Mitigation Techniques & Treatment Options for Radionuclides

Overview

- Acronyms & Abbreviations
- Mitigation Checklist
- Non-Treatment Options
- Treatment Options
- Planning for Treatment Installation
- Implementing the Plan

Acronyms & Abbreviations

AA	Activated Alumina
BAT	Best Available Technology
BV	Bed Volumes
Ca	Calcium
EBCT	Empty Bed Contact Time
ED/EDR	Electrodialysis/Electrodialysis Reversal
Fe	Iron
HMO	Hydrous Manganese Oxide
IX	Ion Exchange
Mg	Magnesium
POU	Point of Use
RO	Reverse Osmosis
TDS	Total Dissolved Solids

Mitigation Checklist

1. Monitor at entry points
2. Determine compliance status
3. Consider non-treatment options
4. Raw water testing
5. Determine treatment evaluation criteria
6. Select a mitigation strategy

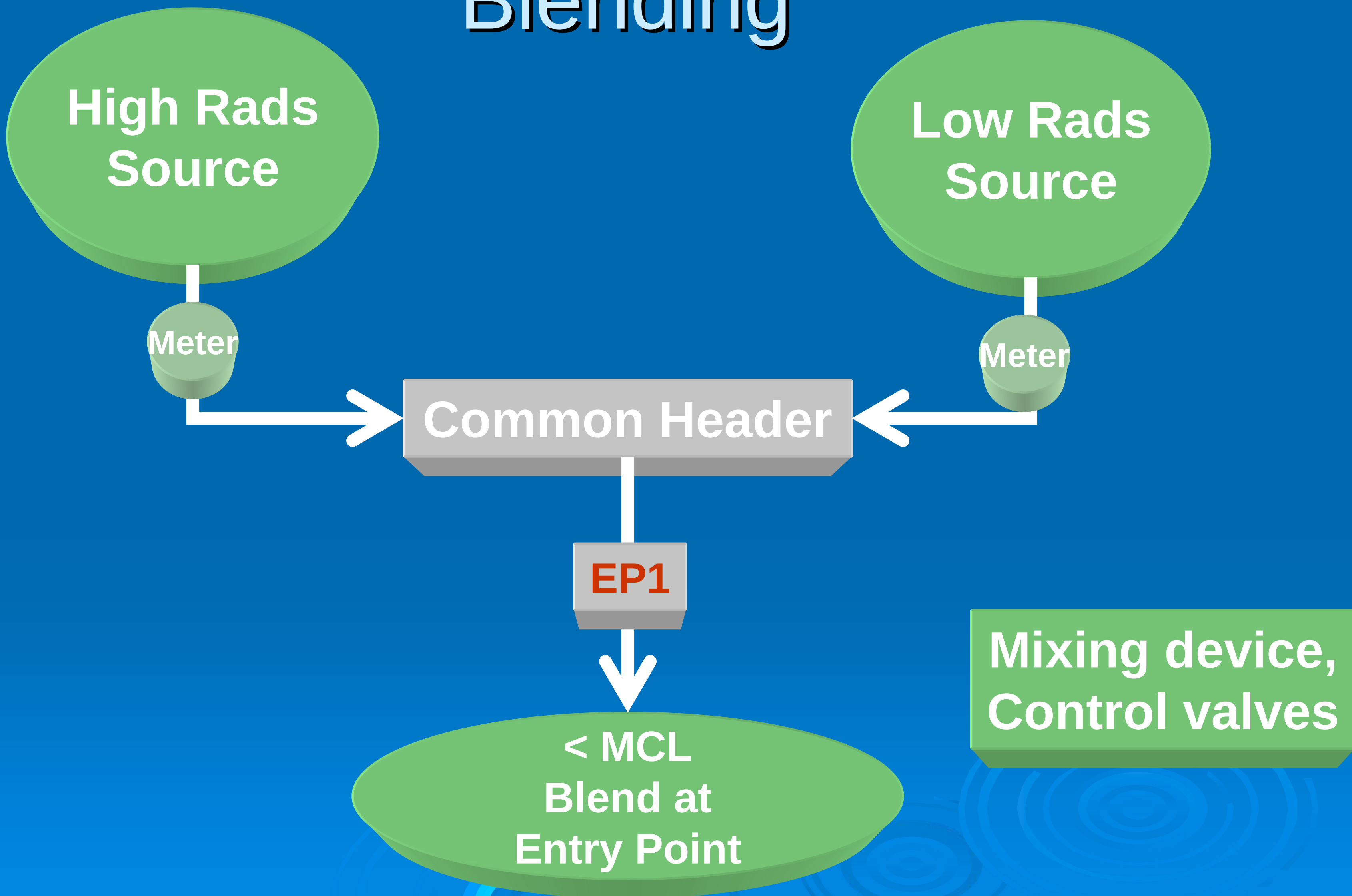
Mitigation Checklist, cont.

7. Estimate capital and O & M costs
8. Evaluate design considerations
9. Pilot test
10. Develop construction cost estimates & plan
11. Implement the strategy
12. Monitor at entry point

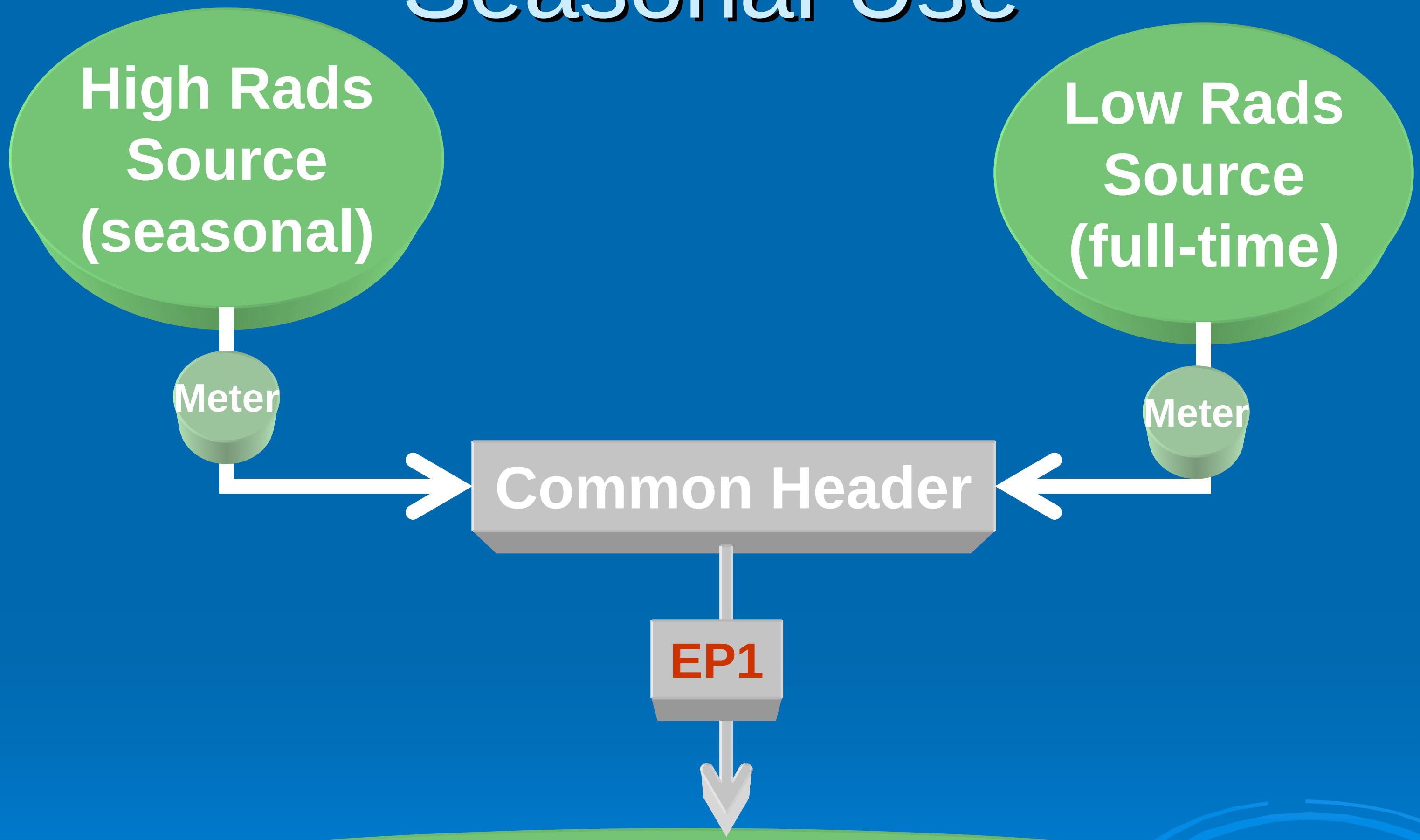
Consider Non-Treatment Options

- Alternative Source(s)
  - Install new source
  - Purchased water/interconnection
- Geological solutions
  - Rehab existing wells
  - Drill new wells
- Blending or Seasonal Use

Non-Treatment Options: Blending



Non-Treatment Options: Seasonal Use



- ≤ MCL using low rads source only
- > MCL when blended, but RAA ≤ MCL over
- any 4 consecutive quarters0

Raw Water Testing

- Look for interfering or competing ions
  - May plug media
  - May cause aesthetic problems (e.g., iron and manganese)
- Other contaminants for simultaneous removal?
  - Nitrate
  - TDS
  - Iron
  - Hardness

Determine Treatment Evaluation Criteria

- Existing treatment processes
- Finished water targets
- Land availability and related costs
- Water loss
- Capacity
- Residual disposal options
- Operator expertise
- Additional requirements

Mitigation Checklist

1. Monitor at entry points
2. Determine compliance status
3. Consider non-treatment options
4. Measure water quality parameters
5. Determine treatment evaluation criteria
6. Select a mitigation strategy
   i. Non-treatment options
   ii. Existing treatment
   iii. New treatment

BATs and SSCTs: Radium Only

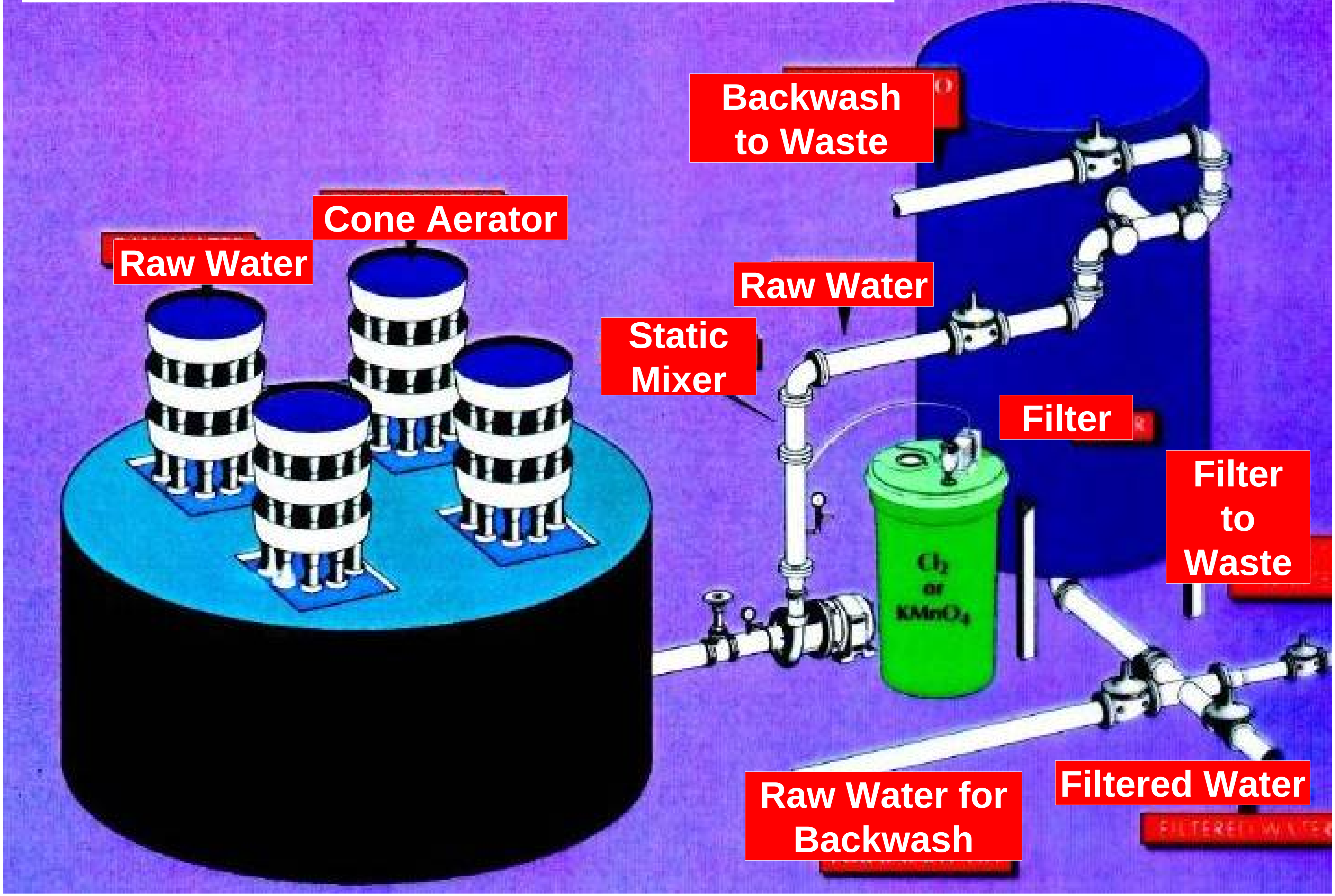
Radium Removal Methods

Technology	BAT	SSCT (25-10,000)
Ion Exchange (IX)	X	X
Point of Use (POU) IX		X
Reverse Osmosis (RO)	X	X
POU RO		X
Lime Softening	X	X
Green Sand Filtration		X
Co-Precipitation w/ Barium Sulfate		X
Performed Hydrous Manganese Oxide (HMO) Filtration		X
Electrodialysis/Electrodialysis Reversal		X

Green Sand Filtration

- SSCT for radium removal
- Effectiveness varies (60 – 97%)
- Simple and operator friendly
- Potassium permanganate feed rate is key
- Disposal considerations (media & backwash)
- Also removes iron, manganese, and arsenic

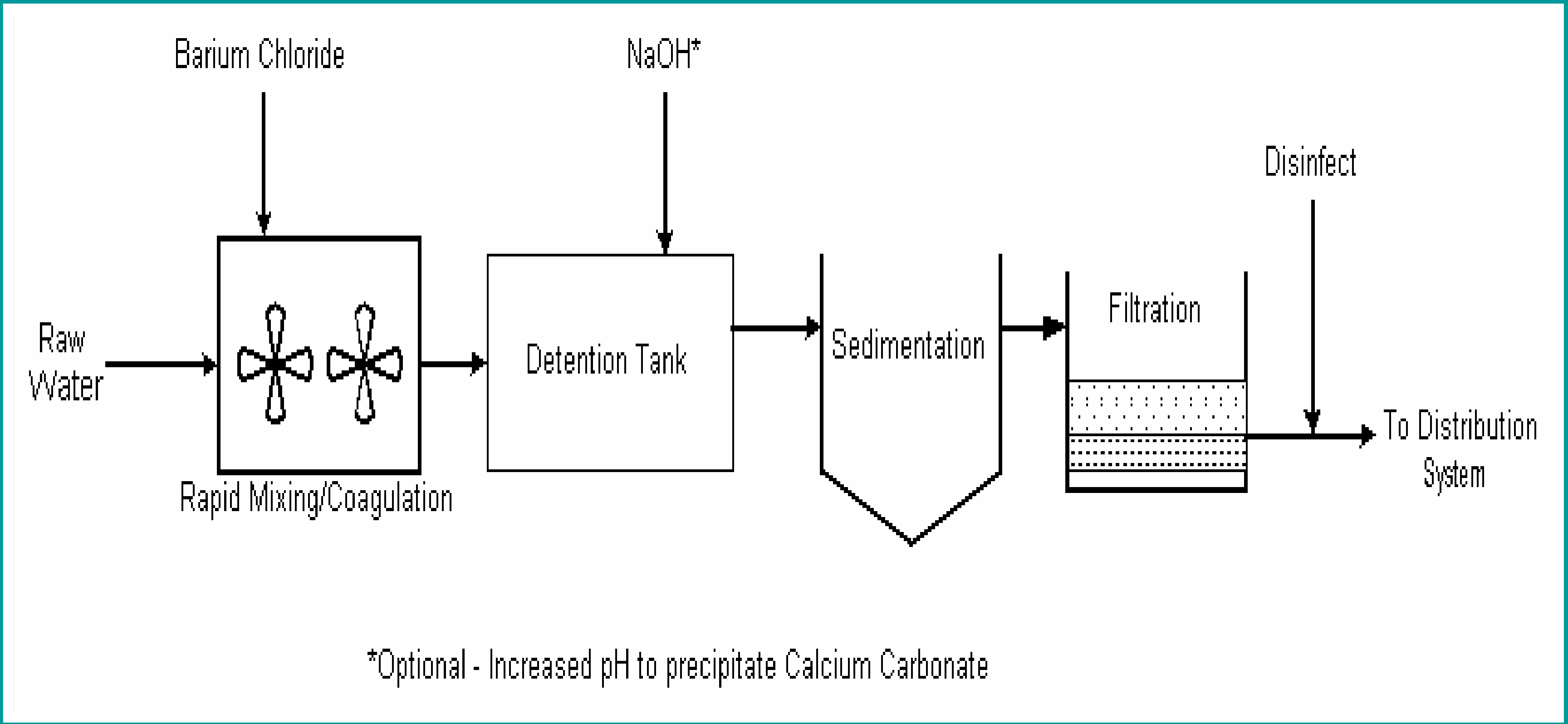
Green Sand Filtration



Co-Precipitation w/ Barium Sulfate

- SSCT for radium removal
- Effectiveness varies (40% - 90%)
- Complex process
  - High level operator skill required
- Requires high sulfate levels in raw water
- Used mainly for waste effluent treatment
  - Has been used with AA

Co-Precipitation w/ Barium Sulfate, cont.

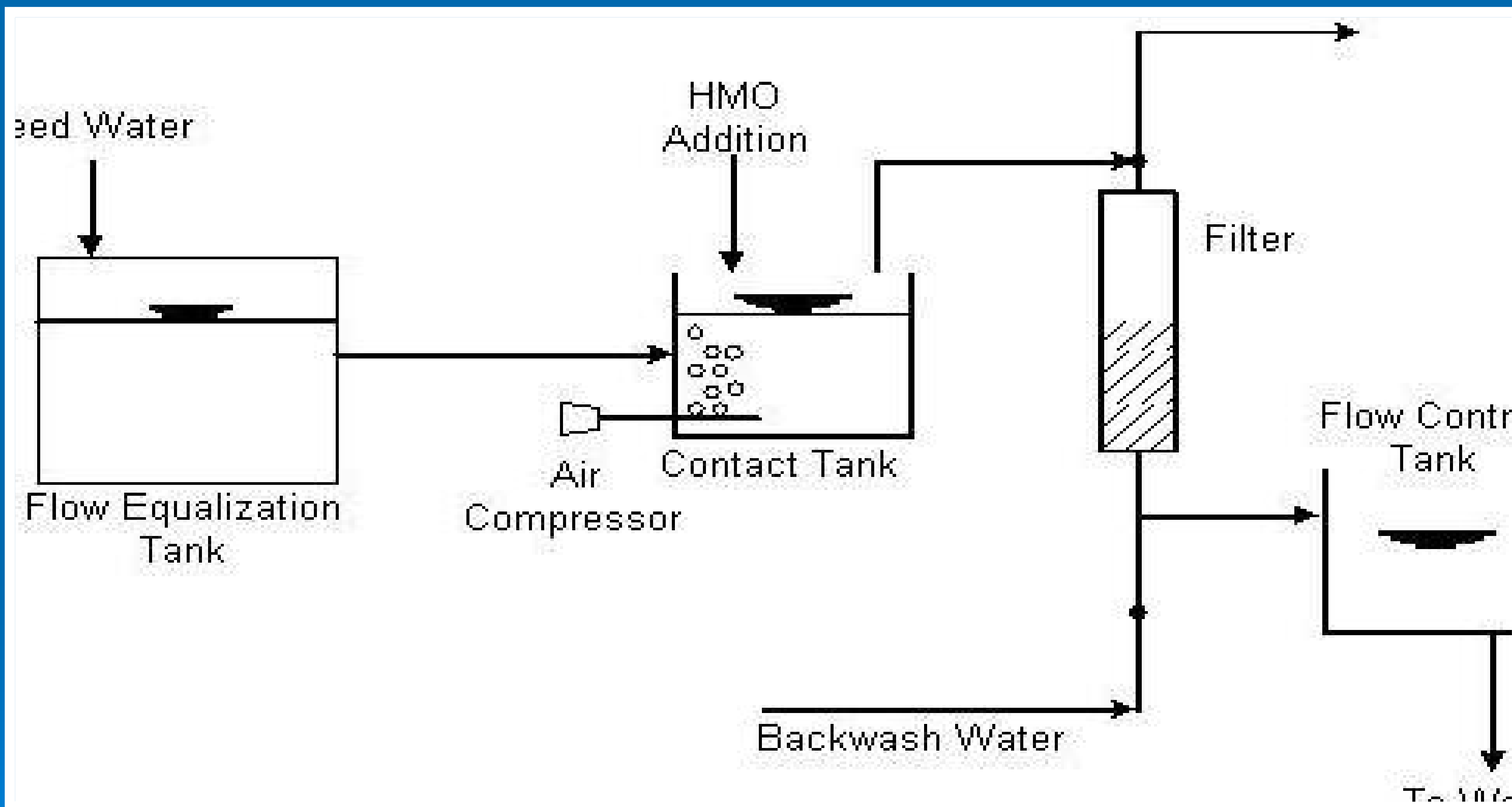


Sludge disposal and radon generation are issues of concern

Pre-Formed HMO Filtration

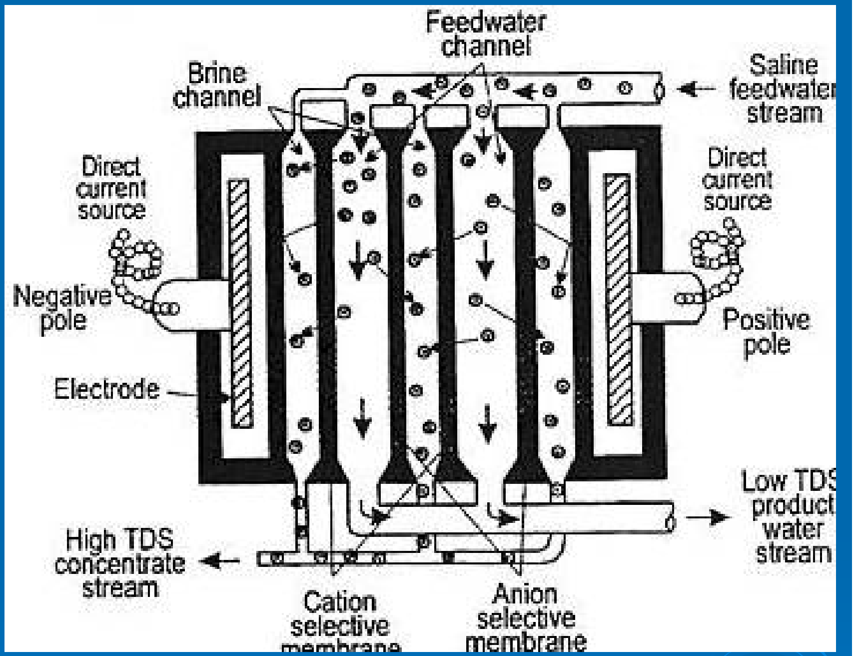
- SSCT for radium removal
- Can be up to 90% effective
- Intermediate operator skill
- Can rely on existing treatment facilities
- May need to oxidize iron first
- Limited effect if HMO under- or over-dosed

Pre-Formed HMO Filtration, cont.



ED/EDR

- SSCT for radium removal
- Up to 95% effective
  - Also removes uranium, arsenic, nitrate, & more
- Ions pass through IX membrane via DC voltage
  - EDR reverses DC power
- Membrane build-up could complicate disposal



BATs and SSCTs: Uranium Only

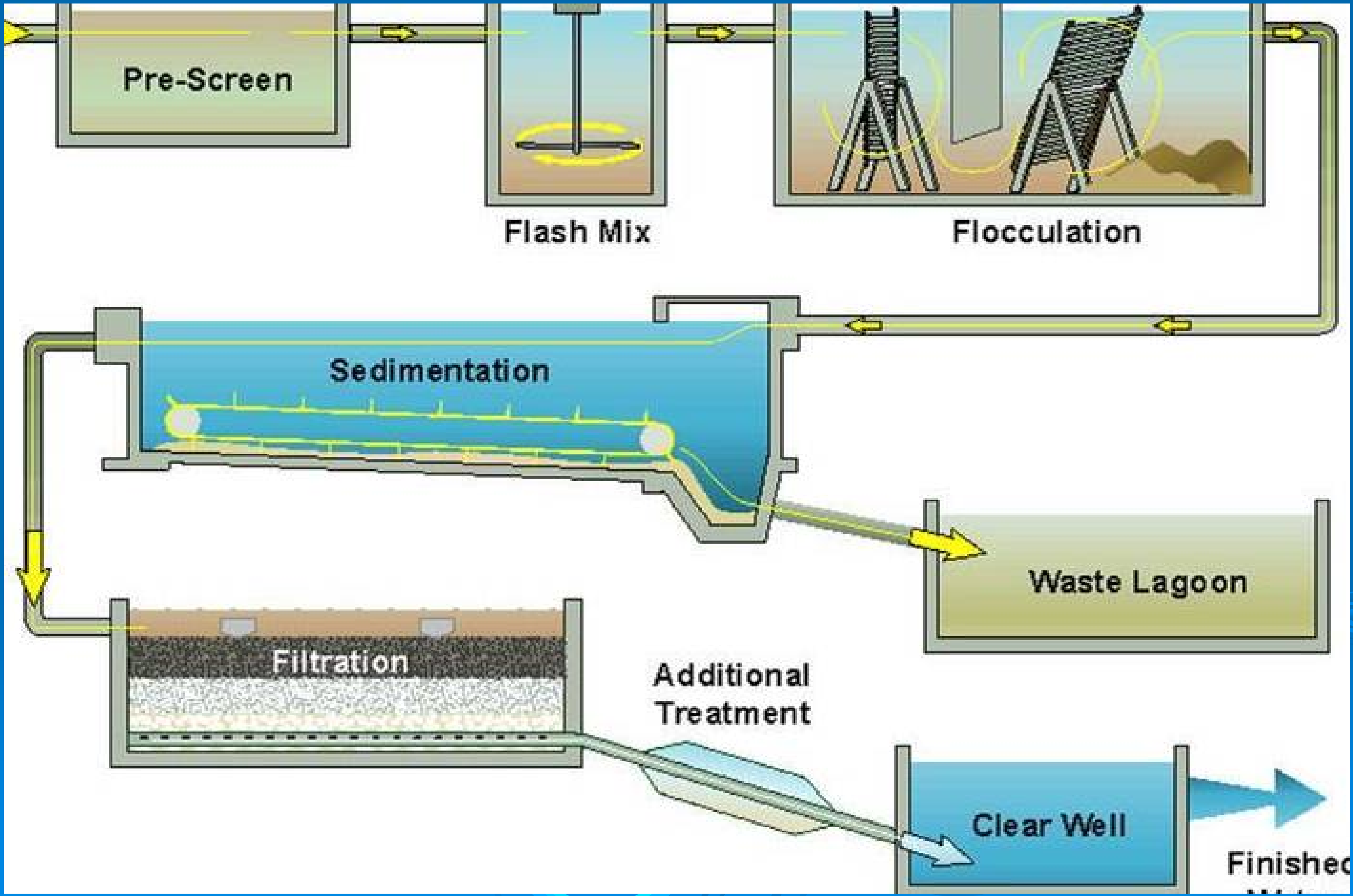
Uranium Removal Methods

Technology	BAT	SSCT	
		25-10,000	501 – 10,000
IX	X	X	
POU IX		X	
RO	X		X
POU RO		X	
Lime Softening	X		X
Activated Alumina (AA)		X	
Coagulation/Filtration	X	X	

Coagulation/Filtration

- BAT & SSCT for uranium
- Generally 50 – 90% effective
- Advanced operator skill required
- Coagulant effectiveness is pH-dependent
- Removal efficiency depends on prevailing charge on floc & uranium species present
- Probably not feasible as a new technology
- Consider backwash, sludge, and media disposal

Coagulation/Filtration, cont.



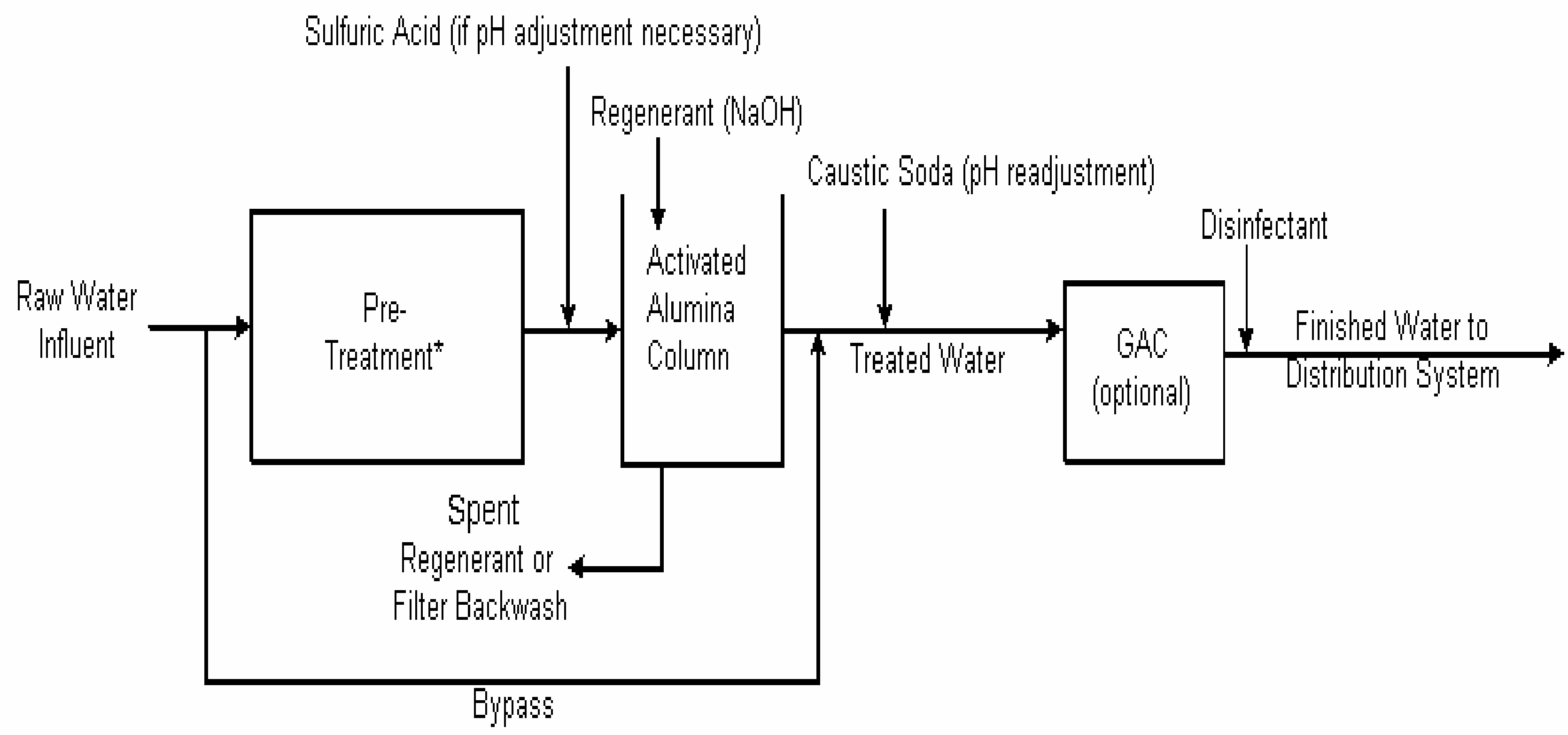
Activated Alumina

- **SSCT for uranium removal**
  - **Up to 99% effective**
- **Operates on demand**
- **Relatively insensitive to TDS and sulfate**
- **Can be regenerated**
- **Potential for disposable media option**

Activated Alumina, cont.

- Pre-treatment may be necessary
  - Oxidize iron, manganese, & arsenic
- Advanced operator skill required (pH adjustment)
- Regeneration
  - Both acid and base required (impractical for small systems)
  - Media tend to dissolve when regenerated
- Disposal of backwash, regenerant, & media a concern
- Beware of arsenic

Activated Alumina, cont.



BATs and SSCTs: Radium and Uranium

Ion Exchange

- Anion exchange for uranium removal
  - Up to 95% removal
  - High uranium capacity
  - Treats 10,000 – 100,000 BV
  - Capacity may be sulfate-dependent
- Cation exchange for radium removal
  - Up to 97% removal
- Mixed bed IX for beta/photon removal

Ion Exchange, cont.

- Operates on demand
- Short contact time (flow insensitive)
  - (EBCT 1.5 - 3 minutes)
- Insensitive to pH
- Can remove other contaminants
- Resin can be regenerated

- Appropriate for small systems (POU also an option)
- 98+% water recovery

Ion Exchange, cont.

- Excess oxidant may degrade resin
  - >0.1 mg/L free chlorine

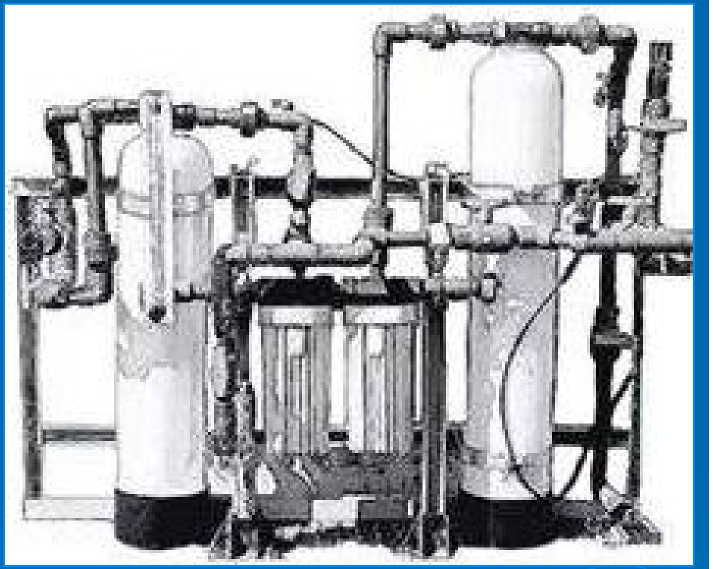
- May require pre-filtration
- Sulfate can be a problem
- May require finished water pH adjustment
  - Removes bicarbonate alkalinity
  - 2-5 columns in parallel may be appropriate
- Generation of brine

Ion Exchange, cont.

- Example costs – cation and anion units installed
  - < 1 GPM: $10,000 - $15,000
  - 1 – 25 GPM: $20,000 – 30,000
  - 40 – 50 GPM: $35,000 – 53,000
  - 80 GPM - $65,000 – 98,000

POU IX

- SSCT for radium, uranium, & beta/photon
  - None are NSF-certified yet
- System or contractor owns, controls, and maintains units
- Moderate to high initial, O&M, and operating costs
- Removes inorganic chemicals & nitrate



Royal Melbourne, Long Grove, IL

- Governing Body
  - Royal Melbourne Homeowners Association
- Community Water System
  - Gated golf course community
  - Golf course and club
    - Country club with banquet facilities
  - 125 residential luxury homes
  - 3 wells with average depth of 290m (950ft)
  - Radium levels in water out of compliance
- Water Quality
  - Combined Radium 226/228 – 8.3pCi/L (avg.)
  - Gross Alpha – 11.4pCi/L (avg.)
  - Water Hardness – 308 to 410 mg/L (18 to 24gpg)
  - Iron – 0.21mg/L

Proposed Radium Mitigation Solutions for Royal Melbourne CWS

- Central treatment
  - Ion exchange
  - Reverse osmosis
  - Blending of shallow and deep wells
- New non-contaminated water source
  - Shallow wells have iron and hydrogen sulfide issues – limited flow capabilities
  - Lake Michigan water not an option
- POE ion exchange

Treatment Cost Summaries

Radionuclide Treatment Method	Initial Cost ($)	Annual Cost ($)	Total 10 Year Program Cost ($)
Central Ion Exchange	726,000	19,400	920,000
Central Reverse Osmosis	1,200,000	40,200	1,602,000
POE Ion Exchange	215,000	26,000	475,000

Royal Melbourne POE Program Requirements

- Equipment
  - Identical equipment for each installation site
  - ANSI/NSF approved softener
  - Regenerate with NaCl only
  - Alarm condition for equipment malfunction
  - Owned by CWS or leased from service provider
  - Monitor condition of resin bed to trigger regeneration

POE Water Softener Solution

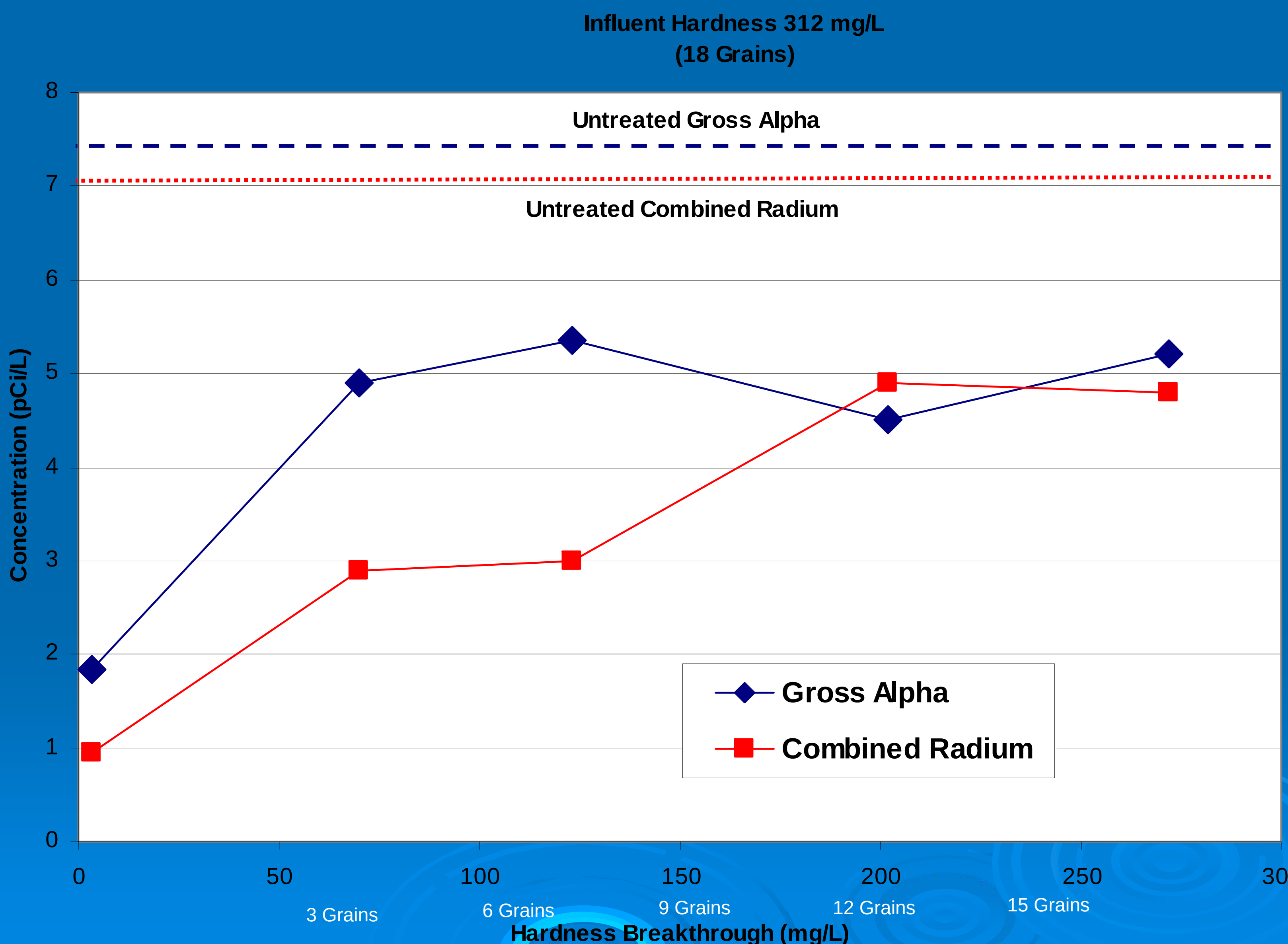
POE Program Requirements (Cont.)

- Service
  - Salt delivery and equipment maintenance
  - Regular monitoring of equipment
  - Assure brine tank filled with salt
  - Yearly maintenance
  - 10 year service agreement with renewal at 9 years
    - Assures compliance is maintained

Royal Melbourne POE Program Requirements (Cont.)

- Monitoring Equipment
  - Monitor - sense actual condition of resin bed to trigger regeneration – lower reserve required
    - Greater softener efficiency
    - Automatic adjustment to changes in influent water
  - Meter regeneration not as accurate – higher reserve required
    - Variable hardness through year
    - Potential meter inaccuracies with low flows
- Radionuclide Monitoring
  - Monthly monitoring of hardness
  - Develop hardness as indicator
    - Determine trigger and action levels through testing

Radionuclide Trigger Level Test



Conclusions

- POE water softening provides efficient economical solution to radium mitigation for the "right sized" community water system
- Community association must have ability to implement and enforce POE compliance plan
- Compliance of POE solution attained with long-term maintenance and monitoring plan

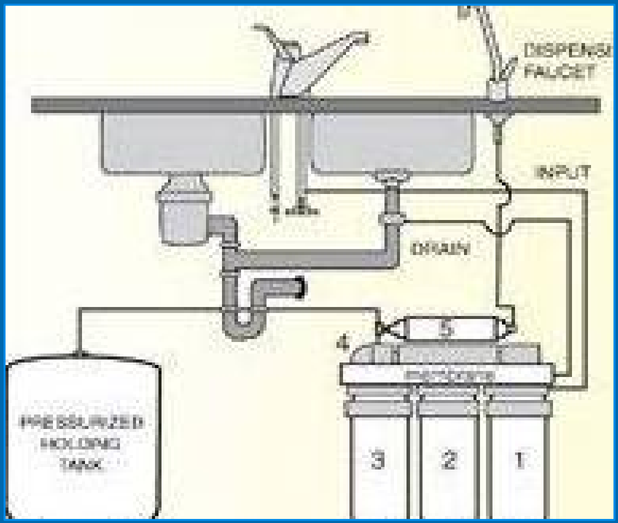
Reverse Osmosis

- At least 90% effective for radionuclide removal
- Effectively removes other inorganics
- Advanced operator skill required
- Pretreatment often required
- Energy requirements
- Water loss
- Post-treatment
- Highly concentrated residuals

RO Filtration Process

POU RO

- SSCT for all radionuclides
- System or contractor owns, controls, and maintains units
- Moderate initial costs, high O&M costs
- Removes inorganic chemicals, microbials, metals, minerals, and some organic chemicals

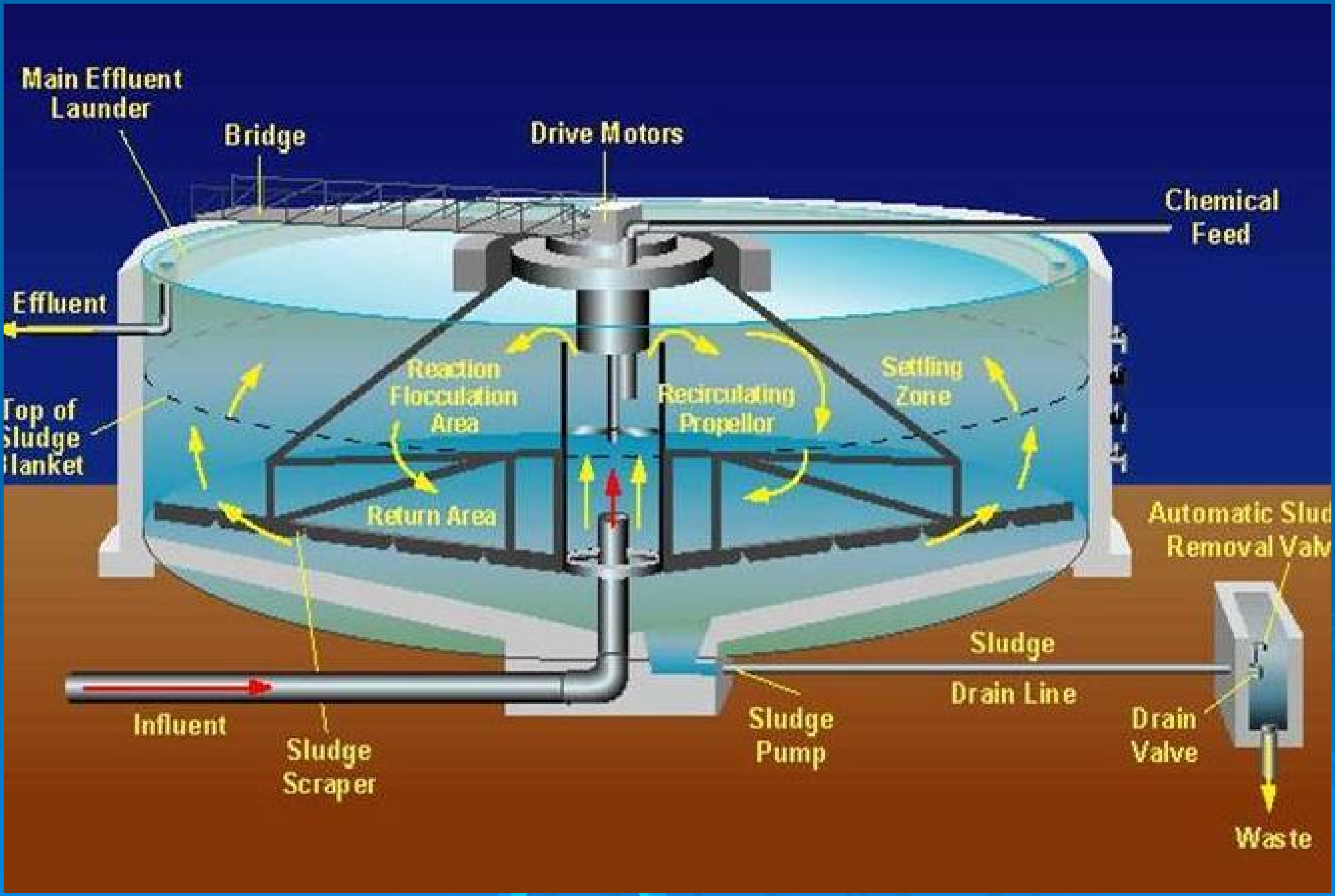



Culligan

Lime Softening

- BAT and SSCT for radium and uranium
  - Hydrated lime or quicklime addition
  - pH should be >10.5
  - Magnesium hydroxide
- Removes arsenic, Fe & Mg, and more
- Advanced operator skill required
- Direct discharge not permitted
- Excessive softening can corrode pipes

Enhanced Lime Softening



Treatment Considerations: Estimating Costs

- Raw and treated water quality
- Piloting, permitting, and training
- Engineering, design, and construction
- Licensing – NRC (?)
- Chemicals and chemical storage
- Media replacement
- Energy
- Labor
- Compliance monitoring
- Recordkeeping
- Residual handling and disposal

Treatment Considerations: General Design

- **Configuration**
  - Parallel
  - Series
  - Guard columns
- **Split stream treatment**
- **Redundancy**
- **Process control monitoring**
- **Pre & post-treatment**
- **Residuals**
- **Loading rates**

Treatment Considerations: Testing

- Bench scale testing
- Pilot testing
- Use reputable vendors
  - Low bidder approach
  - Seek warranties/leases
  - Ask appropriate questions

Pilot Testing: Pros & Cons

- Answers questions:
  - Effectiveness
  - Net water production
  - Finished water quality
  - Residuals
  - Impact of variables
  - Costs
- Develop site-specific design criteria
- Can be costly & time consuming

Establish a Protocol

- Introduction
- Objectives
- Media Description
- Process Description
- Project Schedule
- Data Collection
  - Parameters
  - Locations
  - Schedule
- Quality Assurance Program
- Residuals Management & Disposal
- Pilot Study Summary

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Compliance!

Questions?