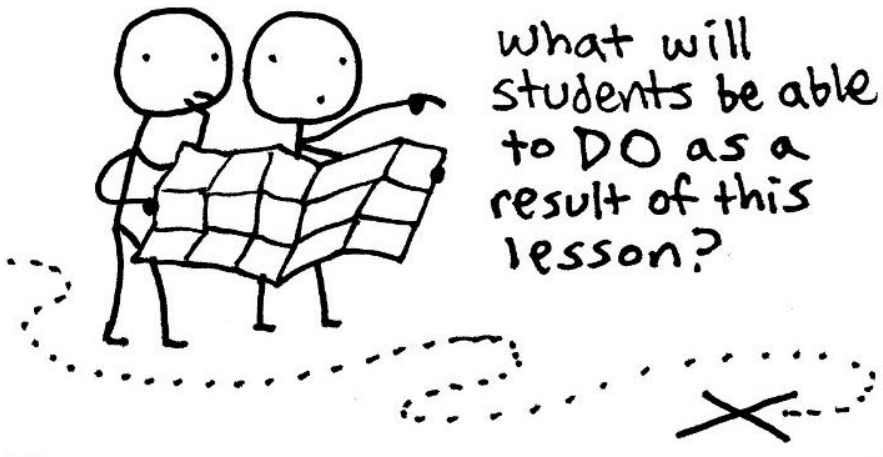
PNWS-AWWA SPRING CONFERENCE

Ion Exchange Essentials: The Foundations of Design and Operations for Water Treatment

May 6, 2026

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Learning Objectives



- Select resin for specific application
- Understand operational hydraulics
- Identify chromatographic peaking
- Identify fouling and apply pretreatment
- Understand regeneration bottlenecks
- Understand how IX could be used for PFAS.



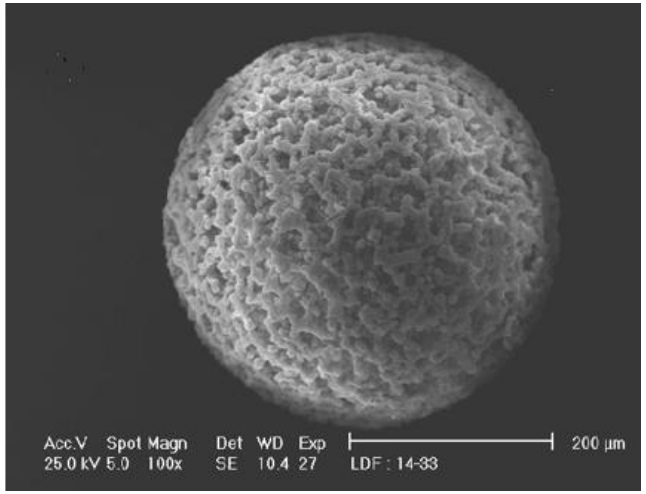
1. Fundamentals

OF IX TECHNOLOGY

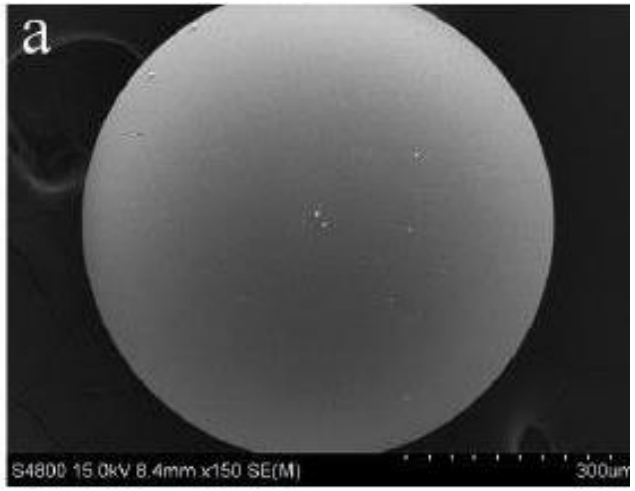
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Porosity









99% of the ion exchange sites are within the bead

Macroporous IX Resin

- Crosslinked
- Porogen added during fabrication
- 10-100 nm pores

Gel IX Resin

- Minor or no crosslinking
- No porogen
- 1-2 nm pores

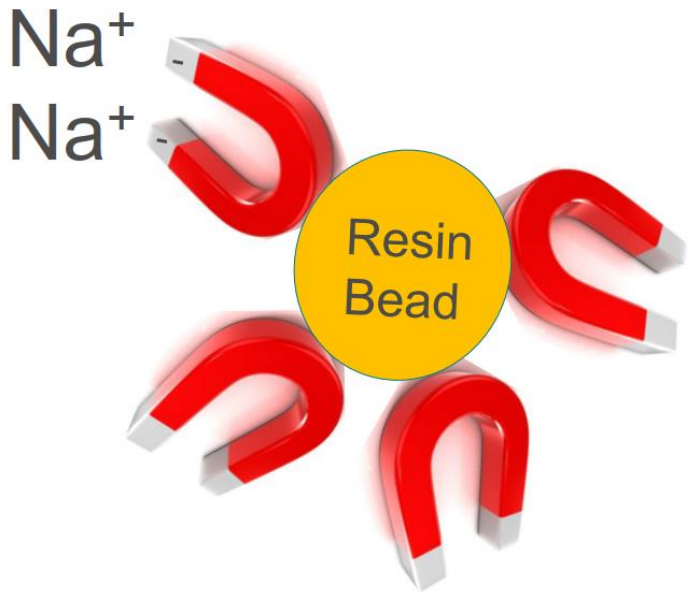
- Need to be NSF 61 certified
- The bead is charged.

https://www.purolite.com/index/core-technologies/industry/hydrometallurgy/ion-exchange-resin-pilot-and-resin-testing

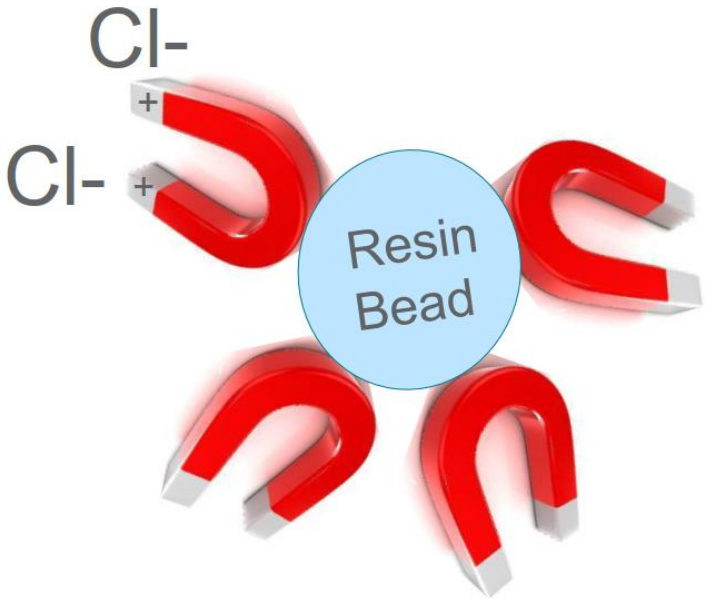
Working Mechanism

It is all about charge

Dissolved ions are exchanged with mobile ions of the same charge

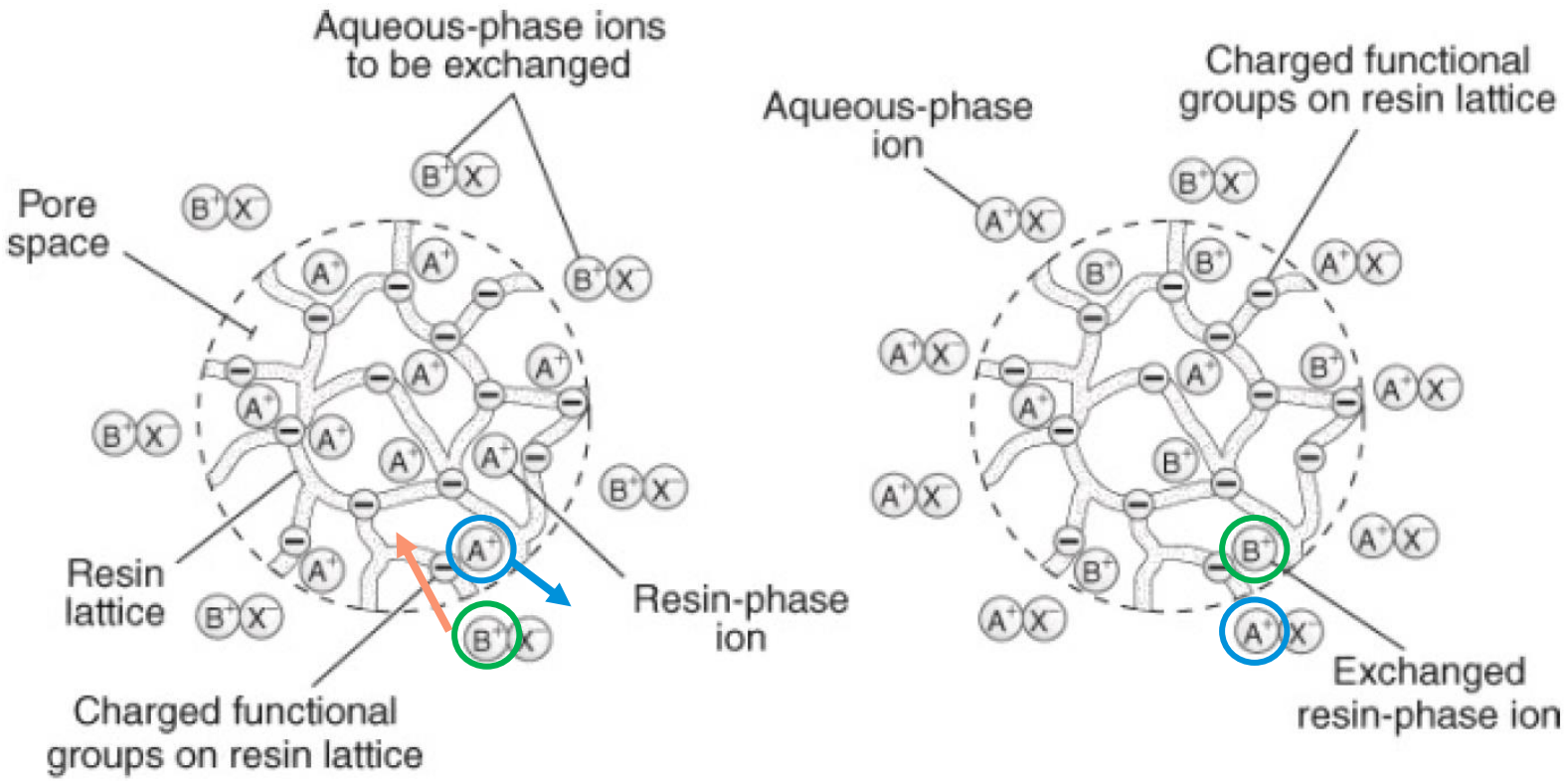


Cation Resin in the Sodium Form
Exchanges Na^+ for Ca^{2+} ,Mg^{2+}, etc.



Anion Resin in the Chloride Form
Exchanges Cl^- for NO_3^-, As^-, etc.

Exchange Schematic



A^+ represents a mobile cation originally on the resin that is released into the water

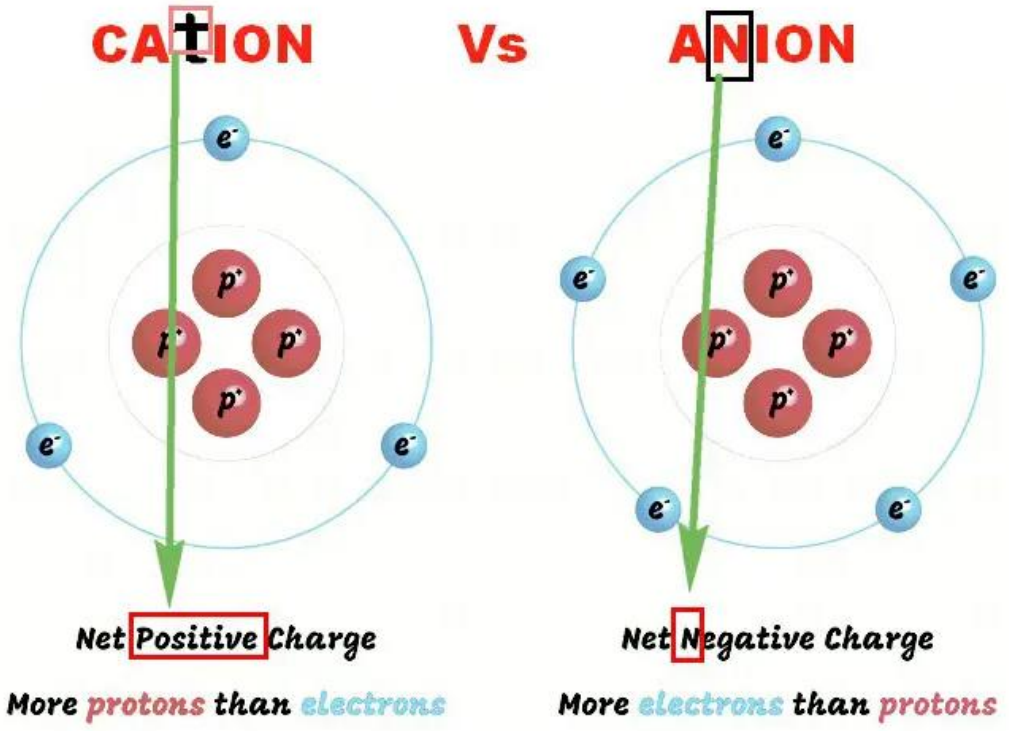
B^+ is a dissolved cation from the water that is captured by the resin, replacing A^+

From MWH's Water Treatment: Principles and Design, Third Edition: Principles and Design, 2012

Contaminants Targeted by Ion Exchange

Cationic

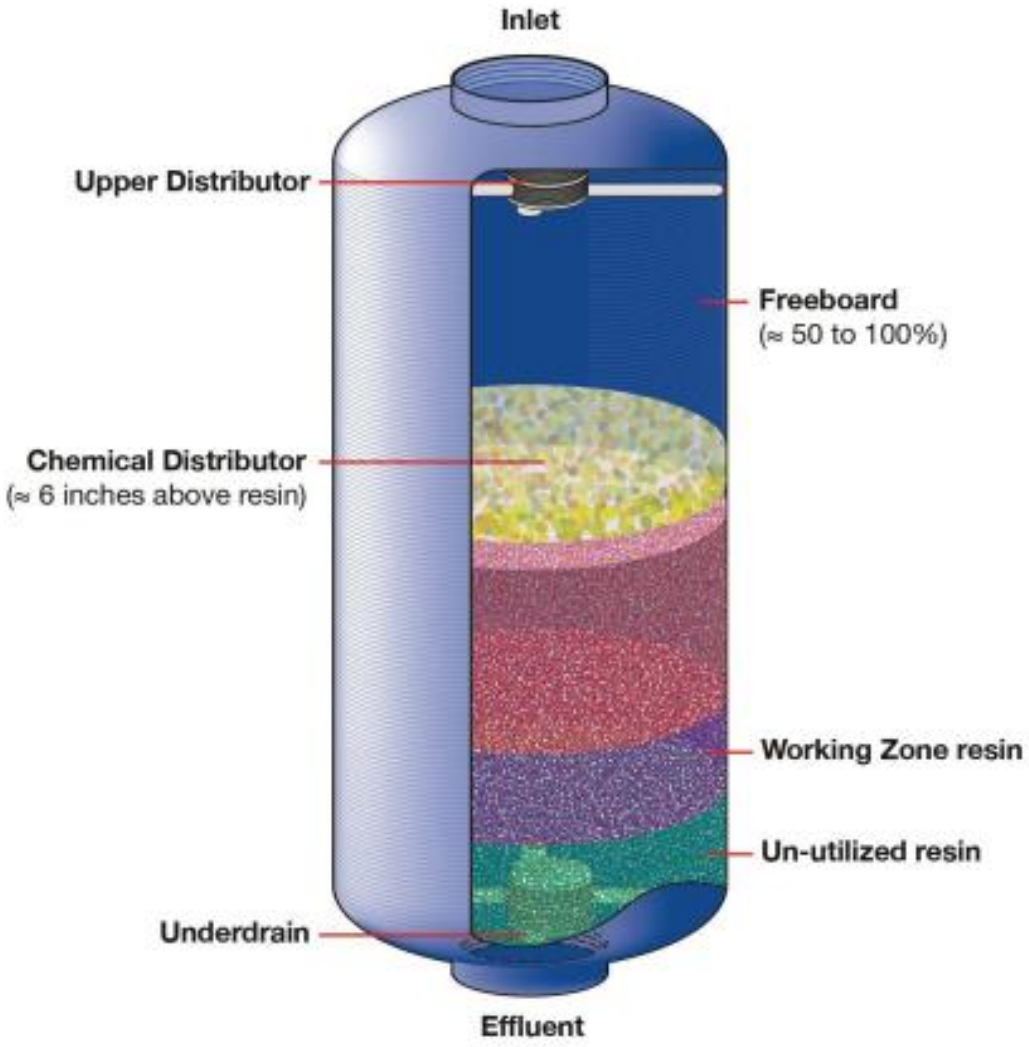
- Hardness
- Iron & Manganese
- Barium
- Strontium
- Radium



Anionic

- Nitrate
- Arsenic
- Uranium
- Perchlorate
- Chrome VI
- TOC
- PFAS

Sizing Criteria



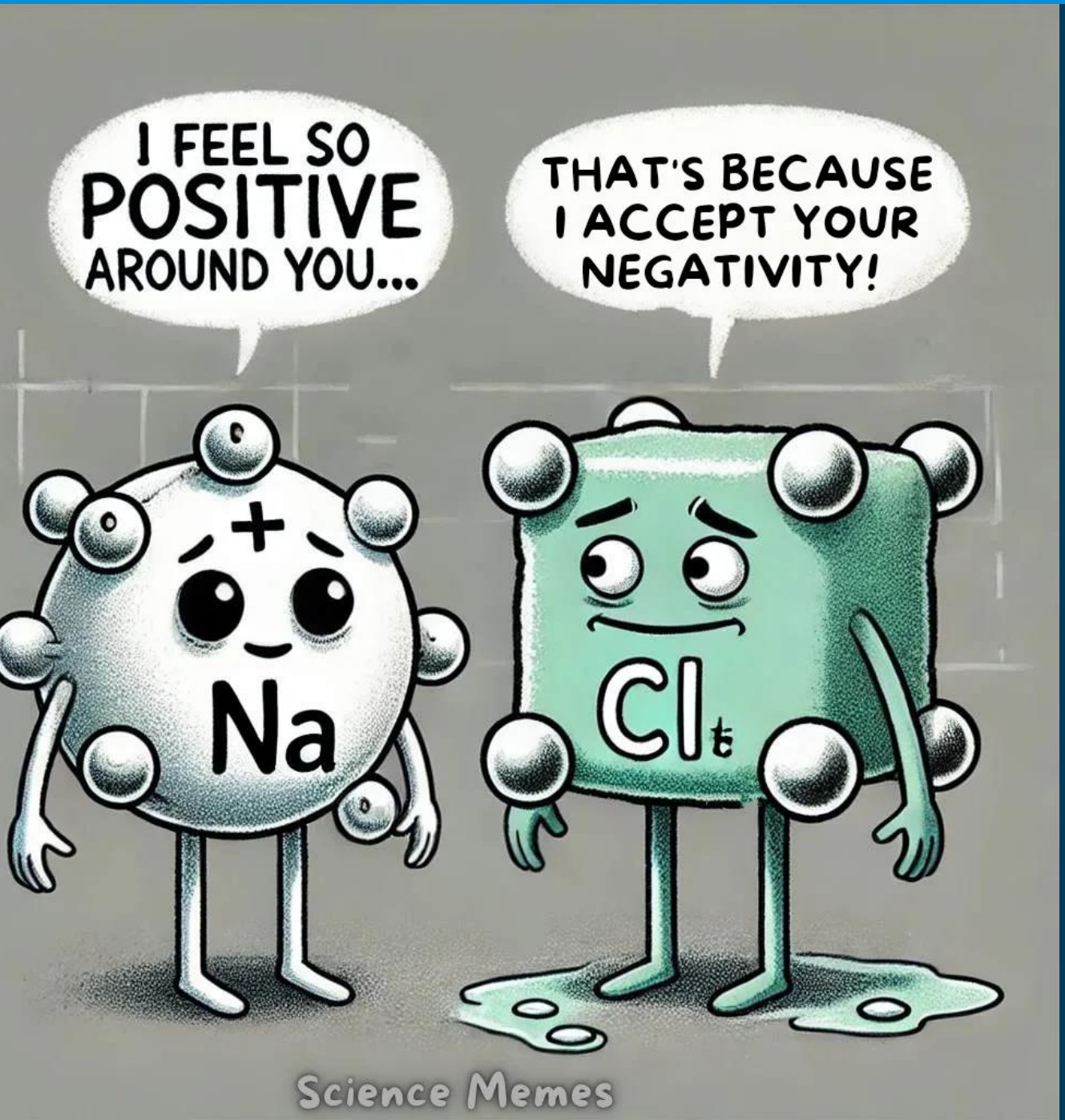
Criteria:

- Full mass transfer
- Fixed bed
- Pressure vessel operation
- Porous media operation
- Flow distribution

Parameters:

- Media depth (3 ft minimum)
- Freeboard (30-50%)
- Hydraulic loading rate (6 – 12 gpm/sqf)
- Empty bed contact time (fast, 2-3 minutes)

From ResinTech - Ion Exchange Part 3: Tips for Loading and Unloading IX Resins



2. Operational Efficiency

SELECTIVITY AND FOULING

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Selectivity - The Needles in the Haystack



Higher valence – stronger selectivity

Higher MW – stronger selectivity

Strong Acid Cation (SAC)		Strong Base Anion (SBA)	
Ra^{2+}	13	CrO_4^{2-}	100
Ba^{2+}	5.8	SeO_4^{2-}	17
Pb^{2+}	5	SO_4^{2-}	9.1
Sr^{2+}	4.8	$HAsO_4^{2-}$	3.5
Cu^{2+}	2.6	HSO_4^-	4.1
Ca^{2+}	1.9	NO_3^-	3.2
Zn^{2+}	1.8	Br^-	2.3
Fe^{2+}	1.7	SeO_3^{2-}	1.3
Mg^{2+}	1.67	HSO_3^{2-}	1.2
K^+	1.67	NO_2^-	1.1
Mn^{2+}	1.6	Cl^-	1
NH_4^+	1.3	HCO_3^-	0.27
Na^+	1	OH^-	0.1
H^+	0.67	F^-	0.07

Cations – It's all about hardness

Anions – It's all about sulfate

Always present in water and constantly competing

Chromatographic Peaking

Sloughing / chromatographic peaking/rollover of less selective chemicals
A common manifestation is a higher concentration in the effluent than in the influent water

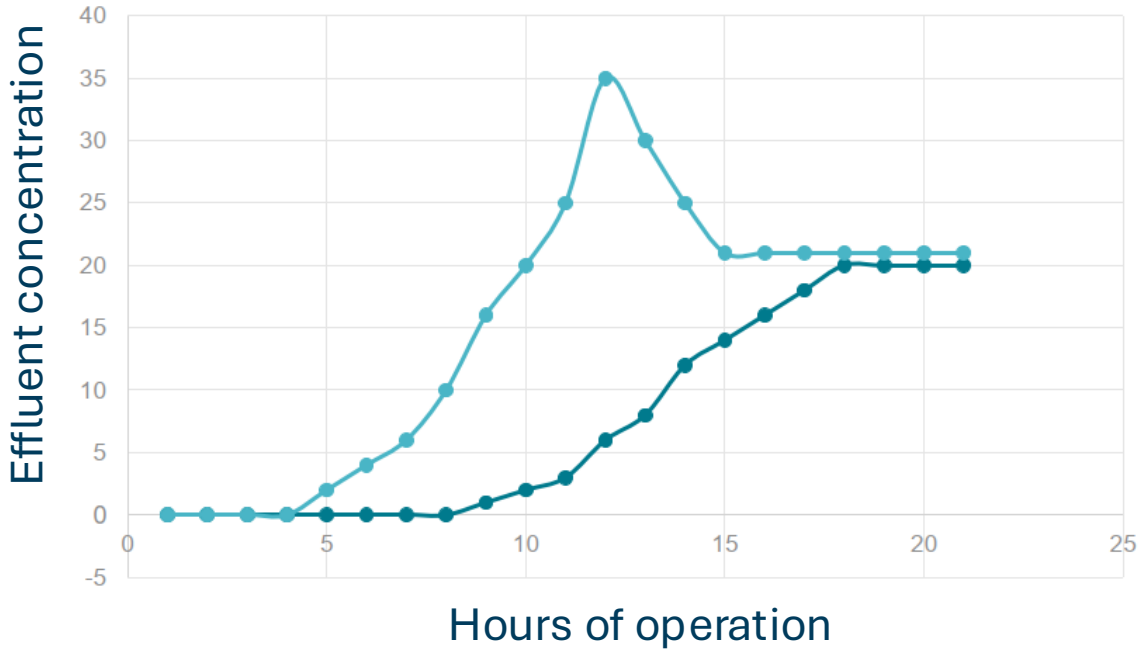
Driving factors:

1. Concentration gradient
2. Selectivity

SULFATE



NITRATE/ARSENIC/PFAS



Is the light blue or dark blue compound more prone to chromatographic peaking?

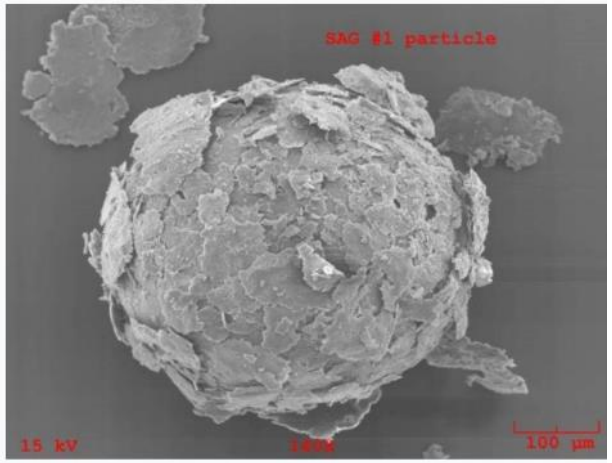
Fouling Concerns

Factors:

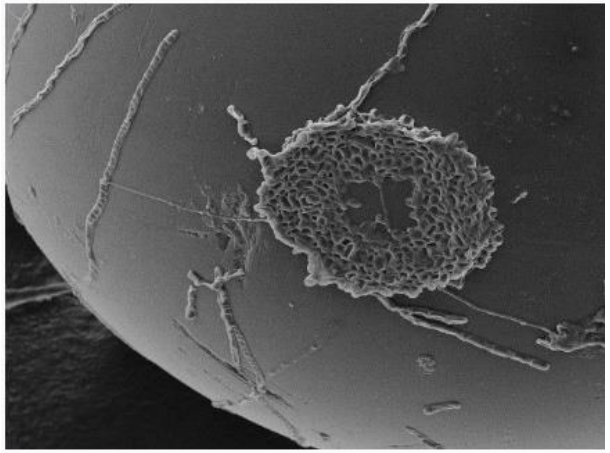
1. Total suspended solids (TSS) – 0.3 NTU
   - As part of the standard setup, 5–10 micron bag or cartridge filters are installed upstream of the resin
2. Iron and manganese – minimum secondary standards (0.3 ppm Fe and 0.05 ppm Mn)
3. Scaling – LSI > 1
4. TOC – 1 to 2 ppm
5. Biological fouling – TC hits or HPC > 500 CFU/mL
6. Oil and grease - any concentration is detrimental

Fouling Examples

600µm Resin Bead Scale Fouling



500 µm Resin Bead Bacteria Fouling



5-year-old macroporous resin with iron fouling inside the beads.

Reaction sites are inside the pores.
Regenerant strength is reduced as it moves to the center of the beads.

https://www.purolite.com/index/core-technologies/industry/hydrometallurgy/ion-exchange-resin-pilot-and-resin-testing

Available Pretreatment Strategies

Filtration
Removing suspended solids and turbidity through sand filtration, multimedia filtration, or membrane filtration.

Oxidation – Filtration
Reducing iron and manganese fouling by manganese dioxide coated or catalytic type media. Often used in conjunction with an oxidants and require removal all traces of oxidants before the resin.

Softening
Reducing hardness (calcium and magnesium) to prevent scaling on the resin and improve performance.

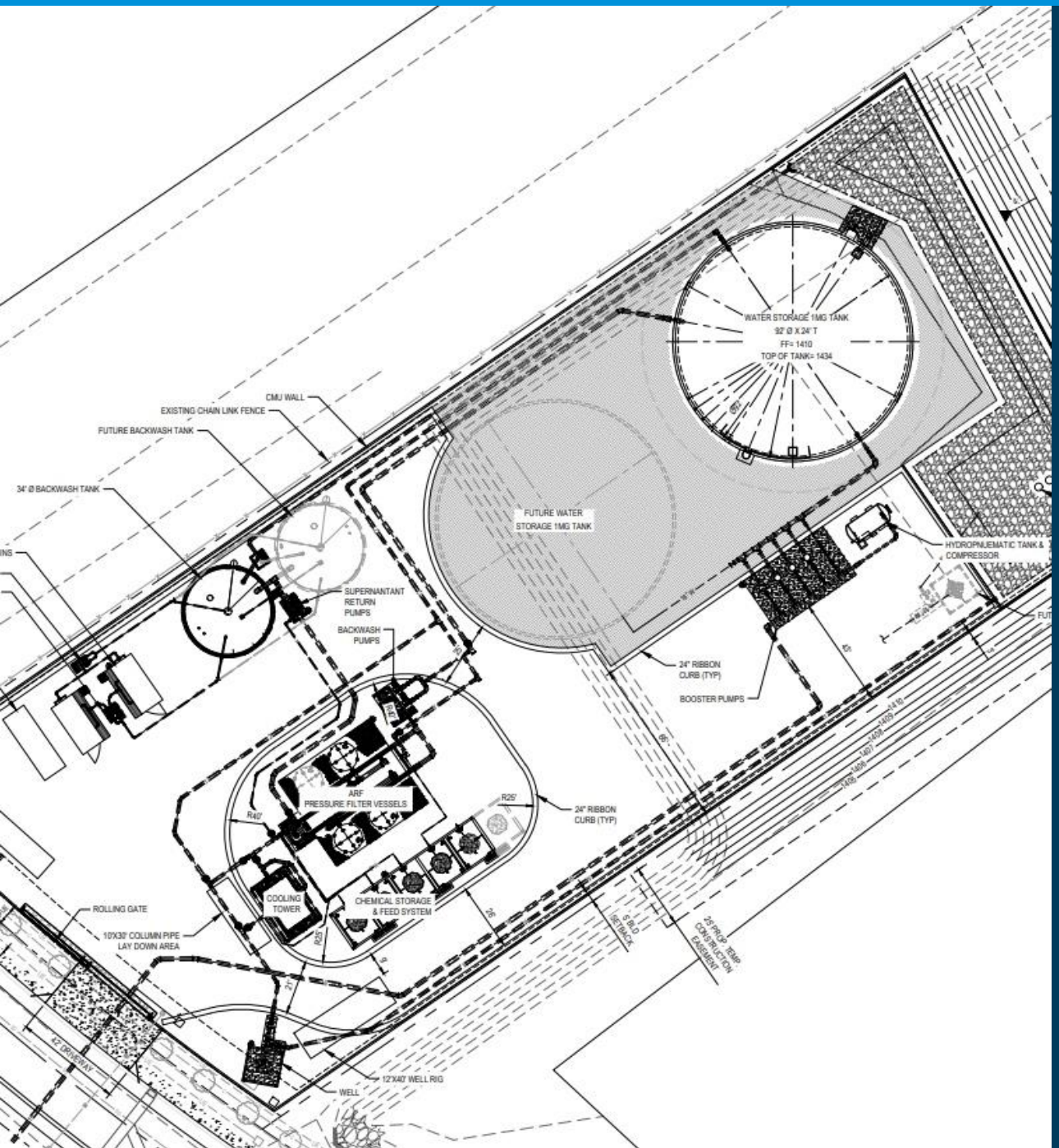
Antiscalant
Inhibiting the formation of scale on the resin.

Disinfection
Reducing the possibility of microbial colonization in filter. For disinfection other than UV, all traces of oxidants must be removed before the resin.

Activated Carbon Adsorption
Reducing organic matter, chlorine, and other contaminants that can foul or degrade resins.

Reducing Agents
Preventing oxidation damage to anion exchange resins. Sodium bisulfite and calcium thiosulfate are common.

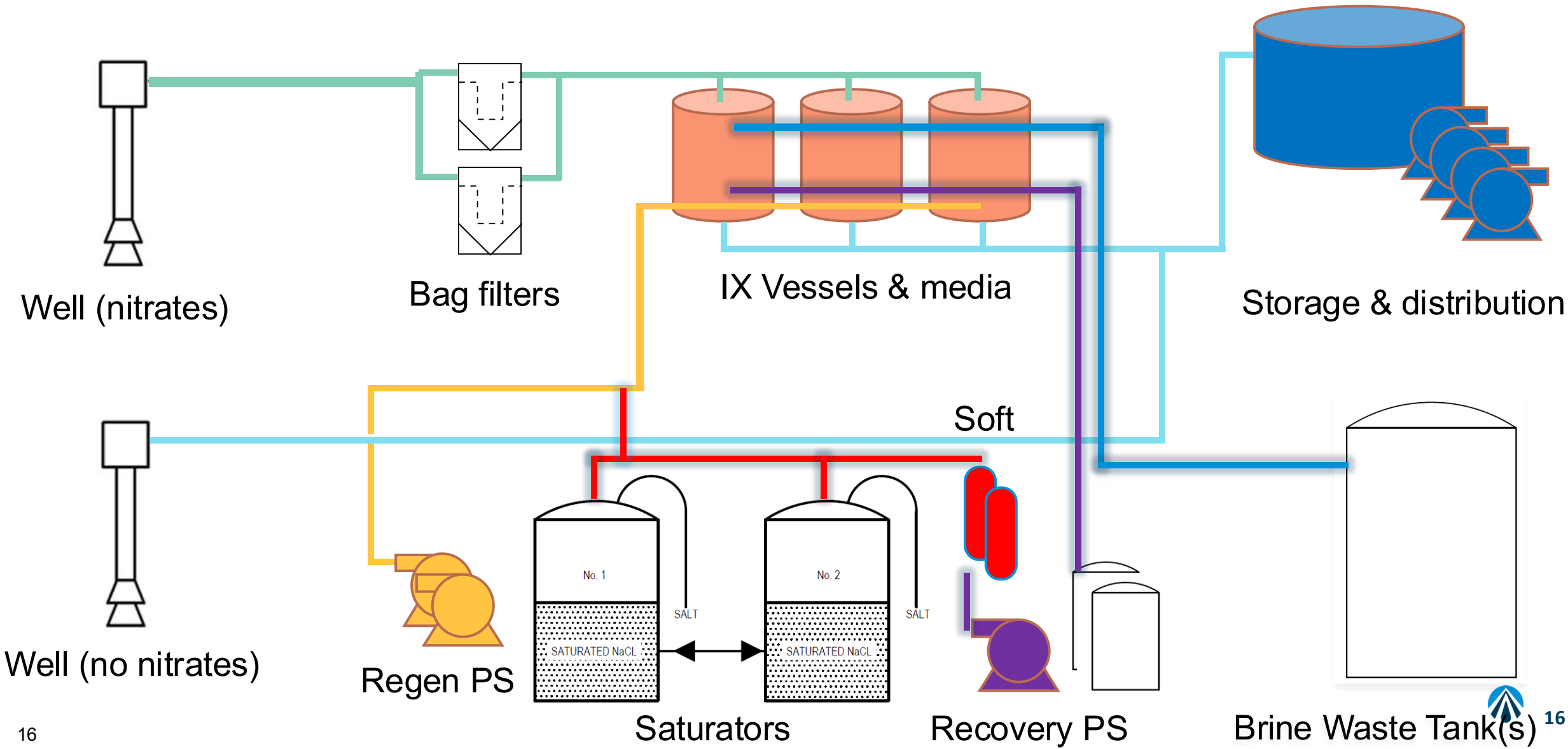
Chemical Treatment (Coagulation and Flocculation)
Removing colloidal particles and organic matter that can foul the resin.



3. IX Process Configurations

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Process Flow Diagram



16

3,000 GPM Scale

BAG FILTERS



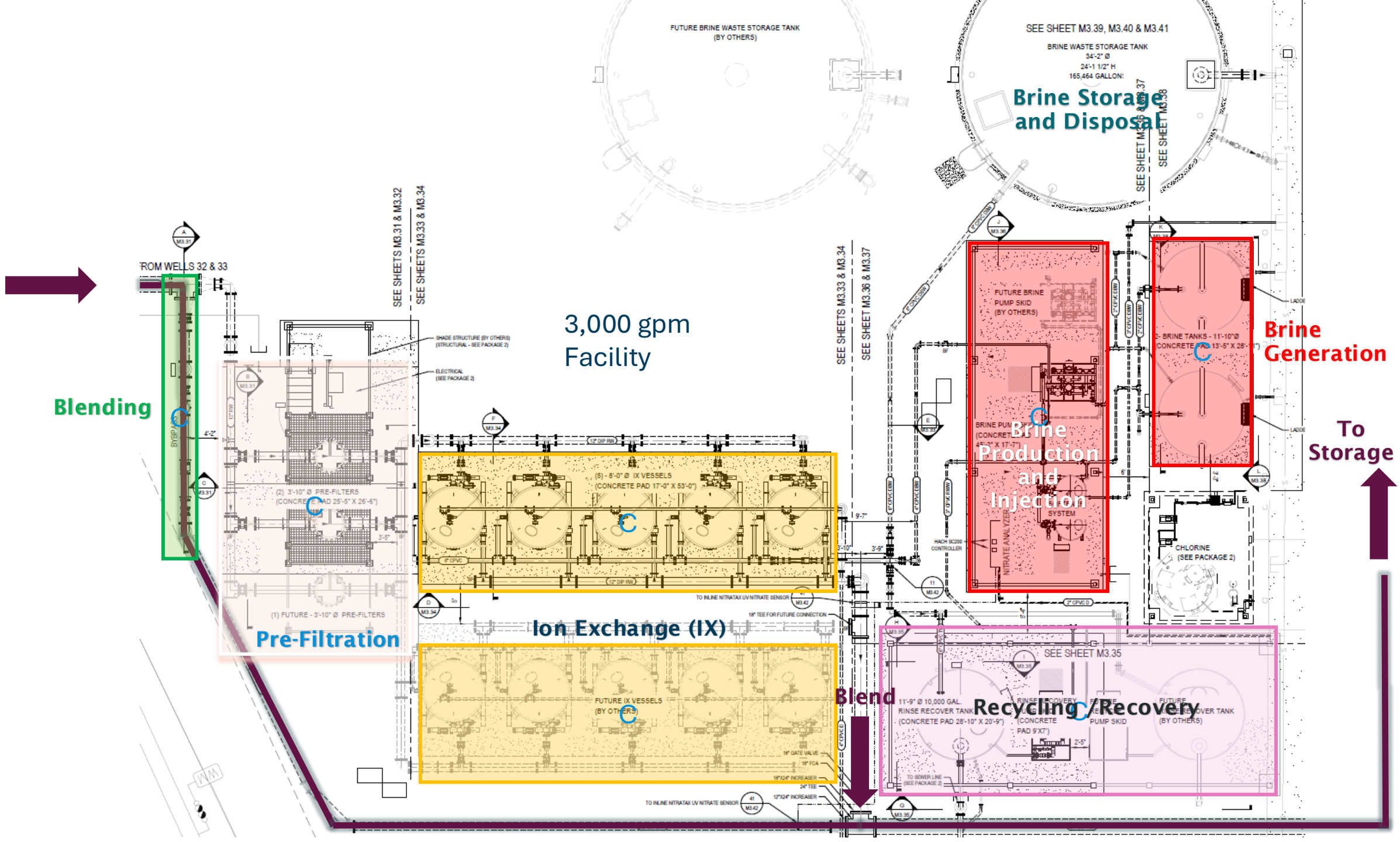


BRINE TANKS AND SOFTENER

ION EXCHANGE VESSELS



RECYCLE TANK


FUTURE BRINE WASTE STORAGE TANK
(BY OTHERS)
SEE SHEET M3.39, M3.40 & M3.41
BRINE WASTE STORAGE TANK
34'-2" Ø
24'-1 1/2" H
165,464 GALLON:
Brine Storage and Disposal
SEE SHEETS M3.31 & M3.32
SEE SHEETS M3.33 & M3.34
SEE SHEETS M3.33 & M3.34
SEE SHEET M3.36 & M3.37
SEE SHEET M3.36 & M3.37
SEE SHEET M3.38
FROM WELLS 32 & 33
Blending
3,000 gpm Facility
SHADE STRUCTURE (BY OTHERS)
(STRUCTURAL - SEE PACKAGE 2)
ELECTRICAL
(SEE PACKAGE 2)
(2) 3'-10" Ø PRE-FILTERS
(CONCRETE PAD 25'-5" X 26'-6")
(1) FUTURE - 3'-10" Ø PRE-FILTERS
Pre-Filtration
(5) - 8'-0" Ø IX VESSELS
(CONCRETE PAD 17'-0" X 53'-0")
Ion Exchange (IX)
FUTURE IX VESSELS
(BY OTHERS)
TO INLINE NITRATAX UV NITRATE SENSOR
18" TEE FOR FUTURE CONNECTION
18" GATE VALVE
18" FCA
18"X24" INCREASER
24" TEE
12"X24" INCREASER
FUTURE BRINE PUMP SKID
(BY OTHERS)
BRINE PUMP SKID
(CONCRETE PAD 45'-0" X 17'-7")
Brine Production and Injection
SYSTEM
NITRATE ANALYZER
HACH SC200 CONTROLLER
2- BRINE TANKS - 11'-10"Ø
(CONCRETE PAD 13'-5" X 28'-1")
Brine Generation
CHLORINE
(SEE PACKAGE 2)
To Storage
Blend
SEE SHEET M3.35
11'-9" Ø 10,000 GAL.
RINSE RECOVER TANK
(CONCRETE PAD 28'-10" X 20'-9")
RINSE RECOVERY
(CONCRETE
PAD 9'X7')
PUMP SKID
FUTURE
(BY OTHERS)
Recycling / Recovery
TO SEWER LINE
(SEE PACKAGE 2)

300 GPM Scale



WATER SOFTENERS
AND BAG FILTERS



ION EXCHANGE
VESSELS



BRINE AND
WASTE TANKS

Overall Configuration Guidance

Best practices:

- All components NSF-61 approved
- All vessels are properly sized so that EBCT and HLR are in the acceptable range for all operational scenarios
- Vessel freeboard accommodates the backwash required bed expansion
- Effluent collectors/underdrain maintain uniform flow distribution
- Resin traps in effluent lines are sized to keep resin from escaping
- Vessels equipped with inlet and outlet pressure gauges and differential pressure monitoring instrumentation
- Slurry loading or resin is accommodated

Overall Configuration Guidance

Best practices:

- Lead/lag operation is uncommon
- Parallel operation with multiple vessels is recommended
- Staggered operation mitigates corrosion
- Blending with raw water is common and beneficial for corrosion control and cost effectiveness
- Temperature adjustment of backwash rates during regeneration cycles is needed in colder regions to prevent resin loss.
- If using single pass through for PFAS don’t need freeboard for backwash.

PFAS IX Guidance

Typical Operations:

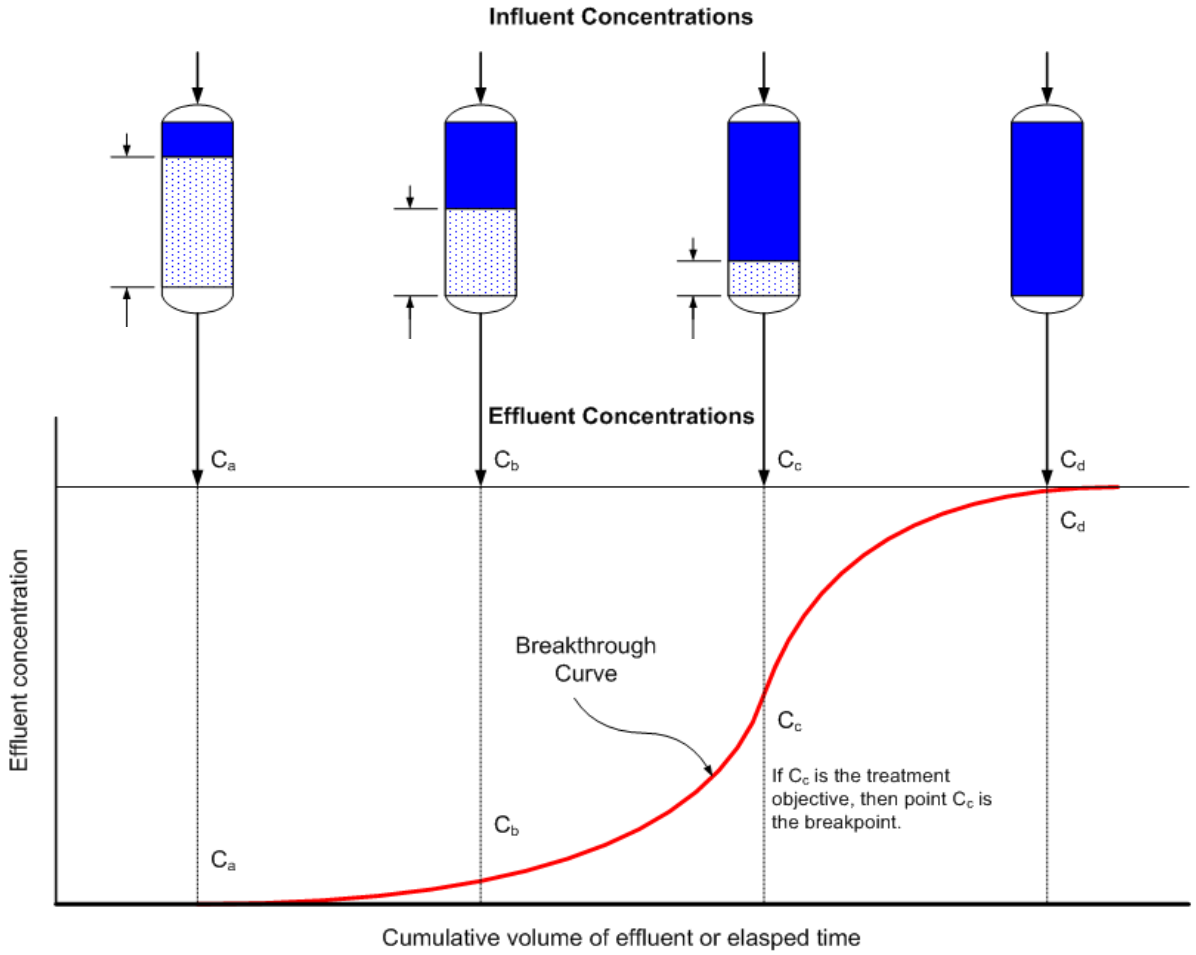
- Single-use Resin that is not backwashed or regenerated.
- Resin needs to be protected from fouling by pre-treatment (5-µm bag filters or smaller)
- Selective media for PFAS or upstream treatment of nitrate and sulfate.
- Because PFAS is at parts per trillion single-use resin can reach 200,000 bed volumes and last around 2 years.



4. Resin Regeneration

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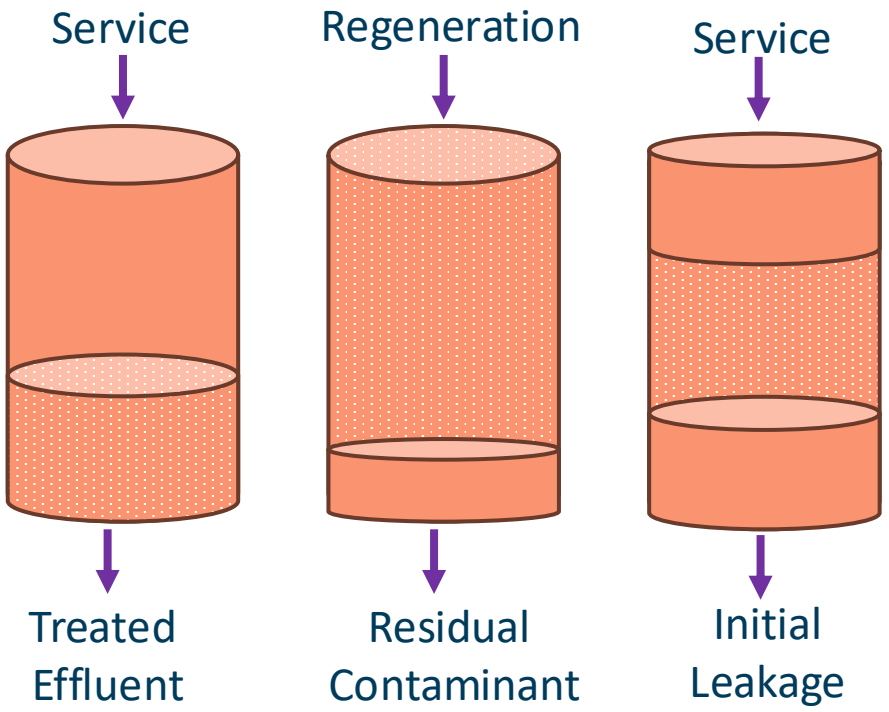
Purpose of Regeneration



Restore resin for reuse

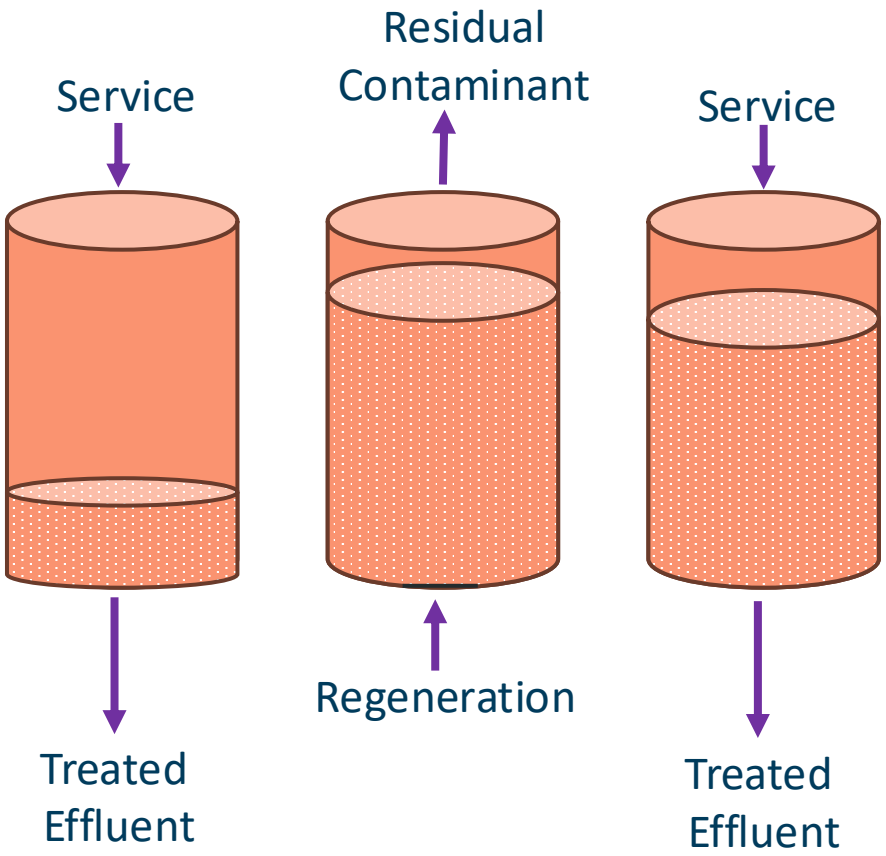
- Operation typically starts regeneration at 80% breakthrough.
- Without regeneration, media treating ppm-level contaminants lasts < 1 week
- Contaminants are moved from solid (resin) to liquid phase - not destroyed
- Both cation and anion resins are regenerated and use sodium chloride (NaCl) or salt for regeneration
- Regeneration types are Co-Flow, Counterflow, and Split Flow

Co-Flow Regeneration



Steps	Criteria	Duration
Backwash	50% bed expansion followed by bed settling	1 BV for clean water, 2-3 BVs where solids are present, 3-8 minutes for bed to settle
NaCl injection	10% solution at 2-4 BVs/h, 0.25-0.5 gpm/cuft	20-45 minutes
Slow Rinse	2-4 BVs, 0.25-0.5 gal/cuft at regenerant flow rate	30-40 minutes
Fast rinse	3-6 BVs, 22.5-45 gal/cuft at service flow rate	10-20 minutes

Counterflow Regeneration

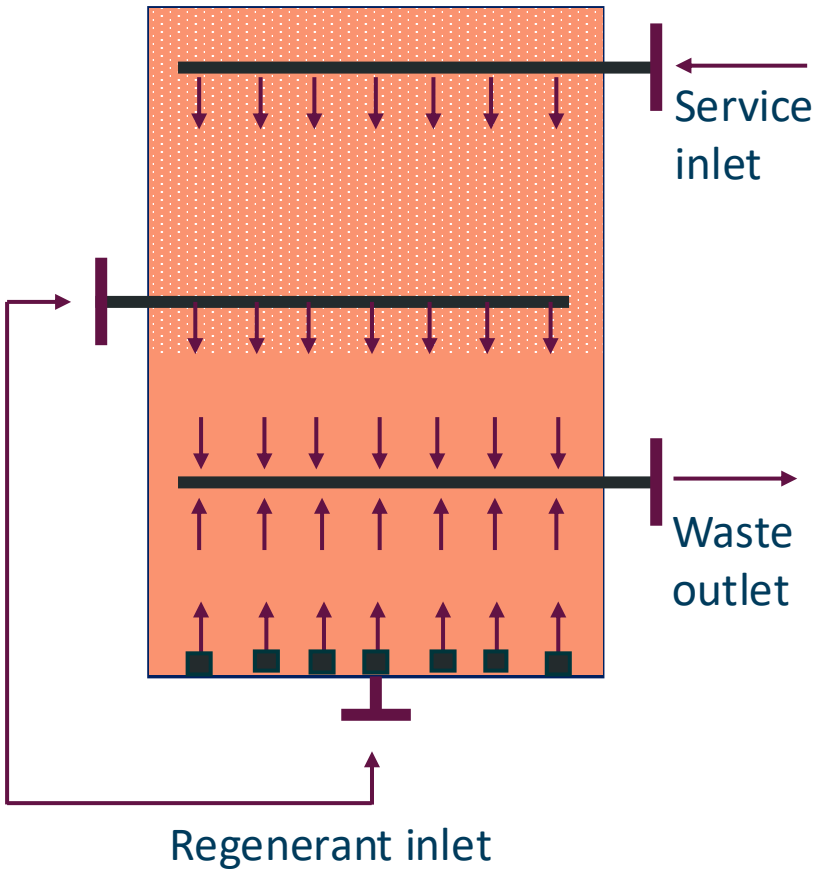


Steps	Criteria	Duration
Backwash	Not required	-
NaCl injection	10% solution at 2-4 BVs/h, 0.25-0.5 gpm/cuft	20-45 minutes
Slow Rinse	1-2 BVs, 7.5-15 gal/cuft at regenerant flow rate	30-40 minutes
Fast rinse	2-4 BVs, 15-30 gal/cuft at service flow rate	10-20 minutes

Compared to co-flow:

- Backwashing not required, performed only when needed
- Reduced water usage for both slow and fast rinse steps
- No initial leakage

Split Flow Regeneration

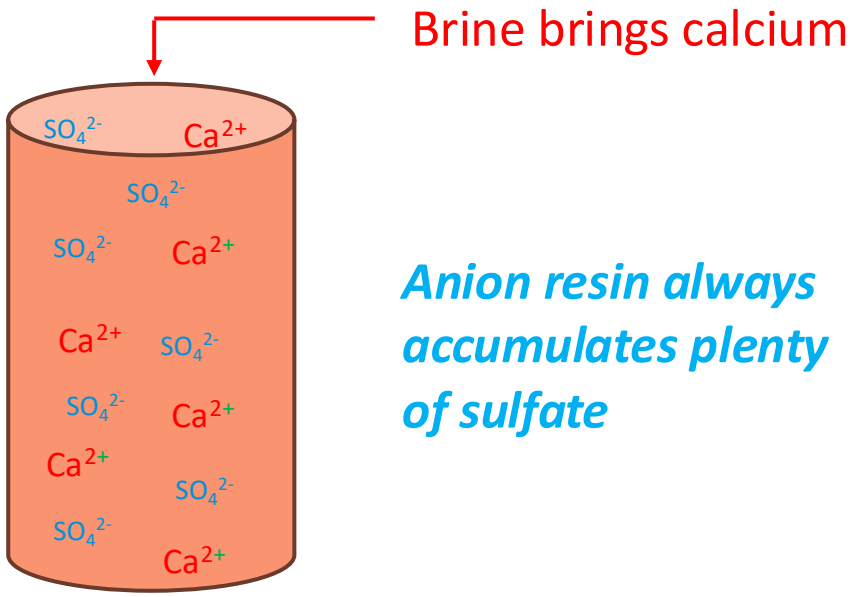


Steps	Criteria	Duration
Simultaneous regeneration steps		
NaCl injection downlow	3 lb/cuft, 10% solution, 2-4 BVs/h, 0.25-0.5 gpm/cuft	20-45 minutes
NaCl injection up flow	6 lb/cuft, 10% solution, 2-4 BVs/h, 0.25-0.5 gpm/cuft	20-45 minutes
Simultaneous slow rinse steps		
Slow rinse	1-2 BVs, 7.5-15 gal/cuft at regenerant flow rate	20-45 minutes
Slow rinse	1-2 BVs, 7.5-15 gal/cuft at regenerant flow rate	20-45 minutes
Fast rinse		
Final rinse down on entire vessel	2-4 BVs, 15-30 gal/cuft at service flow rate	10-20 minutes

The most efficient type of regeneration

Scaling Issue During Regeneration

- Hard water must be softened prior to regenerant preparation to avoid **$CaSO_4$** precipitation
  - Ksp ($CaSO_4$) = 5 x 10^{-5} mol^2/L^2 (very low solubility)



Anion resin always accumulates plenty of sulfate

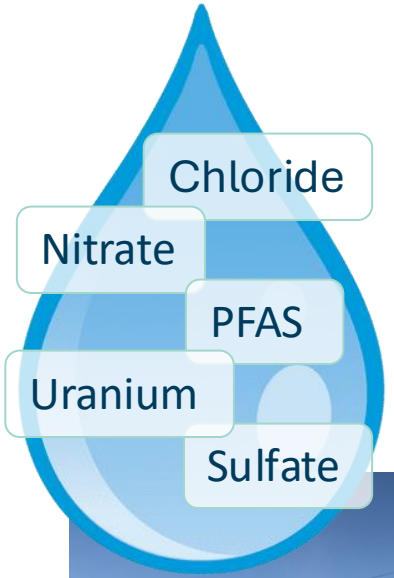


Brine Waste

Issue:
- Continuous production
- Regeneration may occur multiple times per week

Options:
- ✓ Sewer
- ✓ Deep well injection
- X Irrigation is not an option for high salinity water and any disposal can be limited with aquafer protection standards
- ✓ Evaporation ponds

Evaporation ponds are suitable for:
- ✓ Rural area with sufficient land
- ✓ High ambient temperature that enables good evaporation rate
- ! Cost may exceed that of the treatment process itself



- Brine waste may contain more than just salt and the removed contaminants
- SBA IX brine waste will contain multiple anions



Inappropriate evaporation pond type for ion exchange brine

Evaporation Ponds with Liners

Used to contain and manage brine waste while preventing seepage or contamination of aquifers



Footprint (area) intensive

- Estimated Cost: $2/sf

Design considerations:

- Brine
- Off-spec
- Precipitation
- Peak storm events
- Freeboard



Regeneration Wastewater Recycling



Regeneration wastewater is minimum 2% (more likely 4 to 6%) of total water treated

Part of wastewater can be recycled

- Recovers fast rinse water fraction
  - 3-6 BVs/cycle or > 50% of total ww
- Reused for brine preparation and backwashing
- Sent through a softener to remove hardness
- Requires additional:
  - Tank
  - Monitoring – conductivity
  - O&M
  - Scales control

Learning Objectives - Take Me Home Messages

- Select resin for specific application – invest in water analysis
- Understand operational hydraulics – operate within the optimal range; avoid flow that is too slow or too fast
- Predict throughput – do not rely solely on sensors
- Identify chromatographic peaking – investigate upstream treatment and reassess resin selectivity
- Identify fouling and apply pretreatment – starts with water analysis
- Understand regeneration bottlenecks – evaluate duration, frequency, and brine waste generation
- IX for PFAS requires single-pass media without backwashing or regeneration. Extra attention to fouling and selectivity



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