

APPLICATION GUIDE

Choosing an ion exchange system for nitrate removal

Nitrate levels are coming under stricter control due to health and environmental concerns. Ion exchange technology not only effectively removes nitrate from groundwater, but also generates minimum waste volume—resulting in significant savings for total operating costs.

CHOOSING AN ION EXCHANGE SYSTEM FOR NITRATE REMOVAL

Inside this Application Guide you will find information on nitrate removal using ion exchange resins. For more information, please contact your local technical sales person or the Purolite office closest to you, listed on the back cover.

INTRODUCTION

Purolite is a leading manufacturer of ion exchange, catalyst, adsorbent and specialty resins. With global headquarters in the United States, Purolite is the only company that focuses 100% of its resources on the development and production of resin technology.

Responding to the needs of our customers, Purolite has built the largest technical sales force in the industry, the widest variety of products and five strategically located Research and Development groups. Our ISO 9001 certified manufacturing facilities in the U.S.A, Romania and China combined with more than 40 sales offices in 30 countries ensure complete worldwide coverage.



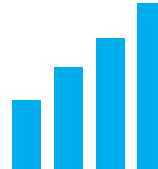
PREMIER PRODUCTS

The quality and consistency of our products is fundamental to our performance. Throughout all Purolite plants, production is carefully controlled to ensure that our products meet the most stringent criteria, regardless of where they are produced.



RELIABLE SERVICE

We are technical experts and problem solvers. Reliable and knowledgeable, we understand the urgency required to keep businesses operating smoothly. Purolite employs the largest technical sales organization in the industry.



INNOVATIVE SOLUTIONS

Our continued investment in research & development means we are always perfecting and discovering innovative uses for ion exchange resins and adsorbents. We strive to make the impossible possible.

Background

Nitrate levels in water systems are under scrutiny due to potential detrimental effects on human health. Ground water is particularly susceptible to escalated nitrate levels for a number of reasons, primary of which is increased fertilizer use. In the U.S.A., states such as Nebraska, Kansas, Ohio, California and New York are significantly impacted, but the problem is expanding globally. To help reduce the impact, The U.S. Environmental Protection Agency and the World Health Organization have set maximum contaminant levels (MCL) for nitrate in drinking water to 45 and 50 mg/l as NO₃ respectively. Ion Exchange technology is recognized as an effective solution to help treatment systems comply with regulations.

The task of wading through resin options and available equipment design configurations can be challenging, even for an experienced design engineer. This document will help engineers quickly focus on the best resin and equipment choices for specific design conditions.

Ion exchange for nitrate removal

Depending on the treatment system and the chemistry of the water being treated, ion exchange waste volume typically ranges from 3% to as low as 0.2% compared with 20% – 25% for Reverse Osmosis (RO), making ion exchange technology the preferred choice for groundwater nitrate removal.

Technologies that generate minimum waste volumes are now being looked at more closely due to stricter regulations and increasing disposal costs. Waste brine is often hauled offsite for disposal, routed to an offsite evaporation pond, or it is disposed of by deep well injection to an underground aquifer.

A recent study shows that transfer costs to haul waste brine offsite for disposal can total as much as 70% – 80% of total operating costs for nitrate removal systems using ion exchange. Overall operating costs can be significantly reduced by cutting waste volume as little as 0.1%.

Achieving minimum waste volume for a nitrate removal system through ion exchange technology is dependent on the following:

- The chemistry of the water being treated
- The choice of resin
- The design selected for the ion exchange plant

Getting started

To begin, the design engineer must choose from a number of ion exchange equipment designs, which include:

- Co-flow regenerated systems
- Counter-flow regenerated systems
- Packed bed counter-flow regenerated systems
- Continuous ion exchange systems

The final design selected will determine if standard particle size resin or a specific grade of resin is needed. A water chemistry analysis and discussion of general customer requirements should also take place to further narrow the resin choices. Once complete, it will be easier to evaluate the most appropriate resin for the equipment design.

Resin choices

Nitrate removal can be accomplished with a variety of resin types:

- Nitrate selective Strong Base Anion (SBA) resin
- Type I Strong Base Anion (SBA) resin
- Higher capacity Type I Strong Base Anion (SBA) resin
- Type II Strong Base Anion (SBA) resin
- Weak Base Anion resin (patented process)

Choosing between resin types is dependent on customer-based or system-based factors such as:

- The pungent odor associated with Type I SBA resin versus odorless Type II SBA resin
- The potential of Type I and Type II resins to dump nitrate if the system is accidentally over-run
- The use of nitrate selective SBA resin when influent water sulfate is high
- The use of new higher capacity Type I SBA resin to reduce operating cost and minimize waste volume
- The need for simultaneous removal of nitrate and arsenic (nitrate selective SBA resins would not be used when designing this type of system)
- The use of a new Weak Base Anion (WBA) process to minimize waste volumes to no more than 0.2% of total water treated

Choosing the right resin

In the aforementioned list, two items are directly related to customer preference:

- The potential for odor to develop in the treated water
- The potential of the resin to dump nitrate into the treated water

Odor and potential nitrate dumping

Type I SBA resins, which are manufactured with trimethylamine to create ion exchange functionality, tend to give off a fishy amine smell that can be detected by some sensitive consumers, even at very low parts per trillion concentrations. (Purolite A600E/9149 is an example of Type I SBA resin).

Choosing an odorless resin can be important in household and small community water treatment systems. In such cases, Type II SBA resin and new

higher capacity Type I SBA resin would be eliminated from consideration because of odor. Type II SBA resins that use dimethyl-ethanolamine—an odorless functional amine—were developed to address this need. (Purolite A300E is an example of a Type II SBA resin.)

If Type I and Type II SBA resins are incorrectly operated beyond safe throughput levels, or if mechanical or operator issues arise that result in improper regeneration, elevated levels of nitrate may enter the treated water system.

Nitrate initially loaded on the resins can be pushed off the resin by other anions for which these resins show a stronger affinity, such as sulfate. This is illustrated in the breakthrough curves for nitrate and sulfate shown in Figure 1 below.

Figure 1 – Nitrate breaks before arsenic for Type I or Type II SBA resin

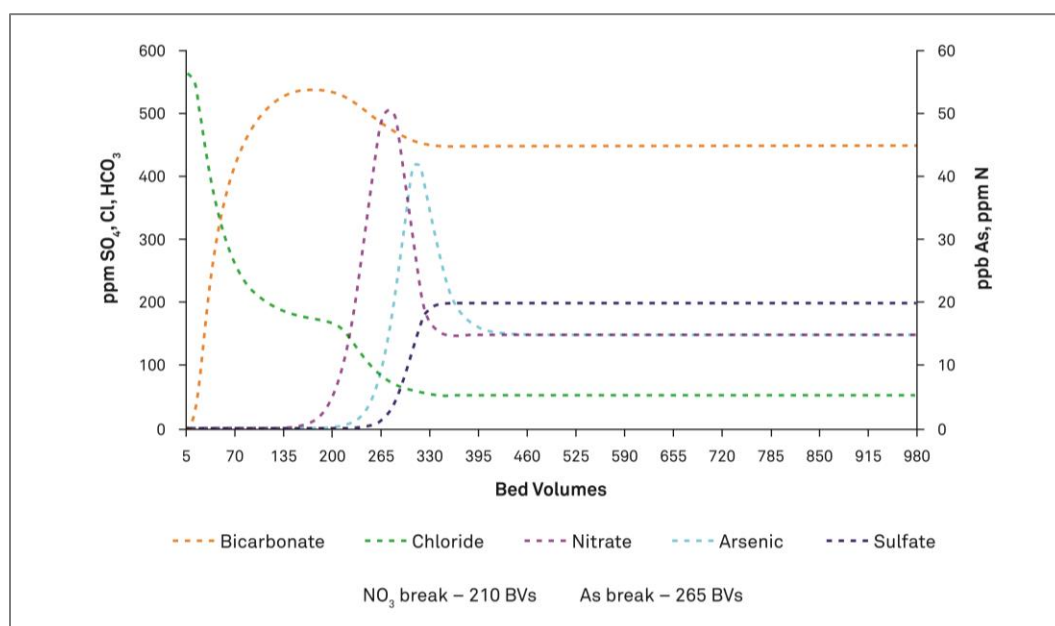
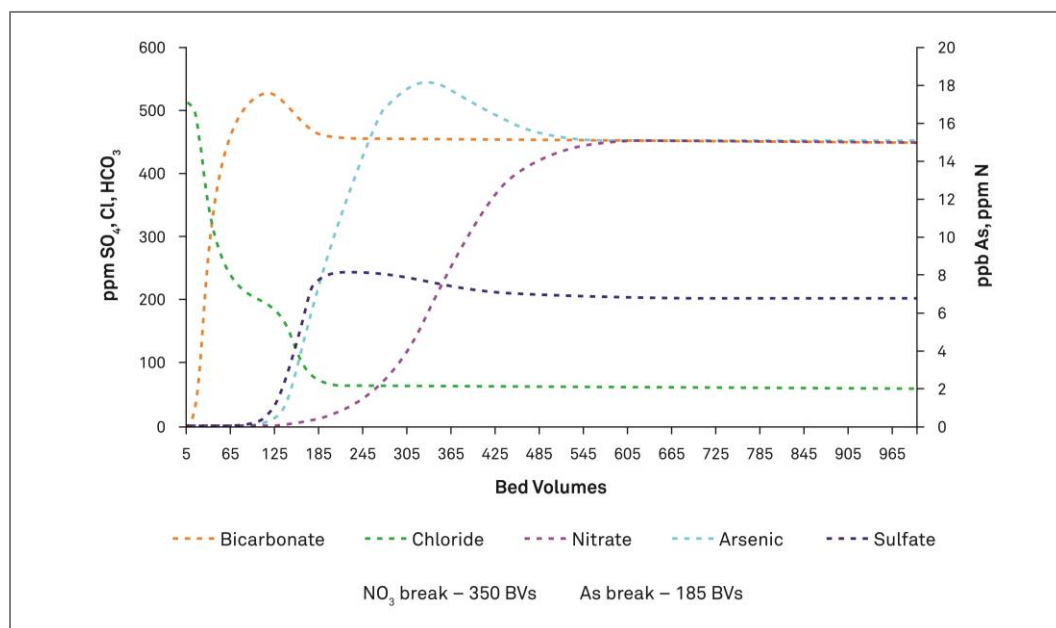


Figure 2 – Arsenic breaks before nitrate for nitrate selective resin



In typical drinking water treatment, the major competing anions are sulfate, nitrate, bicarbonate and chloride. The order of selectivity of Types 1 and 2 SBA resins under these conditions is as follows:

Sulfate > Nitrate > Chloride > Bicarbonate.

If dumping occurs, the nitrate concentration in the treated water can peak at a level higher than the influent level. This occurs only if the resin is operated far beyond the break point for nitrate. Manufacturer's recommendations for operating capacity are intended to stop the service cycle before peaking can occur, usually with an added margin of safety.

Nitrate selective resins

Nitrate selective SBA resins such as Purolite A520E were developed in part to address the potential nitrate dumping problem as well as to maintain adequate operating capacity of the resin when feed water sulfate levels are high. With nitrate selective SBA resins, the selectivity is reversed for sulfate and nitrate compared to Type I and Type II SBA resins as shown below:

Nitrate > Sulfate > Chloride > Bicarbonate.

Figure 2 shows the typical breakthrough curves for nitrate and sulfate with a nitrate selective SBA resin, showing no peaking for nitrate.

Municipal plant choices and waste minimization

For municipal plants with long distribution lines to the consumers, odor is usually not an issue. Because municipal ion exchange treatment plants usually have dedicated operators and have the resources to monitor performance more often, the potential for nitrate dumping is better controlled than in a household environment. Larger treatment plants tend to use resin that provides the lowest operating cost. Type I, Type II and nitrate selective SBA resins are popular choices.

When sulfate comprises a large fraction of the total anions present in the water to be treated, nitrate selective SBA resins are usually favored. A general industry rule-of-thumb is to consider use of nitrate selective SBA resin over Type I or Type II SBA resin when the ratio of sulfate divided by the sum of sulfate and nitrate in the feed water is greater than 60%.

This is reflected in the equation:

$$\text{Sulfate} / (\text{Sulfate} + \text{Nitrate}) > 60\%.$$

To compute this ratio, express sulfate and nitrate in common units. For example, if sulfate concentration is 70 mg/l expressed as CaCO_3 and nitrate concentration is 40 mg/l expressed as CaCO_3 , then

$$\text{Sulfate} / (\text{Sulfate} + \text{Nitrate}) = 70 / (70 + 40) = 0.63 \text{ or } 63\%.$$

In this case, the value is over 60% and consideration can be given to using a nitrate selective SBA resin. This rule is based on the higher price differential of nitrate selective resins over Type I or Type II SBA resins being offset by the higher operating capacity of the nitrate selective resin under high sulfate conditions. The rule, however, is somewhat outdated since cost drivers have changed over the years. Currently, the major cost driver is waste disposal, and it makes sense to choose whichever resin and equipment design yields the lowest waste volume.

A high capacity Type I SBA resin, Purolite A600E/9149, is now available and provides approximately 12% – 15% higher operating capacity over standard Type I SBA resin, which can significantly reduce waste volume.

In addition, a new patented process is available using a special weak base anion system designed to reduce waste volume to $\leq 0.2\%$, compared to the 1% – 3% waste volume generated with standard resin designs.¹

If resin choice is still not clear after evaluating odor and nitrate selectivity, an economic evaluation of available nitrate removal resins should be performed. At minimum, this comparison should include the cost of resin, the cost of regenerant per volume of water treated, and the cost for waste disposal.

Table 1 below is a summary of the main criteria that should be used to select the right resin.

Special case of simultaneous removal of nitrate and arsenic

Resin choices can be narrowed down further in cases where a municipality wants to simultaneously remove additional contaminants—such as arsenic—to reduce costs and achieve compliance for both species. A number of plants across the U.S. have gone this route as both contaminants are removed in a single vessel and the same brine is used to elute both nitrate and arsenic from the resin. The simultaneous, multi-contaminant removal approach results in lower cost for salt and waste disposal as well as lower capital costs.

Note, however that nitrate selective SBA resins are not recommended for joint removal of arsenic and nitrate since the higher selectivity for nitrate over divalent anions (e.g. sulfate and arsenic) results in the earlier breakthrough of arsenic compared to nitrate from the resin during service. Since arsenic is more toxic than nitrate, it makes better sense to use a resin in which nitrate breaks before arsenic, such as with the Type I and Type II SBA resins.

Plants that use this technology successfully are highlighted on the Web site of the U.S. Environmental Protection Agency. These include plants in Vale, Oregon and the City of McCook, Nebraska, with the latter plant using special brine regenerated layered bed of resins to simultaneously remove nitrate, arsenic, uranium and total organic matter (TOCs) from the feed water.²

Table 1 – Summary of criteria for selecting resin to remove nitrate

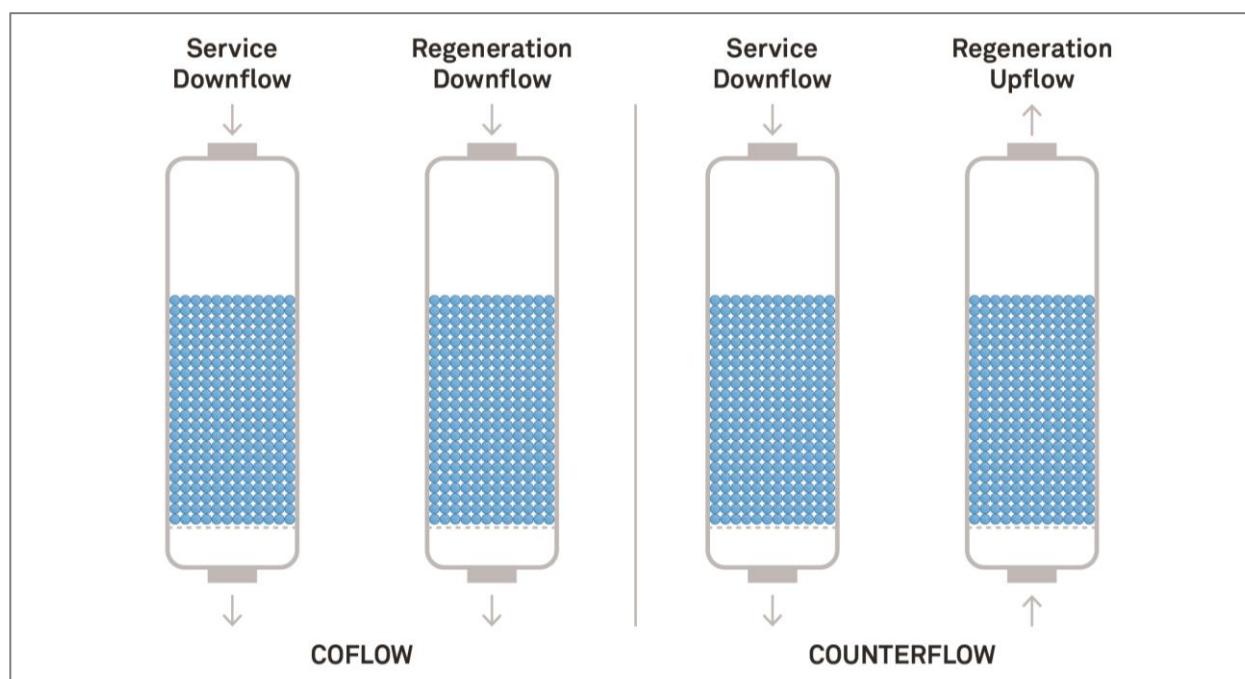
RESIN TYPE	ODORLESS	POTENTIAL FOR NITRATE DUMPING	HIGHEST CAPACITY
Nitrate selective SBA	Yes	No	No
Type I SBA	No	Yes	No
Type I higher capacity SBA	No	Yes	Yes
Type II SBA	Yes	Yes	No
Patented process with WBA	Yes	No	No

Equipment design choices

Despite higher capital costs, when waste minimization is a primary goal, equipment should include a counter-flow regenerated system—such as packed bed, air hold down or split-flow—as opposed to a co-flow regenerated system. Counter-flow regeneration also results in lower nitrate leakage, allowing for treatment of a portion of the water while bypassing the rest.

Bypassing a portion of the water around the ion exchange plant is common practice in larger plants while producing a blend of treated and untreated water that still meets the maximum allowable level in drinking water. It is well known that counter-flow regenerated systems generally produce water with lower nitrate leakage than co-flow systems. Lower nitrate leakage levels allow a greater percentage of the water to be bypassed around the treatment unit, resulting in lower overall treatment cost.

Figure 3 – Types of Regeneration Service



With co-flow regenerated systems, both the service water to be treated and the brine used for regeneration pass through the ion exchange resin bed in the same direction, generally downflow. Sulfate and nitrate tend to load on the resin bed largely at the inlet or top end, while chloride and bicarbonate load largely on the bottom or exit end of the resin bed.

When brine is applied to regenerate the bed in a co-flow mode, the brine strips sulfate and nitrate from the top of the bed and these ions are then pushed by the brine through the resin column to the bottom of the resin bed. As a result, some of the nitrate tends to exchange with and displace the less tightly bound chloride and bicarbonate ions. When the resin bed is returned to the service phase, nitrate that is bound to the lower part of the resin bed contributes to an initial elevated level of nitrate leakage in the treated water.

With counter-flow regenerated systems, feed water and brine enter and leave the resin bed in opposite directions. Nitrate loaded on the resin during service is essentially pushed back out of the bed without traversing the entire bed during regeneration.

Counter-flow regeneration is more efficient, leaving the exit end of the resin bed essentially free of nitrate ions. As a result, nitrate leakage is significantly lower compared to that from co-flow regenerated systems when the bed is returned to service.

There are several equipment design options to choose from with counter-flow systems:

- Conventional counter-flow regenerated vessels with air hold-down that keep the resin from fluidizing during the up-flow brining and rinse steps
- Split-flow designs in which 2/3 of the brine is introduced from the bottom and 1/3 through a top brine distributor
- Packed bed designs where the ion exchange vessel is packed with resin

The counter-flow and split-flow options usually allow for enough freeboard in the vessel design to periodically backwash the resin to remove suspended solids accumulated from influent water. Influent suspended solids to packed beds must be kept to a minimum, since the resin cannot be backwashed within the vessel, and would have to be taken out and backwashed in an external vessel.

Waste volumes

Below is an example of how a Type I and a Type II SBA compare to a nitrate selective SBA resin in treating typical influent water with a composition of:

1 meq/l (62 mg/l) NO₃,
1 meq/l (48 mg/l) SO₄,
2 meq/l (122 mg/l) HCO₃
1 meq/l (35.5 mg/l) as Cl

The use of the same salt dosage (120 g NaCl/l or 7.5 lb/ft³) for either resin and comparing them in both co-flow and counter-flow regenerated designs using a 90% design factor is shown in Table 2 below.

With a MCL of 45 mg/l as NO₃ in U.S.A. (equal to 10 mg/l as N), operators usually target for 36 mg/l as NO₃ for operation control (80% of the MCL). In the above cases, a fraction of the water can be bypassed to minimize the amount that must be treated. For example, comparing Purolite A600E/9149 in co-flow versus counter-flow regeneration designs shows leakages of 10.35 and 5.53 mg/l as NO₃ respectively.

Table 2 – Comparing Type I SBA, Type II SBA and Nitrate Selective SBA resins

RESIN	TYPE	REGEN MODE	SERVICE (BV)	NO ₃ LEAKAGE (mg/l)	BRINE (BV)	SLOW RINSE (BV)	FAST RINSE (BV)	TOTAL WASTE (BV)	WATER BYPASSED (%)	TOTAL WASTE AS % OF PRODUCTION
A200E	II	CF	257	10.35	1.12	1.5	5	7.62	50	1.48
A200E	II	CTF	282	5.53	1.12	3	0	4.12	54	0.67
A300E	II	CF	257	10.35	1.12	1.5	5	7.62	50	1.48
A300E	II	CTF	282	5.53	1.12	3	0	4.12	54	0.67
PFA300E	II	CF	257	10.35	1.12	1	3	5.12	50	1.00
PFA300E	II	CTF	282	5.53	1.12	2	0	3.12	54	0.51
A520E	NS	CF	272	8.15	1.12	1.5	5	7.62	52	1.34
A520E	NS	CF	250	4.35	1.12	3	0	4.12	55	0.74
PFA520E	NS	CF	272	8.15	1.12	1	3	5.10	52	0.90
PFA520E	NS	CF	250	4.35	1.12	2	0	3.12	55	0.56
A600E/9149	I	CF	293	10.35	1.12	1	3	5.12	50	0.87
A600E/9149	I	CTF	321	5.53	1.12	2	0	3.12	54	0.45

Table 3 – Impact of salt dosages on production

RESIN	SALT DOSE g/l CTF	SERVICE (BV)	NO ₃ LEAKAGE (mg/l)	BRINE (BV)	TOTAL WASTE (BV)	WATER BYPASSED (%)	TOTAL WASTE AS % OF PRODUCTION	SALT & WASTE COST (\$/m ³ PRODUCED)
A600E/9149	120	321	5.53	1.12	3.12	54	0.45	0.140
A600E/9149	160	408	4.03	1.5	3.5	55	0.39	0.123
A600E/9149	200	438	2.52	1.87	3.87	57	0.38	0.124

As such, the following equation would be valid for calculating the percentage of water that must be treated and the percentage that must be bypassed:

$62(1-X) + 10.35X = 36$ mg/l as NO₃ (the operating target) where X is the fraction of water treated.

Solving, X = 50%.

Similarly for counter-flow systems:

$62(1-X) + 5.53X = 36$, So X = 54%.

The counter-flow regenerated systems will be about 50% less costly to operate versus co-flow systems when comparing the cost for disposal of waste water.

The waste volume with Purolite A600E/9149 provides the most efficient level at 0.45% of the total water produced. The impact of waste water volume on overall operating costs can be better understood by comparing the cost of haulage of the waste to an offsite disposal facility. Assuming a typical haulage cost of USD \$0.1/gallon of waste (\$26.42/m³) for an ion exchange plant treating 1,000 m³/h (6.3 mgd) of water, the total volume of waste generated per year would be as follows:

Purolite A300E, (1.48% waste – using co-flow regeneration: approximately 130,000 m³/year.

Purolite A600E/9149, (0.45% waste) – using counter-flow regeneration: approximately 40,000 m³/year.

Savings = (130,000 – 40,000) x 26.42:
approximately \$2.4 million/year.

Higher levels of sulfate would require repeating the exercise to determine the resin that would generate the lowest waste volume.

Evaluating higher salt dosages

An evaluation of the impact of various salt dosages on overall economics can also be performed. Higher salt dosage can reduce waste volume but will increase salt cost. We recommend dosages of 120g/l (7.5 lb/ft³), 160 g/l (10 lb/ft³) and 200 g/l (12.5 lb/ft³) be evaluated.

The aforementioned is based on salt, water and wastewater disposal cost of \$0.10/kg, \$0.1/m³ and \$26.42/m³ (\$0.1/gallon) respectively. From Table 3 above, Purolite A600E/9149 using a salt dosage of 160 g/l (or 10 lb/ft³) is the lowest cost option.

Purolite's nitrate economic calculator

The nitrate economic calculator is an accurate and efficient design tool for ion exchange systems. Using system-specific data, Purolite experts address control conditions, compare operating costs for various resins and regeneration modes, calculate waste volumes and determine the payback period for the investment—to help our customers choose the best design option. The screen shots on the following pages represent views for water input, chemistry, performing calculations and viewing regeneration schedules.

Summary


The need for nitrate removal in drinking water is growing, but so are the regulations governing brine disposal. To be competitive, it is important to choose the right nitrate removal resin based on overall operating costs. It is imperative to consider costs for both the resin and the salt used for regeneration, as well as costs associated with waste water disposal as these can exceed all other cost components.

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CHOOSING AN ION EXCHANGE SYSTEM FOR NITRATE REMOVAL

Figure 4 – Water chemistry and design targets

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Date: 12-Dec-14

Customer: ABC Municipal

Project: New Nitrate Plant

Set all ions to: ppm as CaCO₃

Inlet Water Chemistry:

Ca	174.500	ppm as CaCO ₃	HCO ₃	135.246	ppm as CaCO ₃	TH/T Alk	1.77
Mg	65.164	ppm as CaCO ₃	Cl	70.282	ppm as CaCO ₃	Temp	59.0 °F
Na	52.609	ppm as CaCO ₃	SO ₄	63.021	ppm as CaCO ₃	SO ₄ /TA	34 %
K	3.295	ppm as CaCO ₃	NO ₃	41.734	ppm as CaCO ₃	FMA	3.50 meq/l
NH ₄	0.000	ppm as CaCO ₃	F	0.000	ppm as CaCO ₃	FMA	54.93 %
Ba	0.153	ppm as CaCO ₃	Other	0.000	ppm as CaCO ₃	TOC	1.00 ppm TOC
Sr	0.000	ppm as CaCO ₃	Sub-total	6.206	meq/l		
Fe	0.000	ppm as CaCO ₃	SiO ₂	8.350	ppm as CaCO ₃	SiO ₂	4.55 %
Other	0.000	ppm as CaCO ₃	CO ₂	0.000	ppm as CaCO ₃	CO ₂	0.0 %
Total Cations	5.914	meq/l	Total Anions	6.373	meq/l	HCO ₃	43.6 %
						Cl	22.7 %
						NO ₃ /(SO ₄ +NO ₃)	39.84 %

Total Hardness 4.796

Total Cation / TH Ratio 1.233

Target Nitrate Leakage Breakpoint:

	ppm as NO ₃	ppm as N
	36	8.13

Figure 5 – Calculations for a nitrate removal system

Purolite		(A) Standard Purolite A400E	(B) Performance Resin Purolite A600E/9149
Operating Specifications			
# Parallel Vessels Installed	1		
# of Vessels Active During Service	1		
Flow Rate/Vessel	250 US gal/min		
Total Flow Rate	250 US gal/min		
Daily Production	360,000 US gal/day		
Cycle Time	hours 12.00		12.00
Net Water treated per Cycle	US gal/cycle 72,000		59,400
Product (Choose from down list) >>		SBA A400E	SBA A600E/9149
Gross water treated per cycle	US gal/cycle 73,496		60,256
Regenerant Mode	CF		CTF
(CF=coflow, CTF=counterflow)			
Regenerant Dose	lbs/ft ³ 5.00		4.20
Regenerant concentration	% 6.00		6.00
Leakage			
Avg. Nitrate leakage ex IX	ppm as NO ₃ 13.15		6.60
Avg. Nitrate leakage ex IX	ppm as N 2.97		1.49
Percent of Total Flow Treated	% 40.00		33.00
Percent Water Bypassed around IX	% 60.00		67.00
Avg. Nitrate leakage in total production	ppm as NO ₃ 36.31		36.85
Avg. Nitrate leakage in total production	ppm as N 8.20		8.32
Capacity			
Available Capacity	Kgrain/ft ³ 3.94		3.79
Design Factor	0.85		0.85
Operating Capacity	Kgrain/ft ³ 3.35		3.22
Ionic Load			
Resin Volume	ft ³ 40.00		40.00
Service Flowrate per Vessel	US gal/min 100.00		82.50
Specific Flowrate	US gpm/ft ³ 2.50		2.06
Ionic Load Per Train	eq 173.20		166.11
Total Ionic Load	eq 173.20		166.11
Regenerant			
Regenerant used	lbs 199.94		167.95
Regenerant used	eq 1,550.74		1,302.62
Excess regenerant	eq 1,377.54		1,136.51
Regenerant use as % of theory	% 895.35		784.18
Vessel Parameters			
Bed depth	inches 49.88		49.88
Diameter	inches 42.00		42.00
Cross-sectional area	ft ² 9.62		9.62
Linear Velocity	USgpm/ft ² 10.16		8.38
Pressure Drop	psi 6.33		4.86
Wastewater			
Backwash Water	US gal/ft ³ 14.96		0.00
Dilution Water	US gal/ft ³ 7.66		6.44
Slow Rinse	US gal/ft ³ 11.22		14.96
Fast Rinse	US gal/ft ³ 37.40		0.00
Backwash water volume recycled	US gal/ft ³ 0.00		0.00
Brine volume recycled	US gal/ft ³ 0.00		0.00
Rinse volume recycled	US gal/ft ³ 0.00		0.00
Total waste water	US gal 2,849.91		855.94
Savings B/A			
Waste water as % of total water	% 1.58	70%	0.48
Mass NaCl per volume of water produced	lb/k US gal 1.11	16%	0.93

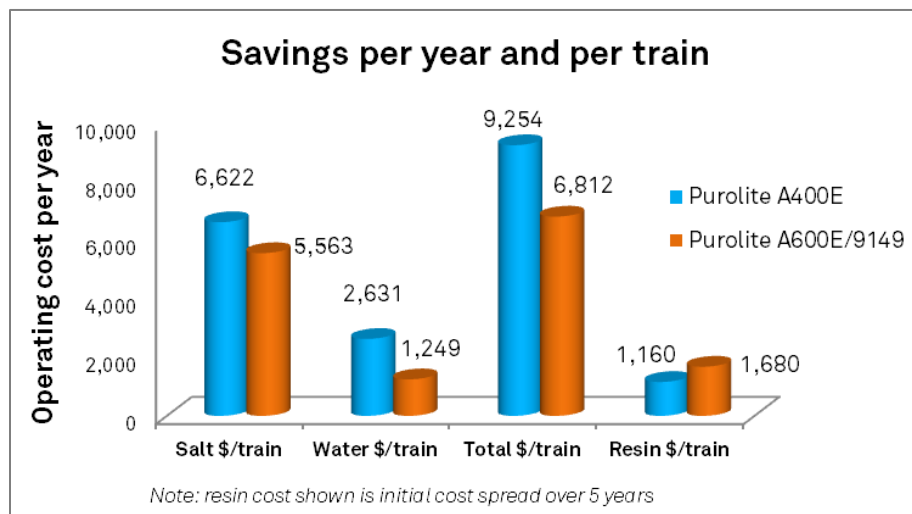
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Figure 6 – Detailed overview of savings

PuroLite		(A) Standard Resin PuroLite A400E	Savings B/A	(B) Performance Resin PuroLite A600E/9149
Water & Regenerant				
Waste water as % of production	%	1.58	70.0%	0.48
Mass NaCl per Volume of Water Softened	lb/kUSgal	1,111	20.5%	0.933
Total Resin cost per train	\$/train	\$5,799.00		\$8,399.00
Water treated	kUSgal/year	52,560		43,362
Waste water volume	kUSgal/year	2,080		625
Water used for dilution	kUSgal/year	224		188
Water used for slow rinse	kUSgal/year	328		437
NaCl Use	M. Tons/year	66		56
Unit Costs				
Unit cost of waste water	\$/kUSgal	1		1
Unit cost for softened water	\$/kUSgal	1		1
Unit cost for NaCl	\$/M. Tons NaCl	100		100
Annual Costs				
Annual NaCl cost	Per Year	\$6,622.00	\$1,060.00	\$5,563.00
Annual water/waste water cost	Per Year	\$2,631.00	\$1,382.00	\$1,249.00
Total regenerant & water cost	Per Train	\$9,254.00	\$2,442.00	\$6,812.00
Payback & ROI				
Operating cost over 5 years per train	Per Train	\$46,268.00	\$12,209.00	\$34,059.00
Return on Investment (ROI) -avg. per year	%		85	
Payback in months	months		12.8	
Savings	Per 5 Years		\$9,610	

Figure 7 – Operational savings



References

1. Nitrate and Perchlorate – ARA
<http://www.ara.com/perchlorate/>
2. Arsenic & Nitrate Removal from Drinking Water by Ion Exchange U.S. EPA
<http://nepis.epa.gov/Adobe/PDF/P100AVF2.pdf>

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