

SAWEA

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Removal of Radioactive Contaminants from Drinking Water Sources

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A decorative graphic consisting of several concentric circles of varying shades of blue, centered in the lower half of the slide. The circles are arranged in a way that they appear to be ripples on water, with the largest circle on the right and smaller ones to its left and below.

Uranium 238 $\xrightarrow{\text{Decays to give}}$ Radium 226 $\xrightarrow{\text{Decays to give}}$ Radon 222
 α emitter

Thorium 232 $\xrightarrow{\text{Decays to give}}$ Radium 228
 β emitter



Chemical Nature and Health Risks

Radon 222

Chemically inert gas which is odorless, tasteless and colorless

Upon respiration : Increases the risk of lung cancer

Upon drinking contaminated water : It increases the risk of stomach cancer

Radium 226-228

Alkaline earth metal

Bone seeker : It fixes in bone tissues.

Upon drinking of contaminated water : It increases the risk of bone cancer.

The current values of MCLs of radionuclides in drinking water and in air *

SN	Radionuclide	Current MCL in water
1	Radium 226-228 combined	5 pCi/L
2	Alpha emitters	15 pCi/L
3	Beta emitters	4 mrem/year
4	Uranium 238	0.02 mg/L

SN	Radionuclide	Current MCL in air
1	Radon 222	4 pCi/L

* US-EPA Regulations

Methods of removal of Radium 226-228 from water

1. Chemical precipitation

Usual lime soda ash softening

Dosing of BaCl_2 to deposit complex Ba-Ra-SO_4

2. Ion Exchange Resins

Exchange by simple monovalent cations (Na^+)

3. Adsorptive Media

Chemical chelation by synthetic adsorption media of certain specificity

4. Selective membrane Methods

Reverse Osmosis

Nanofiltration

Ultrafiltration

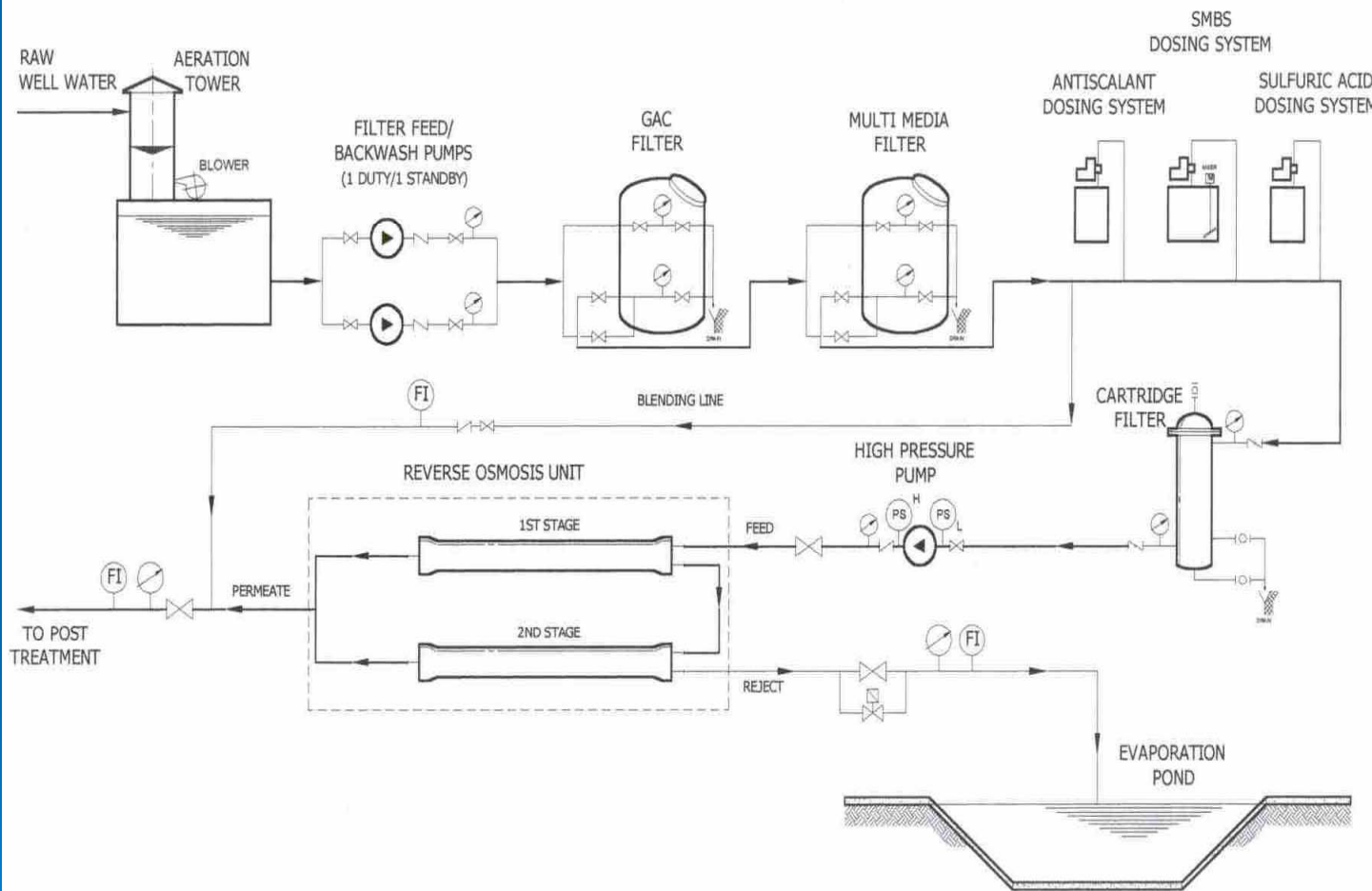


SN	Parameter of Comparison	Chemical Precipitation	Ion Exchange Resins	Adsorptive Media	Reverse Osmosis or Nanofiltration
1	Efficiency of removal of the radionuclide	Stoichiometric chemical removal equivalent to chemical dosing	90% of radium content	95 to 97% of radium content	96 to 98% of radium content
2	Interference of other components in the water and effect on process efficiency and process cost	Softening extends also to the usually higher Ca concentration. BaCl ₂ dosing is rather specific to radium	Other divalent cations like Ca and Mg interfere with exchange of Ra. A bigger system is, therefore, required	Hardness components and iron interfere with radium removal	Parallel salts rejection occurs without interference
3	Required regeneration of the active media and the process continuity	NA	Periodical regeneration is required	Media are rejected after saturation	NA
4	Radioactive sludge formation, and disposal	Present	Soluble radioactive concentrate	Absent	Soluble radioactive concentrate

Comparison between methods of removal of combined radium 226-228

SN	Parameter of Comparison	Chemical Precipitation	Ion Exchange Resins	Adsorptive Media	Reverse Osmosis or Nanofiltration
5	Need for chemical dosing and the related equipment/ installations	Present	Required for IER regeneration	Media are rejected upon saturation	NA
6	Parallel desalination of water	Absent	Absent	Absent	Present
7	Modification of product water composition	Lime-soda ash softening increases Na content of water by about 10%. BaCl ₂ dosing causes no modification	Na content of water increases	NA	NA
8	Parallel removal of radon gas	NA	NA	Present	NA
9	Process cost effectiveness	Low cost	Expensive process	Expensive process	Most cost effective

Comparison between methods of removal of combined radium 226-228



- LEGEND:**
- LINE FLOW
 - MAIN PROCESS LINE
 - SECONDARY PROCESS LINE OR UTILITY LINE
 - ELECTRICAL LINE
 - ⊠ ELECTRICALLY ACTUATED VALVE
 - ⊗ MANUAL VALVE
 - BALL VALVE
 - ∩ BUTTERFLY VALVE
 - ∇ NON-RETURN VALVE
 - ⊕ (FI) FLOWMETER
 - ⊕ (LS) LEVEL SWITCH
 - ⊕ (PS) PRESSURE SWITCH
 - ⊕ (PG) PRESSURE GAUGE
 - ⊕ (DP) DOSING PUMP
 - ⊕ (TDS) TOTAL DISSOLVED SOLIDS INDICATOR
 - ⊕ (PH) pH METER
 - ⊕ (ORP) ORP INDICATOR

Parameter of Comparison	Normal Brackish RO Membrane	Low Energy RO Membrane	Nanofiltration Membrane
Process Percent Recovery	85	85	85
Feed Pressure (bar)	12.5	8.1	6.2
Permeate TDS (ppm)	50.1	94.1	303.8
Percent TDS Rejection	95.1	90.6	69.6
Percent Rejection of Divalent Cations	98.6	94.4	87.4
Blending with Feed Stream	Blending or TDS adjustment usually required for drinking purpose	NA	NA

Comparison between the behaviour of RO, LERO, and NF membranes in rejection of polyvalent radioactive cations under the same operation conditions.

Conclusions:

Optimum process for removal of Rd 222 and Ra 226-228 from drinking water:

1. Enhanced aeration for removal of Rd gas ($\ll 4$ pCi/L in air)
GAC can be used for removal of traces of residual RD
2. Selective membrane processes RO and NF are the most efficient and cost effective for Ra rejection. They have the advantages of:
 - High efficiency of radionuclide rejection.
 - Relative insensitivity to feed rate and concentration of the radionuclide.
 - Parallel general water desalination without need to specific equipment.
 - Does not require chemical dosing, membrane regeneration and does not produce solid radioactive sludge.
3. Selection of optimum membrane processes is determined by feed TDS and extent of contamination and is preferred in the order NF > LERO > RO for energy saving.
4. No blending of permeate stream with treated feed water is permitted.
5. Radium should be deposited from the concentrate stream prior to delivery to evaporation ponds e.g. as (Ra-Ba-SO₄).
6. If it is required to avoid the contamination of the pretreatment and RO plant and complex waste disposal, Radium and hardness may be removed by chelation adsorptive media directly after the aeration towers of Rd removal