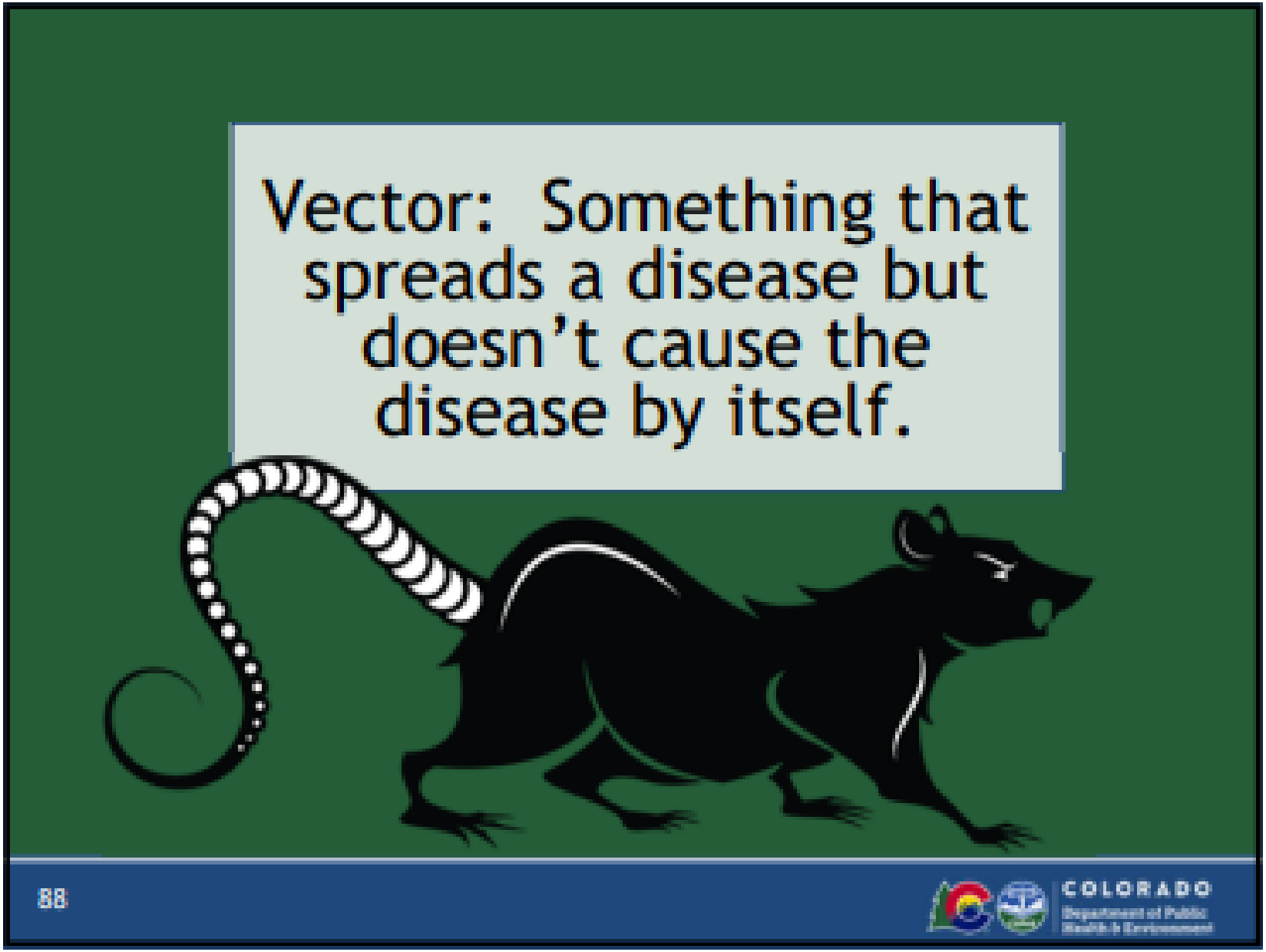
Department of Public Health & Environment

Class "A" With Respect to Pathogens

- Fecal < 1000 MPN/g OR
- Salmonella s.p. < 3 MPN/4g AND
- Use one of seven PFRPs
  (Processes to Further Reduce Pathogens)
  - Composting
  - Heat Drying
  - Heat Treatment
  - Thermophilic Aerobic Digestion
  - Beta Ray or Gamma Ray Irradiation
  - Pasteurization

COLORADO
Department of Public Health & Environment


Vector: Something that spreads a disease but doesn't cause the disease by itself.
88
COLORADO

Vector Attraction Reduction

- 38% Volatile Solids Reduction (VSR)
- Anaerobic - bench scale test (40 days)
- Aerobic - bench scale test (30 days)
- Aerobic* - SOUR =< 1.5 mg O_2/hr @ 20 °C
- Aerobic - 14+ days @ >40 °C (avg >45 °C)
- pH > 12+ for 2 hr then 11.5+ for 22 hr
- Dry to 75% when stabilized solids used (digested)
- Dry to 90% when unstabilized solids used (undigested)
- Sub. injection (no significant after 1 hr)
- Surface application w/incorporation (w/in 6 hrs)

*(SOUR not for anaerobically digested sludge.)

COLORADO
Department of Public Health & Environment

Vanderbilt Study

Municipal Wastewater Nashville, Tennessee

	Raw	Treated	% Removal
COD	490	26	94.70
Total Solids	602	401	43.40
Suspended Solids	73	7	90.4
Settleable Solids	21	5	76.20
Total Hardness	127	11	91.30
Alkalinity	267	11	95.80
pH	6.88	7.02	
IOD	0.98	<0.1	89.80
BOD	220	9	95.90
Coliform	318,000/ml	0	99 +
Phosphates	38	0	99 +

29,000 mg/l BOD Waste to Fertilizer

Sample ID	44624-25		
Sample Detail	Cooker Water		
mg/l	As Received	Dry Weight	Percentage
Total Kjeldahl Nitrogen (TKN)	1,580	9,190	0.92%
Phosphorus	18,970	110,300	11.03%
Potassium	3,686	21,430	2.14%
Calcium	1,272	7,395	0.74%
Magnesium	1,100	6,395	0.64%
Sodium	17,590	102,300	10.23%
Sulfur	15,000	87,200	8.72%
Iron	37,770	219,600	21.96%
Phosphate P205	43,400	252,000	**25.20%**
Potash K20	4,440	25,800	2.58%

Coagulated Solids from Industrial Process, 75% of the Wastewater Converted to Fertilizer.

Army Corp of Engineers

30 gpm Huntsville, Alabama

Adjustable to 3, 6, and 12 volts between the blades to accommodate for the conductivity of the water.

Office of Navel Research
6 gpm Skid Mounted Unit Oxnard, California

Amperage controlled Power supply

Polarity Reversing

Full wave rectification of the AC power to DC power

Typical Removal Rates

Metals And Minerals

Contaminant	Before (mg/l)	After (mg/l)	% Removal
Aluminum	224	ND (0.7)	99+
Arsenic	0.076	ND (<0.002)	97
Barium	0.014	ND (<0.001)	93
Boron	4.86	1.41	70
Cadmium	0.125	ND (<0.004)	96
Calcium	1,321	21.4	98
Chromium	139.	ND (<0.1)	99+
Cobalt	0.1238	0.0214	82
Copper	0.7984	ND (<0.0020)	99+
Cyanide (free)	723	ND (<0.02)	99+
Fluoride	1.1	0.415	62
Gold	5.72	1.38	75
Iron	68.34	0.19	99+
Lead	0.59	0.0032	99+
Magnesium	13.15	0.04	99+
Manganese	1.061	0.018	98
Mercury	0.72	ND (<0.003)	98
Molybdenum	0.35	0.029	91
Nickel	183	0.07	99+
Platinum	4.4	0.68	84
Selenium	68	38	44
Silicon	21.07	ND (0.10)	99+
Silver	0.0081	0.0006	92
Tin	0.213	ND (<0.020)	90
Vanadium	0.262	ND (<0.002)	99+
Zinc	221	0.140	99+

Nutrients			
Contaminant	Before (mg/l)	After (mg/l)	% Removal
Ammonia	49	19.4	60
Nitrate	11.7	2.6	77
Nitrite	21	12	42
Nitrogen TKN	1,118.88	59.08	94
Phosphate	28	< 0.2	99+
Potassium	200	110	45
Sulfate	104	68	34

Removal rates improve significantly when combined with processing aids like micro algae, microbes, and or hydrogen peroxide.

Biologicals

Contaminant	Before	After	% Removal
Bacteria	110,000,000 cfu	2,700 cfu	99+
Coliform	318,000,000 cfu	ND (<1) cfu	99+
E. coli	>2,419.2 mpn	ND (<0.01) mpn	99+
Enterococcus	83 mpn	ND (<10) mpn	82
Total Coliform	>2,419.2 mpn	ND (<0.1) mpn	99+
Cyanotoxin	97.1 ug/l	0.001 ug/l	99

Pesticides

Contaminant	Before (mg/l)	After (mg/l)	% Removal
Aldrin	0.063	ND (0.001)	98
Chlorpyriphos	5.87	ND (0.03)	99+
Cypermethrin	1.3	0.07	94
DDT	0.261	0.002	99+
Diazinon	34	0.21	99+
Lindane	0.143	ND (0.001)	99+
Propetamphos	80.87	0.36	99+

Hydrocarbons

Contaminant	Before (mg/l)	After (mg/l)	% Removal
Benzene	90.1	0.3590	99+
Ethyl Benzene	428	0.372	99+
MP-Xylene	41.6	0.057	99+
MTBE	21.58	0.0462	99+
O-Xylene	191	0.416	99+
PCB	0.0007	ND (<0.0001)	85
Petroleum Hydrocarbons	72.5	ND (<0.2)	99+
Toluene	28,480	0.227	99+

Dyes			
Contaminant	Before (NTU)	After (NTU)	% Removal
Ref. 006-691	125.1	12.1	90
Ref. 006-692	129.4	2.2	98
Ref. 006-854	68.30	0.68	99+
Ref. 006-851	2,340	4.5	99+

Radioisotopes			
Contaminant	Before	After	% Removal
Americium-241	71.99 pCi/l	0.57 pCi/l	99+
Plutonium-239	29.85 pCi/l	0.29 pCi/l	99+
Radium	1093 pCi/l	0.10 pCi/l	99+
Uranium	0.13 mg/l	0.0002 mg/l	99+

Organic & Inorganics Compounds			
Contaminant	Before	After	% Removal
BOD_5	1,050 mg/l	14 mg/l	98
NTU	35.38 mg/l	0.32 mg/l	99+
TSS	1,560 mg/l	8 mg/l	99+
PFOS	421 ng/l	<2.36 ng/l	99
PFOA	1,540 ng/l	<3.97 ng/l	99

BTEX in 260,000 mg/l TDS Water United Arab Emirates 130 gpm System

mg/l	Untreated	Treated	% Removed
• Benzene	90.1	0.359	99.6%
• Toluene	28.48	0.227	99.9%
• Ethyl benzene	428	0.372	99.9%
• M, P - Xylene	41.6	0.057	99.8%
• O-Xylene	191	0.416	99.7%

United Arab Emirates

130 gpm system
At an Oil Refinery

pH adjustment
Electrocoagulation

Vacuum
Clarification

80 degrees cooling

Hydrogen Sulfide

Parameter Tested For: Hydrogen Sulfide **Date:** 10-Mar-2015

Water Source: Well Water: WTP #1

EC Run #	Blade Type	RT (Sec)	Volts	Amps	KWH /1K Gal	H_2S ug/l (ppb)	H_2S % Remvd	ORGANICS UVA254	ORGANICS % Remvd	UVT	pH
RAW (Untreated) Water						2432		0.241		57.3	7.8
1Fe	Fe	60	96	1.7	2.57	10	99.6%	0.049	79.7%	89.3	8.7
2Fe	Fe	30	96	1.7	1.29	18	99.3%	0.054	77.6%	87.9	8.4
3Fe	Fe	10	96	1.7	0.43	61	97.5%	0.108	55.2%	77.8	8.2
4Fe	Fe	5	96	1.7	0.21	84	96.5%	0.126	47.7%	74.7	X
5Fe	Fe	2.5	96	1.7	0.11	145	94.0%	0.183	24.1%	65.5	X

Taste and Oder Elimination for Well Water

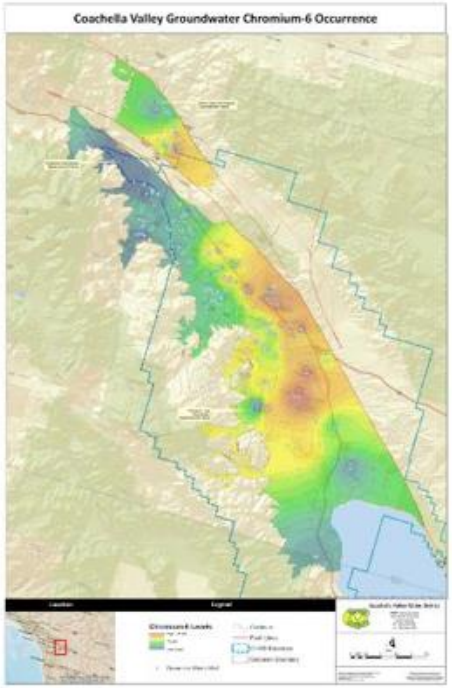
Bert Gerber PE (407) 834 9104

GPI GerberPumps international inc.

Hexavalent Chrome ions in the ground water.

EC Case Study - Anionic Spent Brine

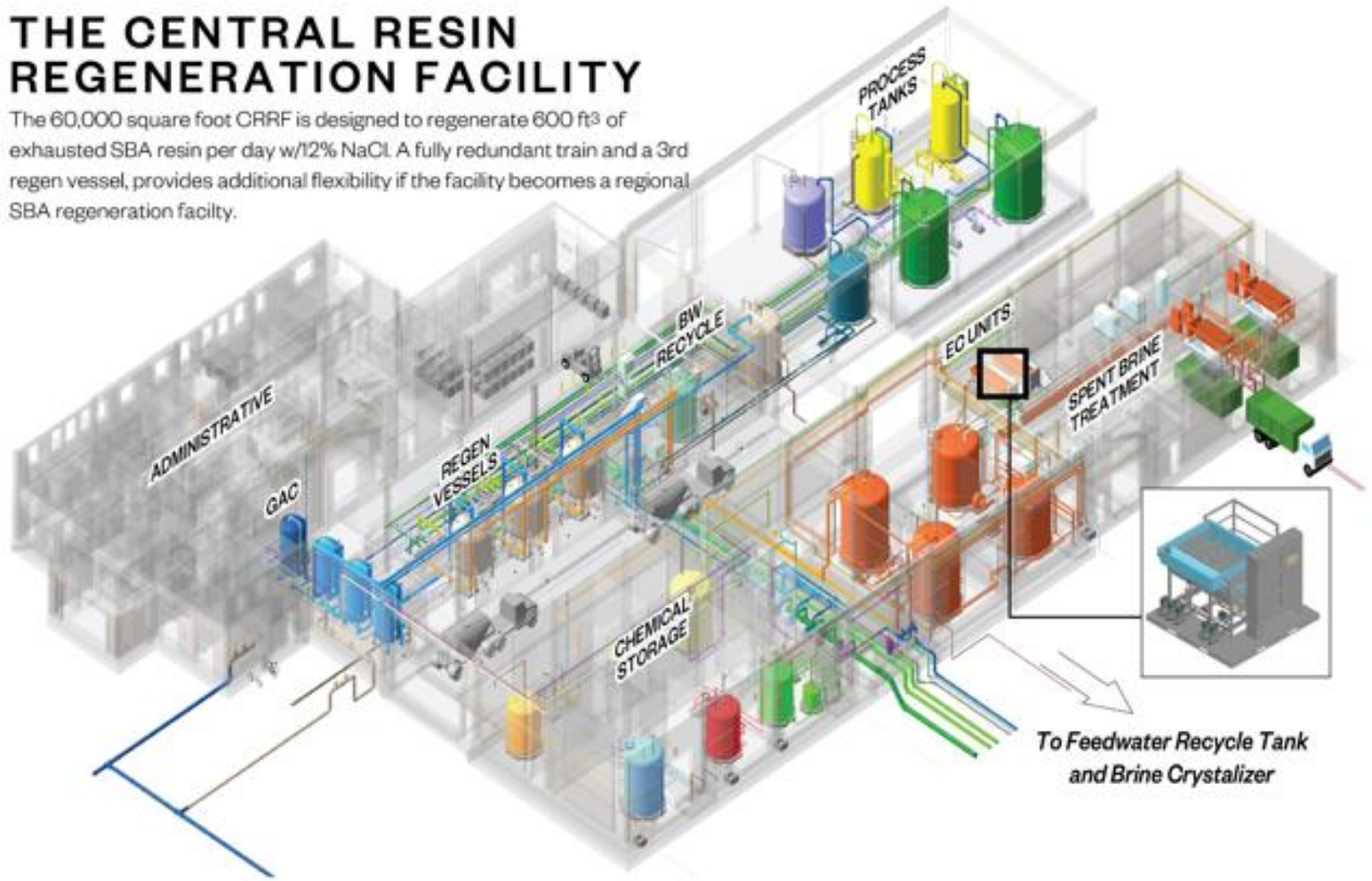
- Cr6 in Coachella Valley, CA groundwater between <1 to 21 parts per billion (ppb) – new MCL = 10 ppb
- 23 wells equipped with Strong Base Anion (SBA) treatment systems
  - 99.95% water recovery
  - 51 MGD capacity with 27,600 cubic feet of resin
- Require regeneration every 2 to 3 months @ CRRF – 600 cf / day
- Regenerated with a 10-12% NaCl solution



Courtesy: Coachella Valley Water District, Coachella Valley, CA

Naturally Occurring

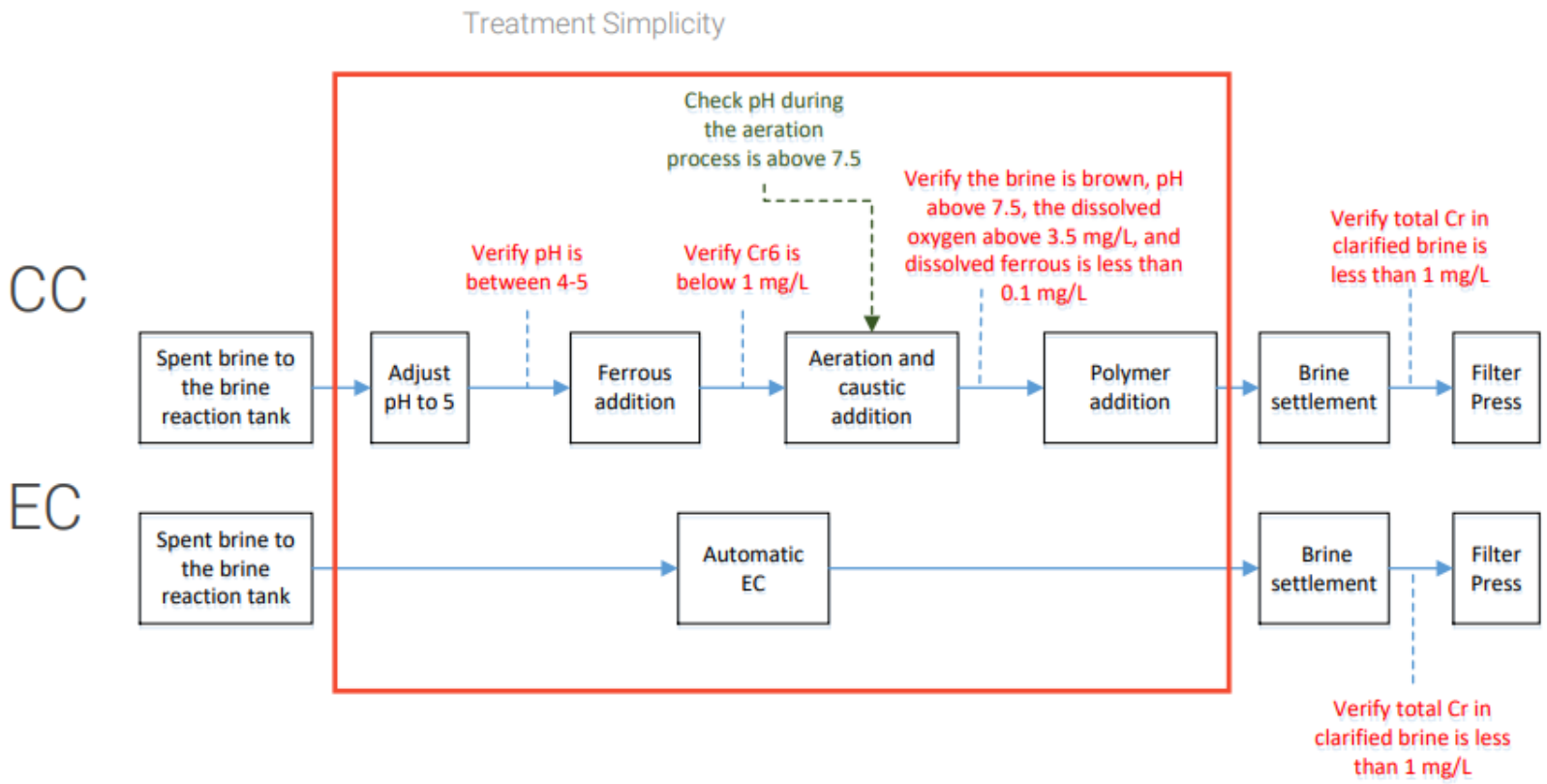
120,000 ppm Total Dissolved Solids Brine Regeneration



Ion Exchange Regeneration Brine Disposal cost is three times the operational cost of ion exchange.

Simplification of the Water Treatment Process

Primary Treatment Selection



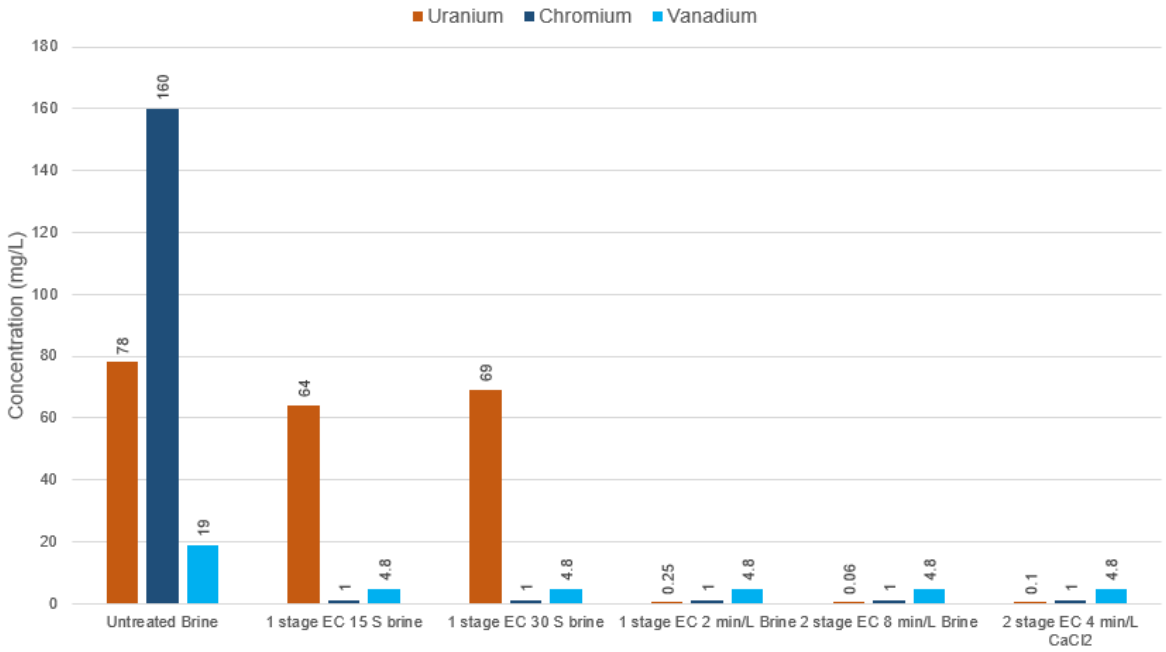
One step in place of Four steps

Chromium come out before Uranium

EC Case Study - Anionic Spent Brine

Palm Desert, CA

Analyte	Concentration (mg/L)	Limit (mg/L)	Regulation	Treatment Goal (mg/L)
Chromium	30 - 250	5.0	TTLC/STLC	1 mg/L
Selenium	1- 3	1.0	TTLC/STLC	0.75 mg/L
Vanadium	< 50	24	TTLC/STLC	24 mg/L
Uranium	10 - 150	500	LLRW	4.5 mg/L



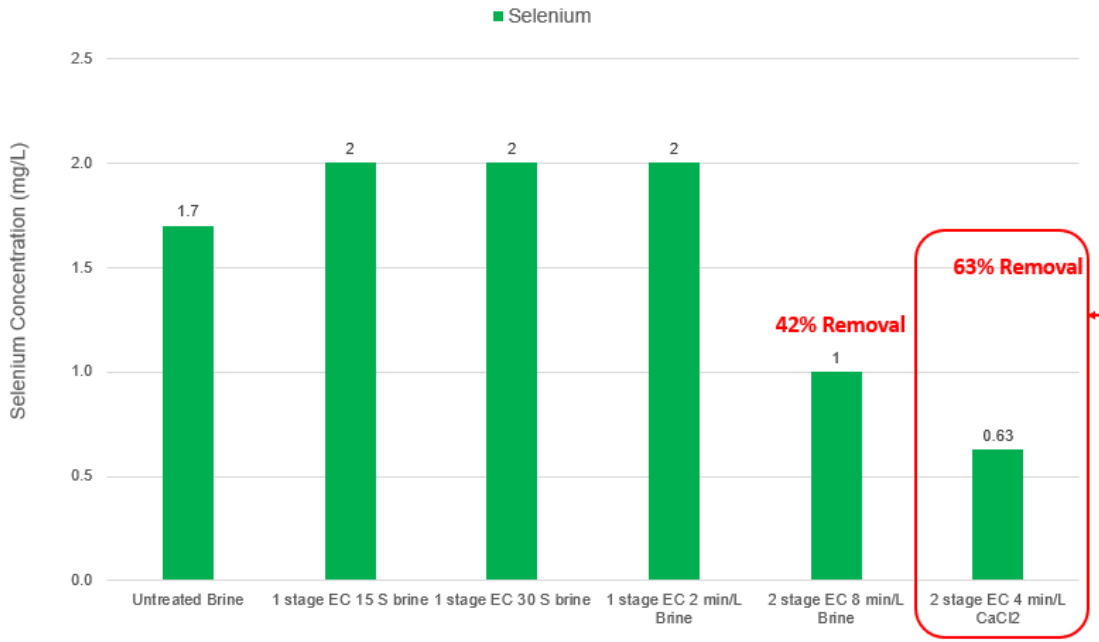
Sequencing metal removal may help with harvesting and disposal requirements

Processing aids increase the removal rates

EC Case Study - Anionic Spent Brine

Palm Desert, CA

Analyte	Concentration (mg/L)	Limit (mg/L)	Regulation	Treatment Goal (mg/L)
Chromium	30 - 250	5.0	TTLC/STLC	1 mg/L
Selenium	1- 3	1.0	TTLC/STLC	0.75 mg/L
Vanadium	< 50	24	TTLC/STLC	24 mg/L
Uranium	10 - 150	500	LLRW	4.5 mg/L



- *88% Removal of Se*
- *73% Removal of SO4*

with 100 g/L CaCL2 @ 2 min/L

Selenium

Red Desert, Wyoming
Frack Flow Back and Produced Water Mixture

Hydraulically-Dredged Wastewater Hudson River Project

Results are reported in ug/L except as noted

Analyte	Raw	Post EC & Clarification	% Reduction
Arsenic	30	3.2	89.3
Cadmium	10	0.32	96.8
Chromium	330	13.0	96.1
Copper	230	3.2	98.6
Iron	22,000	29.0	99+
Lead	590	3.2	99+
Mercury	0.72	0.0031	99+
Zinc	2,200	6.4	99+
TOC (mg/l)	5.8	2.1	65.5
TSS (mg/l)	210	4.0	98.1
Total P (mg/l)	2.3	0.03	98.7

TOSHIBA

The plant water is electrocoagulated, clarified, and returned to the incoming city water tank.

The people in Thailand drink bottled water.

They probably do not believe me when I tell them that I wash my car and water my lawn with drinking water.

250 gpm Unit, Thailand

Disinfection with Electricity

Eliminates Disinfection By-products Associated with Chlorination - Dechlorination and Ultraviolet Light Shadow Challenges

Thank You! Questions

www.powellwater.com

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United States Patent Number 10358361 B2 & 11407660 B2. System and Method for Remediation of Wastewater Including Aerobic, Anaerobic and Electrocoagulation Technology. This patent is wholly licensed by Powell Water Systems, Inc.