Radium Treatment

Envirogen Technologies, Inc.'s radium removal systems offer both an excellent radium removal methodology and guaranteed performance (quantity and quality) of the system through a Water Services Agreement.

Envirogen's Technology Options for the Treatment of Radium		
Type	**Range**	**Envirogen's Solution**
Flow	<35 GPM	Adsorption
	>50 GPM	Adsorption Ion Exchange Coagulation Filtration
Iron	<0.5 ppm	Adsorption Ion Exchange
	>1 ppm	Coagulation Filtration
Hardness	<20 grains	Adsorption Ion Exchange
	>30 grains	Coagulation Filtration

Option #1 – Ion Exchange

Envirogen's SimPACK™ treatment solution is a regenerable ion exchange system based on the latest technology of Simulated Moving Packed Bed. This system is regenerated with brine (NaCl) in a sequential cascading process that is extremely efficient, limits the waste brine amount, and produces the highest quality possible for the dosage. A small brine waste that will contain radium, calcium, magnesium and sodium cations will need to be treated by a POTW system. Basically, this system operates as softeners for the community, and can be operated to a set hardness break.

Our SimPACK system is based on multiple 36-inch or 48-inch tanks in staggered service to optimize throughput and balance the leakages. Typically, post-startup multiple vessels will be in service (8-13) and three in various regeneration modes. Our system includes a PLC controller, storage tanks (brine, waste surge) and a bag pretreatment filtration system. The arrangement of the vessels can be linear or wrapped around the walls or upon itself. The system typically requires approximately 2,600 square feet.

Conventional ion exchange systems typically have a 5-7% waste rate and other counter current systems are in the 2-4% range. Our system design reduces this to less than 2% of the treated volume will be wastewater (regenerant brine water).

Ion exchange treatment is the exchange of ions between the aqueous solution and the ion exchange's fixed charge counter ion. Ion exchange resin has a total capacity and an operating capacity, which is dependent on the following factors:

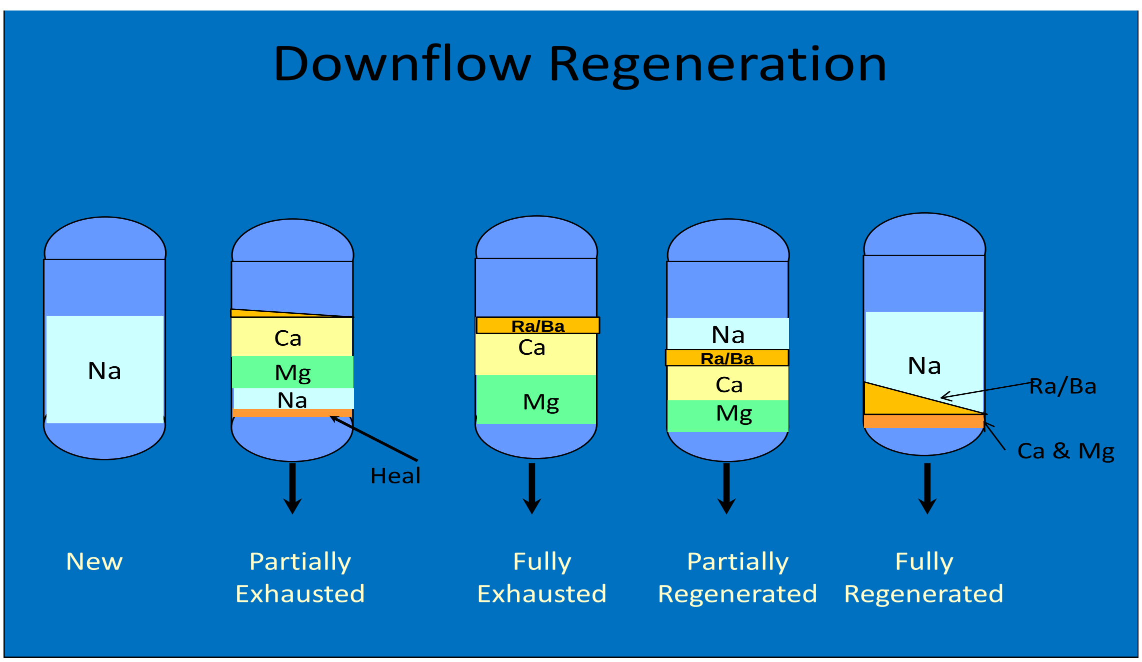
- Regenerant used
- Percent concentration of the regenerant
- Dosage (Lbs/CF)
- Empty Bed Contact Time (EBCT)
- Ratio and affinity of ions in the feed stream to the resin

With perfect downward laminar flow, the ions will segregate based on their affinities for the ion exchange resin. In co-flow regenerated applications, these ions are pushed through the ion exchange resin in the same direction as the service flow. Since the regeneration process is not 100% effective, a heal of exhausted resin will be at the bottom of the vessel and cause leakage of these ions while the system is in service.

Counter-current regeneration pushes the ions out of the vessel in the opposite direction in which they came. With perfect laminar flow, the ion segregation would be reversed, and the highest regenerated resin would be in the lower portion of the vessel, resulting in no leakage of exhaustion ions. In reality, perfect laminar flow is not possible on commercial systems, thus, there is always some leakage, but the level is orders of magnitude lower in counter-current systems.

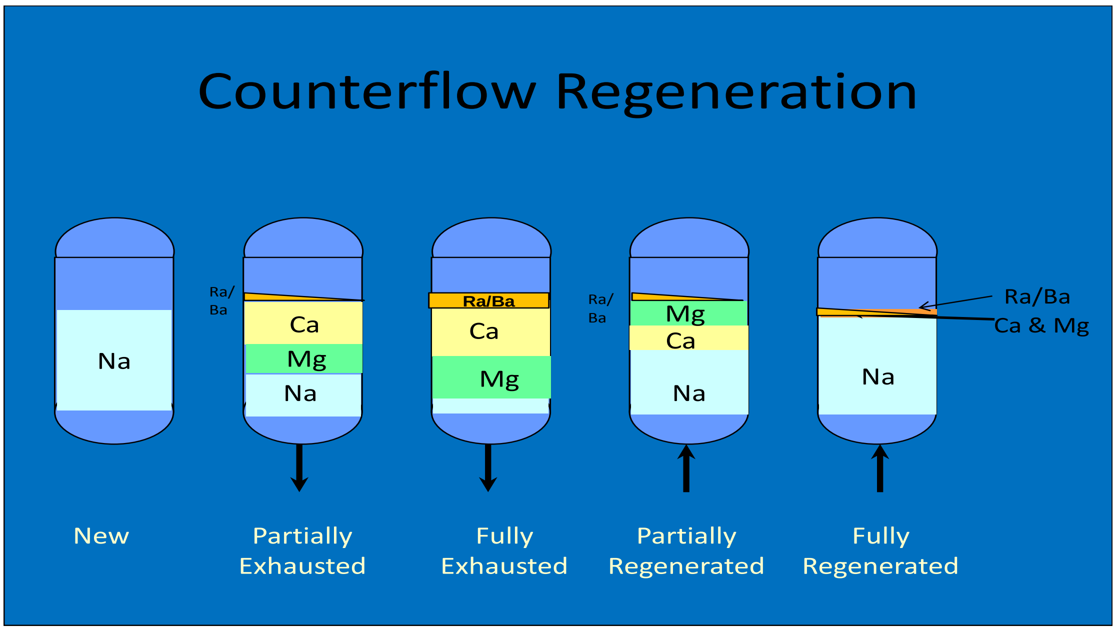
The Radium (Ra) ion is in the same family as Barium (Ba), Calcium (Ca) and Magnesium (Mg); consequentially, it will act similarly. However, it has a higher affinity for the Strong Acid Cation resin than the other ions. Consequently, it does not regenerate off the resin well. In addition, radium and barium will precipitate with sulfates. Due to the high affinity, radium will be concentrated at the upper portion of the ion exchange bed.

In co-current systems, the sodium ion concentration is used to push the Ra, Ba, Ca, and Mg through the vessel. This typically requires 20+ lbs of brine per cubic foot of resin. Consequently, regenerations with only 5 lbs/CF will leave radium in the ion exchange bed. Studies have shown that the driving force in the regeneration process for Ra and Ba is the Ca ion. After 10-20 regeneration cycles, a regeneration equilibrium is established based on the efficiency of the Na, Ca and Mg to displace the Ra. Since Ca and Mg are in higher concentrations within the feed water, as the wave front of higher levels of Ba, Ca and Mg pass through the bed, more radium will be pushed toward the bottom of the vessel, and the leakage rate will increase accordingly. Below is an illustration of the theory:



In counter-current regenerated system, the operating capacity of the resin typically has a 15-20% increase in capacity to the contaminate (hardness) break due to better efficiencies in salt utilization, a reduction in rinse water volume required, better distribution design, and packing the resin to keep it from migrating (top to bottom) to maintain the wave fronts (Chromatographic). Consequently, the leakage rate is significantly lower for the exhaustion ions until the wave front reaches the lower portion of the vessel. The breakthrough curve is exponential versus a more linear breakthrough curve of conventional down flow regenerated systems.

In softening applications, the leakage is typically less than 1 ppm of hardness as $CaCO_3$ (<0.06 grains). However, the exhaustion break is steep and exponential. In this particular application, the goal is to keep the radium in the upper portion of the ion exchange bed without precipitating, and without radium-laden resin beads falling to the bottom of the ion exchange bed. Below is an illustration of the theory:



Typically, only 40-60% of the resin's theoretical capacity is used in softener applications. The balancing of the factors above and the acceptable hardness leakage rate will determine the actual capability of the counter-current regenerated system. The optimum salt usage to determine throughput, leakage rates and low lifecycle cost are determined during validation studies on the water in question. Due to the high affinity of the resin to the radium ion and the relatively low level of radium in the water (typically ppt levels), these systems are not run to the radium break.

Option #2 – Coagulation Filtration

Coagulation filtration (CF) is the addition of an iron oxide and other chemicals to form a radium precipitate that is filtered out of the water. The filters are backwashed and the waste sent to the local POTW.

The Envirogen CF system uses a manganese oxide media with a specific mesh size to allow for higher flow, short duration backwashes, saving valuable water, energy, chemicals and, therefore, money. The system to treat the 1,000- to 1,500-gpm range would consist of eight 48" x 60" vessels in an N+1 configuration with one 96" x 192" vessel for enhanced contact time. The system would produce a liquid waste (approximately 27 GPM/ Ft^2 in a five-minute cycle). The waste rates will vary based on volume and actual Fe/Mn/Ra feed levels; we estimate based on utilization of the well, there will be a waste rate of approximately 3-5%. The iron and manganese levels at these wells are not very high, and more chemicals will need to be used for proper flocculation. Maintenance, instrument calibrations, chemicals, media replacement and labor are included in the WSA. The waste slurry disposal is not included in the WSA calculation; it can be included once the disposal process has been determined.

Option #3 – Adsorption

The adsorption process is a highly selective for radium ion exchange media. The radium is adsorbed onto the media until exhausted (typically, several years of service). The media is then properly disposed per local and federal regulations (Low Level Radioactive Waste (LLRW) facility). Envirogen does provide these treatment options in addition to the above with our performance guarantee.

Envirogen's Hypersorb™ technology and media replacement service have been utilized by many satisfied clients for more than 35 years. The process design is based on a pre-filtration system consisting of bag filters and adsorption columns with our proprietary radium selective media. This system is designed to be durable and user-friendly with zero waste residuals produced on site. The media in the vessels is projected to last approximately 1-2 years for the lead bed, prior to disposal depending on the treated feed volume.

The Envirogen Hypersorb Service Exchange Program is a cost-effective process-guaranteed system with low lifecycle cost to treat the radium. Important operational advantages to consider include the following:

- No on-site chemical usage or storage
- No backwashing
- No on-site waste residuals generated, requiring no transportation and disposal other than bag filters
- Low energy requirements
- Additional personnel are not required, as system operates unattended

The system requires very little client interface. Periodic monitoring of system flows and pressures along with periodic sampling are all that are required from the client. When the media is exhausted, it is removed and replaced with new media. The exhausted media will be shipped to Envirogen's central facility in Memphis, Tennessee, for disposal at a licensed LHW waste facility.

The modular design of the Hypersorb system allows for ease of expansion of capacity by adding vessels as desired. It is recommended that the feed headers be sized accordingly if there are future plans for expansion.

We understand the needs of municipalities to have ratable expenses; therefore, we include the service of changing and disposing of the media in the Water Services Agreement, and we establish a fee based on the estimated disposal fees at the time of the contract. Annually, we work with the municipality to make the necessary adjustments within their budget cycle. We are willing to take some of the risk, and we will establish the process guarantee along with the treatment threshold points, and the appropriate range that is our responsibility.

Water Services Agreement (WSA)

Envirogen sells the capital equipment with a process guarantee that lasts the duration of the WSA. The scope of the agreement is negotiated with the municipality based on its capabilities. The WSA covers routine maintenance, calibrations, chemicals, replacement media and parts. We will not provide a process guarantee without a WSA and, typically, we do not sell the equipment without a WSA. The operating contract would be for a minimum of 10 years and can be for up to 30 years. With the WSA, Envirogen will guarantee the performance of the system to be in compliance for the duration of the service term.

Cost for the WSA is based on the technology and scope of work and can be determined when a technology is chosen and piloted. Estimates are available upon request and are non-binding, and for evaluation purposes only.

Validation System

Envirogen offers to perform a small-scale validation study, conducted at your site, to verify the removal capability of our proposed system. The results of this small-scale validation study will be used to design and determine the operational parameters of the full-scale system; mitigating any full-scale failures that is further complimented by our performance warranty.

Lead-time on startup of the validation study is approximately two to three weeks after the execution of a non-binding Memorandum of Understanding (MOU). Envirogen will use the data to provide firm capital and operation and maintenance costs for this project.

After the verification of a successful validation study, and the purchase of a full-scale system from Envirogen with a WSA, Envirogen will waive all fees associated with the validation study. Upon successful validation and if the client chooses another technology or company to supply the full-scale system, the fees associated with the validation study will be billed accordingly. If the test fails to demonstrate the effectiveness of the proposed system, there will be no charge to the client.