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Initial Cost Analysis of a Desalination Process Utilizing Hydrotalcite and Permutite for Ion Sequestration

Lindsey R. Evans and James E. Miller

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Lindsey R. Evans and James E. Miller
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-1349

Abstract

An initial cost analysis of a proposed desalination process was performed. The proposed process utilizes tailored inorganic ion exchangers, hydrotalcite and permutite, to sequester anions and cations from a brackish water solution. Three different process scenarios were considered: 1) disposal of the spent exchangers as dry waste 2) conventional chemical regeneration, and 3) acid regeneration of permutite coupled with thermal (550 °C) regeneration of hydrotalcite. Disposal of the resin and conventional regeneration are not viable options from an economic standpoint. Applying limited data and optimistic assumptions to the third scenario yielded an estimate of $2.34/kgal of product water. Published values for applying conventional reverse osmosis to similar water streams range from $0.70 to $2.65/kgal. Consistent with these baseline values, the Water Treatment Estimation Routine, WaTER, developed by the United States Department of the Interior, Bureau of Reclamation produced a cost estimate of $1.16/kgal for brackish water reverse osmosis.

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Introduction:
An initial cost analysis has been performed on a proposed desalination process for brackish water. The proposed process, described elsewhere [1], utilizes tailored inorganic ion exchangers, hydrotalcite and permutite, to sequester anions and cations respectively, from a brackish water solution. Figure 1 outlining the process was provided to the authors of this report by the process developers. Based on Figure 1, and additional discussions with the developers, three different process scenarios were considered: 1) disposal of the spent exchangers as dry waste 2) conventional chemical regeneration of the exchangers, and 3) acid regeneration of permutite coupled with thermal (550 °C) regeneration of hydrotalcite. This report outlines the approach and principal results of the analysis.

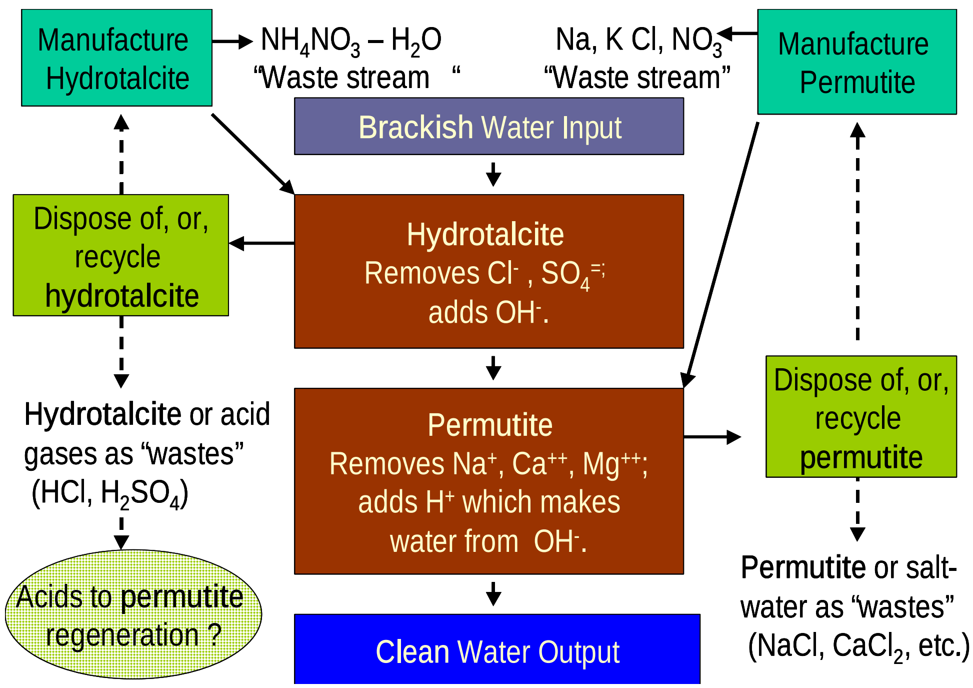


Figure 1. Basic flow chart of proposed desalination process [2].

Scenario 1: Resin Disposal
Conventional wisdom asserts that ion exchange is only applicable to desalination in cases where high purity water is required (e.g. to avoid scaling in boilers), and only then after the majority of ions have been removed by other methods. The reasoning here is that the use of relatively high value products (organic resins and chemical regeneration solutions) to produce a relatively low value product (fresh water) should be avoided, if possible. However, one of the basic premises of the proposed process is that the hydrotalcite and permutite exchangers have geological analogs, and therefore might be synthesized from naturally occurring mineral deposits at a cost significantly lower than conventional organic ion exchange resins. The table below, provided by the developers [2], suggests some potential precursors to the ion exchange materials and their approximate costs. For

comparison, prices for commercial organic cation exchange resins range from $1.20-2.40/lb, while prices for anion resins range from $3.60-7.20/lb [3].

Table 1: Approximate costs of natural or near-natural synthetic precursors.

Precursor/Resin	Description	Price
Bauxite Ore	(45% by weight Al_2O_3 – w/o shipping)	$0.016 – 0.032/lb Al_2O_3
Diatomaceous Earth	(Diatomite – 95%+ SiO_2)	$0.128/lb
Silica Fume	(95%+ SiO_2 – amorphous, very fine grained)	$0.20/lb
Silica Sand	(95%+ SiO_2)	$0.02 – 0.03/lb
Magnesia Ore	(90% MgO)	$0.147/lb

The feasibility of fabricating the exchangers from "dirt" and disposing of the spent material after use is examined in Figure 2. Figure 2 postulates a hypothetical IX material with a high capacity (5 meq/g) and ideal exchange properties (100% selective). The lines in the figure represent target costs for the material per 1000 gallons of desalted water (assuming complete salt removal). The shaded areas represent price ranges for various materials taken from Table 1.

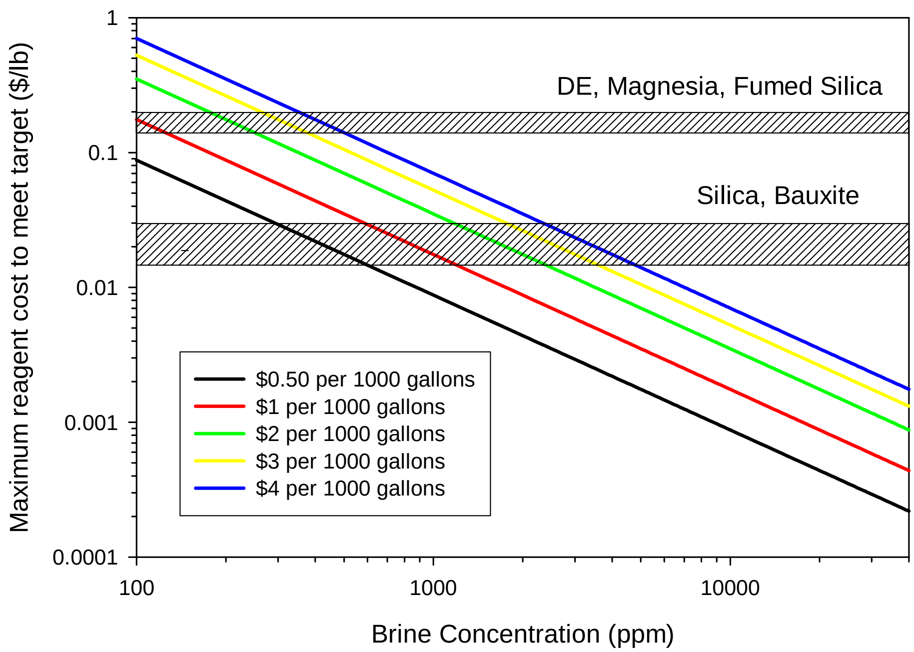


Figure 2. Maximum allowable resin cost to meet a target cost for desalting NaCl brine at an ion exchange capacity of 2.5 meq/g (disposable resin scenario). Price ranges for various materials are included for comparison.

Brackish water can generally be desalted via conventional reverse osmosis (BWRO) at a cost of $1-2/kgal (published values range from $0.70 to $2.65/kgal) [4]. Using $1-2 as a target cost for the synthetic precursors in Figure 2, it is clear that disposal of the ion exchanger will be uneconomical at any brine concentration of interest. That is, the costs of even the least expensive possible precursors (silica and bauxite) begin to exceed the allowable cost at very low brine concentrations. For example, \$2/kgal (for the precursor alone) is exceeded at a concentration of <3000 ppm. Thus, disposal of the spent exchanger appears to be uncompetitive with BWRO, even if very inexpensive precursors are utilized to fabricate the exchangers.

Scenario 2: Chemical Regeneration

The conventional reasoning applied to resin disposable is also applicable to chemical regeneration. That is, unless there is a compelling reason to generate high purity water, it does not make good economic sense to use relatively high value products (acid and base solutions) to produce a relatively low value product (fresh water). Figure 3 illustrates this point; the cost of the regenerant solutions exceeds \$2/kgal at brine concentrations of only 2000 ppm. Figure 3 also shows that most of the total costs are attributable to the base, NaOH.

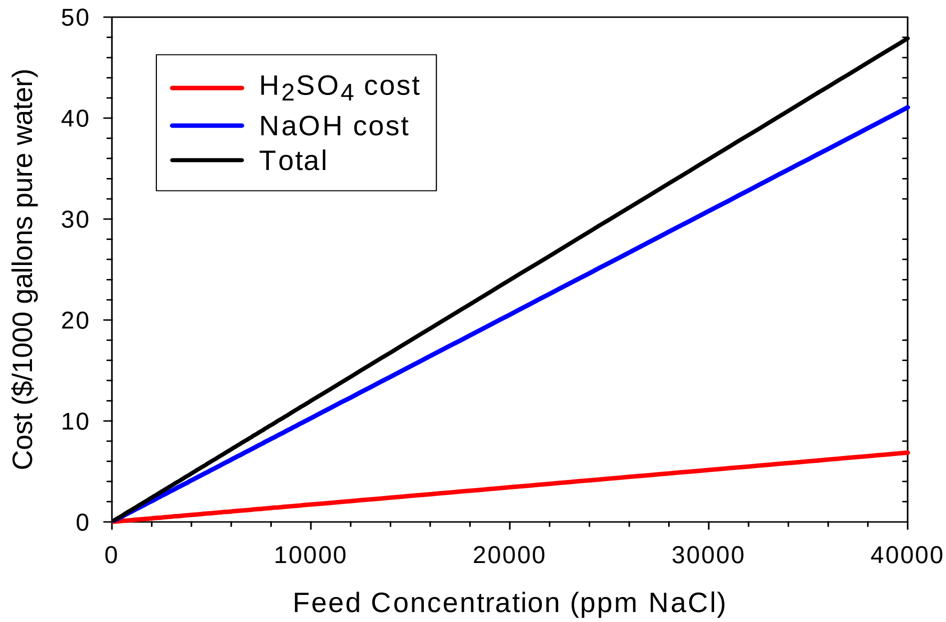


Figure 3. Reagent cost for regenerating ion exchange resins used for treating varying brine concentrations. H_2SO_4 - \$49/ton (\$0.02/lb); NaOH - \$360/ton (\$0.18/lb). Figure taken from [4].

Scenario 3: Acid Regeneration Couple with Thermal Regeneration

This proposed scenario couples acid regeneration of the permutite cation exchanger with high temperature (550 °C) thermal regeneration of the hydrotalcite anion exchanger. During the envisioned thermal treatment, the hydrotalcite would change phases, liberating acid gasses (e.g. HCl) in the process. The hydrotalcite would be recovered upon rehydration.. The acid gasses would be trapped or scrubbed and could conceivably be used to regenerate the permutite cation exchanger [2]. However, since the major cost associated with chemical regeneration is the price of the base, the main opportunity for savings lies in the replacing NaOH with the thermal treatment.

To facilitate the cost estimation process, the Water Treatment Estimation Routine, WaTER, developed by the United States Department of the Interior, Bureau of Reclamation was used [5]. WaTER is an Excel® spreadsheet program developed to address the problems of arriving at water treatment plant costs. The program is based on production capacity, a water analysis and uses a set of generalizations to specify equipment for a particular water treatment process. The program was adapted from the U.S EPA 1979 report, *Estimating Water Treatment Costs, Vol.2, Cost Curves Applicable to 200 mgd Treatment Plants* (EPA-600/2-79-1626, August 1979). To complete the analysis, the WaTER ion exchange routine was modified to accommodate thermal regeneration of the Hydrotalcite resin.

The following assumptions were used in the analysis:

- Brackish water supply similar to Tularosa Basin water
  - Total Dissolved Solids – 3070 mg/L
  - High sulfate concentration – 1100 mg/L
  - Alkalinity as Bicarbonate – 125 mg/L
  - Silica fairly low – 12 mg/L
  - Calcium – 110 mg/L
  - Magnesium – 80 mg/L
  - Anion/Cation equivalence – 0.0479 eq/L
- 5 mgd plant capacity (capital costs of RO plants decrease as capacity increases up to about 5 mgd [6]) operating at 95% availability.
- Ion exchange vessels sized at 20% excess volume using a 2 vessel train for each sequestering process.
- Cation exchange using Permutite with an ion exchange capacity of 2 meq/g at 100% selectivity.
- Anion exchange using Hydrotalcite with an ion exchange capacity of 2.5 meq/g at 100% selectivity.
- 1.5 specific gravity for both materials.
- Each exchange process operated on a service cycle of 2 days with an infinite regeneration capacity.
- Initial cost of resins based only on raw material costs with no other manufacturing costs factored in [7].
- Costs associated with waste streams and material handling of the hydrotalcite during the thermal regeneration step were not factored into the cost analysis.

Ion exchange calculations:

The ion exchange requirement was based on a total ion equivalence of 0.0479 eq/L. This ion equivalence was based on the water analysis specification given in the WaTER program (Table 2).

Table 2: Tularosa Basin water as specified in WaTER.

WATER ANALYSIS

Input analysis in Yellow cells

Links to this page are GREEN

Component	Water Analysis	Units	MCL (mg/L)	Amount Over MCL	Valence Charges	Molecular Wt.	Equivalent Weight	Moles/ Liter	Equiv./ Liter	Ionic Strength	mg/L as $CaCO_3$
METALS:	Brackish 3										
Aluminum		mg/L	0.05		3	26.98					
Antimony		mg/L	0.006		3	121.75					
Arsenic		mg/L	0.05		3	74.92					
Barium		mg/L	2		2	137.34					
Beryllium		mg/L	0.004		2	9.01					
Cadmium		mg/L	0.005		2	112.41					
Calcium	110.00	mg/L	---		2	40.08	20.04	2.74E-03	5.49E-03	1.10E-02	274.45
Chromium, total		mg/L	0.1		2	52					
Copper		mg/L	1		2	63.54					
Iron		mg/L	0.3		2	55.85					
Lead		mg/L	0.015		2	207.19					
Magnesium	80.00	mg/L	---		2	24.31	12.16	3.29E-03	6.58E-03	1.32E-02	329.08
Manganese		mg/L	0.05		2	54.94					
Mercury		mg/L	0.002		2	200.59					
Nickel		mg/L	---		2	58.71					
Potassium	10.00	mg/L	---		1	39.1	39.10	2.56E-04	2.56E-04	2.56E-04	25.58
Selenium		mg/L	0.05		4	78.96					
Silver		mg/L	0.1		1	107.87					
Sodium	815.00	mg/L	---		1	22.99	22.99	3.55E-02	3.55E-02	3.55E-02	3545.02
Strontium	5.00	mg/L	---		2	87.62	43.81	5.71E-05	1.14E-04	2.28E-04	5.71
Zinc		mg/L	5		2	65.37					
Anions:											
Alkalinity-Bicarbonate	125.00		---		-1	61	61.00	2.05E-03	2.05E-03	2.05E-03	204.92
Alkalinity-Carbonate			---		-2	60					
Carbon Dioxide (aq)	13.70		---		0	44		3.11E-04			31.14
Chloride	811.00	mg/L	250	**561**	-1	35.45	35.45	2.29E-02	2.29E-02	2.29E-02	2287.73
Cyanide, free		mg/L	0.2								
Fluoride	1.00	mg/L	4		-1	19	19.00	5.26E-05	5.26E-05	5.26E-05	5.26
Nitrate (as N)			10		-1	14					
o-Phosphate			---		-3	94					
Sulfate	1100.00	mg/L	250	**850**	-2	96	48.00	1.15E-02	2.29E-02	4.58E-02	1145.83
Silica	12.00										
pH	7.20	pH	6.5-8.5		1	1	1.00	6.31E-08	7.20E-03	6.31E-08	0.01
Solids (TDS)	3070	mg/L	500	**2570**							
Total Suspended Solids:	1.00	mg/L	---								
Conductivity	5232.00	uS/cm	---								
Temperature	25.00	**° C**	---								
Cations Equiv./L	4.79E-02			100224		C1	Acidity	236	0.10		39.09
Anion Equiv/L	4.79E-02						Alkalinity	205			7.85E-02
Ratio Cat/An	1.00		2.5			C2		-70			1.30
Anions Equiv./L - HCO3 & SO4	2.29E-02										1.15
Sum TDS	3069.00										0.146
Ion Product for concentrate	1.26E-04	Must be less than 1.9E-04									272.20

Exchange capacity calculations for Hydrotalcite:

Hydrotalcite - 2.5 meq/g exchange capacity (2.5 eq/kg)

Exchange capacity in eq/L – (2.5 eq/kg) * (1.5 kg/L) = <u>3.75 eq/L</u>

Amount of Hydrotalcite per liter of water treated

$$\frac{(.0479\text{eq/L})}{(2.5\text{ eq/kg resin})} = \underline{0.019\text{ kg/L}}\text{ of treated water}$$

Amount of Hydrotalcite required for producing 5 mgd:

$(5\text{ mgd}) = 1.894\text{X}10^{7}\text{ L/day}$

$(1.894\text{X}10^{7}\text{ L/day})*(0.019\text{ kg/L}) = \underline{3.589\text{X}10^{5}\text{ kg/day}}$

$= \underline{7.92\text{X}10^{5}\text{ lb/day}}$

Raw material requirements and costs based on a Hydrotalcite formula of $Mg_3Al(OH)_8Cl_2$:

Magnesia Ore – 3 moles/mole of Hydrotalcite
90% purity @ $0.147/lb

$AlCl_3$ – 1 mole/ mole Hydrotalcite
98.5% purity @ $0.495/lb

NH_4OH – 8 moles/mole Hydrotalcite
29% purity @ $0.58/lb

Hydrotalcite cost:
$1.28/lb or $5442/m^3 (assumes 1.5 sp. gr.)

Exchange capacity calculations for Permutite:

Permutite - 2 meq/g exchange capacity (2 eq/kg)

Exchange capacity in eq/L – (2 eq/kg)*(1.5 kg/L) = 3.0 eq/L

Amount of Permutite per liter of water treated –

$$\frac{(.0479 eq/L)}{(2.0 \text{ eq/ kg resin})} = 0.024 \text{ kg/L of treated water}$$

Amount of permutite required for producing 5 mgd

(5 mgd) = $1.894X10^7$ L/day
($1.894X10^7$ L/day)*(0.024 kg/L) = $4.55X10^5$ kg/day
= $1.00X10^5$ lb/day

Raw material requirements and costs based on a Permutite formula of $Si_{0.772}Al_{0.228}O_{1.886}$:

SiO_2/NaO – 1.078 moles/mole of Hydrotalcite
99.99% purity @ $0.1385/lb

$Al(NO_3)_3$ – 0.32 mole/ mole Hydrotalcite
99.99% purity @ $2.25/lb

Permutite cost:
$0.65/lb or $2148/m^3 (assumes 1.5 sp. gr.)

Regeneration of Resins:
Regeneration of the Permutite resin was based on sulfuric acid addition and the Hydrotalcite regeneration was based on drying at 100 °C followed by thermal regeneration at 550 °C.

Permutite regeneration by H_2SO_4:

Equivalent volume of Permutite (eq/m^3)

$= (2meq/g)*(1.5g/ml)*(eq/1000\ meq)*(10^6 ml/m^3) = \underline{3{,}000\ eq/m^3}$

Equivalence and mass of H_2SO_4 needed for regeneration

5mgd water produced = 1.894×10^7 L/day

Ion equivalence of water = 0.0479 eq/L (from data analysis report)

H_2SO_4 eq = $(1.894 \times 10^7\ L/day)*(\ .0479) = \underline{9.07X10^5\ eq\ H_2SO_4/day}$

$H_2SO_4 = (9.07X10^5 eq\ /day)*(1\ mol/2\ eq) = \underline{4.5X10^5\ mols\ H_2SO_4/day}$
$= \underline{4.45X10^4\ kg\ H_2SO_4/day}$

Total H_2SO_4 required per m^3 of resin:

Eq wt of H_2SO_4 = (98g/mol)*(1mol/2eq)*(1 kg/1000g) =0.0485kg/eq
$(3{,}000eq/m^3\ resin)*(0.00485) = \underline{146\ kg\ H_2SO_4/m_3\ resin}$

Thermal regeneration of Hydrotalcite:

The specific heat for drying the hydrotalcite (to 100 °C) was assumed to be similar to an integrated value reported for zeolite powder, 577 J/g (0.547 BTU/g) [8]. For further heating to 550 °C, a specific heat of 0.257 cal/g/C (0.00102 BTU/g/C) was assumed based on values published for silica [9].

The total weight of Hydrotalcite regenerated per service cycle is $7.25X10^8$g or ~ 800 tons. Then, the energy to dehydrate bed per service cycle at a heater efficiency of 70% is:

$(7.25X10^8 g)*(0.547\ BTU/g)/(0.7) = \underline{5.666X10^8\ BTU = 5666\ therms}$

The cost to dehydrate resin at $0.65/therm [10] is:

(5666 therms)*($0.65/therm)*(1service cycle/10,000,000 gallons)*(1000gallons/kgal) = <u>$0.37/kgal of water produced</u>

Energy to heat from 100C to 550C at 70% efficiency:

$(7.25X10^8 g)*(0.00102 BTU/g/C)*(550C-100C)/0.7 = \underline{4.755X10^8 BTU}$
$= \underline{4755\ therms}$

Cost to heat Hydrotalcite from 100C to 550C at $0.65/therm:

(4755 therms)*($0.65/therm)*(1service cycle/10,000,000 gallons)*(1000gallons/kgal) = <u>$0.31/ kgal of water produced</u>

Total heat requirement assuming a 24hr operation:
$(4.755X10^8\ BTU + 5.666X10^8\ BTU)/24 = \underline{4.34X10^7 BTU/hr}$

Cost estimates for using an industrial furnace for dehydrating and heating the hydrotalcite to 550 °C, are based on fluidized bed incinerator costs [11]. Other operations, e.g. sludge drying, cement kiln, rotary kiln, high temperature steam heating and thermal regeneration of granular activated carbon ($0.11- 0.21/lb, $17.6 – 33.6/kgal [12]) were also considered.

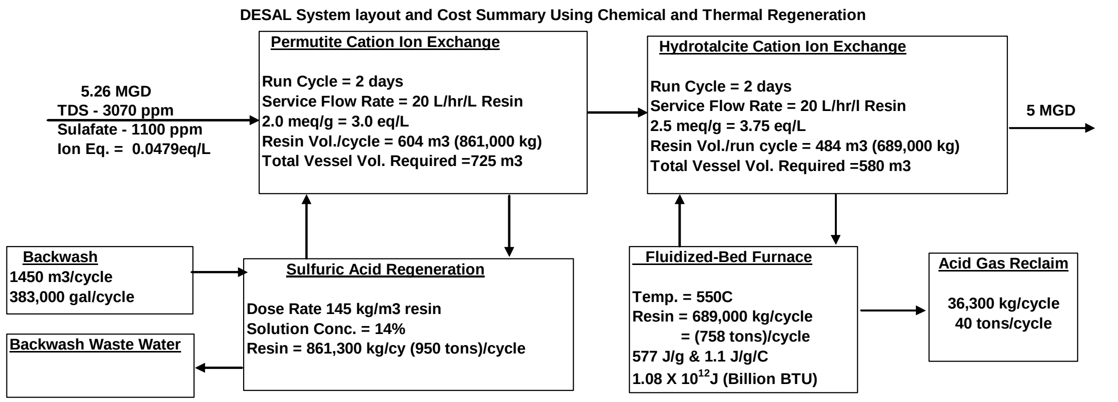
From [11],
Capital cost = $\$112,000/10^6$ BTU/hr furnace capacity
Annual O&M cost = $\$46,500/10^6$ BTU/hr furnace capacity

Thus,
Capital cost = $(\$112,000/10^6\ BTU/hr)*(43.4X10^6 BTU/hr) =$
<u>$4,860,000</u>
Annual O&M = $(\$46,500/10^6\ BTU/hr)*(43.4X10^6 BTU/hr) =$
<u>$2,018,000</u>

WaTER Program Calculations:
From the above, the primary inputs to the WaTER program were:

- Plant production capacity of 5 mgd at 95% plant availability
- Total Cation/Anion eq/L – 0.0479 eq/L
- Permutite cost - $0.65/lb at 3 eq/L for a bed cost of $\$2148/m^3$
- Hydrotalcite cost - $1.28/lb at 3.75 eq/L for a bed cost of $\$5442/m^3$
- Two day run cycle with a service flow rate of 20L/hr/L of resin
- Regeneration chemical loading rate – 146 kg H_2SO_4/m^3 resin
- Standard operation and maintenance cost (i.e., chemical cost, electrical cost, gas cost, backwash water cost)
- Capital cost of the fluidized-bed furnace used for thermal regeneration of the Hydrotalcite resin - $\$4.865X10^6$
- Thermal regeneration system O&M - $\$2.017X10^6/yr$

The cost estimate generated from these inputs is shown in Figure 4. Additional details pertaining to the costs calculated by the program are shown in Figures 5 and 6.



Permutite Ion Exchange	
Capital Cost:	
Resin	$2,520,297
Ion Ex. Vessels	$477,544
Regen. Tank	$165,919
Ion Ex. Const.	$3,162,544
Regen Const.	$120,337
Annual O&M	
Chemical Cost	$771,357
Backwash Water	$155,608
Ion Exchange O&M	$5,471
Cost Summary	
Const. Cost	$3,282,881
Annual O&M	$932,436
Water Cost ($/kgal)	$0.70

Hydrotalcite Ion Exchange	
Capital Cost	
Resin	$4,140,504
Ion Ex. Vessels	$404,060
Therm Regen. Sys.	$4,865,642
Annual O&M	
Ion Ex. O&M	$5,300
Thermal Regen	$2,012,057
Cost Summary	
Const. Cost	$9,410,206
Annual O&M	$2,017,357
Water Cost ($/kgal)	$1.64

Cost Summary	
Total Capital Cost	**Annual O&M**
$12,693,087	$2,949,793
$/kgal	**$/kgal**
$0.64	$1.70
Total Unit Cost of Water ($/kgal)	
$2.34	

Figure 4. Block diagram generated by modified WaTER program showing costs for scenario 3.

The estimate of $2.34/kgal of water produced generated by the program should be viewed as an optimistic "best-case" number since the analysis did not include a number of expected costs, and assumed best case performance. Specifically, the cost of permutite and hydrotalcite was based only on raw material costs. Manufacturing costs were not considered and synthetic yields were assumed to be 100%. Also, the assumptions of infinite regeneration capacity without loss of performance and 100% selectivity are unreasonable best-case scenarios. Periodic bed replacement, and an excess of material in the bed would be required in a real system. There are also a number of issues with the thermal regeneration of the hydrotalcite that were not considered. First, regeneration was considered to be 100% effective at 550 °C. To the best of our knowledge, this has not yet been demonstrated. Also, no costs were included for handling the solids during the regeneration step. In addition, the hydrotalcite will undergo a phase change during the regeneration that will likely lead to physical degradation of the particulate form required for column operations. An additional step to convert the material back into a suitable pelletized form would likely be required. Finally, the waste issues of the process were not addressed, e.g. costs have not been included for acid gas scrubbing (nor has any benefit been claimed for acid reclamation).

Process	Cost Parameter	Units	Construction Cost Total $1000	$/m^3 Cap	$/kgal Cap	Operating Cost $1000/yr	$/m^3	$/kgal
Cation Ion Exchange- Permutite			$3283	$173	$657	$1219	$0.19	$0.70
Cation Equivalents/L Resin	3							
$/m^3 Cation Exchange Resin	$1,973	$/lb = $0.60						
Cation Resin Volume:	725	m^3						
To Remove Cation Equivalents/L:	4.79E-02							

Cation Ion Exchange Permutite

Desired Flow Rate :		219.0	L/s
Equiv/L , Cation		4.79E-02	equiv/L
Equiv/L , Anion		4.79E-02	equiv/L
Service Flow Rate :	Range = 16 - 40	20	L/(hr*L resin)
Cation Equivalents/Liter of Resin		3.00	equiv/L
Desired Run Cycle:		2	days

Medium:	Cation	
Min Volume:	39.4	m^3
Time until exhaustion of min volume	0.1	days
Resin for desired Run Cycle:	604.22	m3
Resin Expansion Coefficient	1.2	
Total Vessel Volume	725	m^3
Nominal Resin Price $/m^3	$1,973	
Resin Cost:	$2,384,656	

Vessel:			
Aspect ratio:		4	height/dia
Bed area :		29.55	m^2
Base pressure vessel correlation:			
Number of Vessels (Reality check)	Height is 24.5 m		
(446 kPa/ 50 psig)	b=	3.446	
log($) = b + m*log(m^3)	m=	0.562	
Cost factor for operating pressure:		2	
Tank cost at base pressure:		$112,961	
TOTAL TANK COST(2 vessels):		$451,843	

Regeneration (with H_2SO_4)				
Mass of H_2SO_4 /vol of resin:	145.50	kg/m^3	9	lb/ft^3
H_2SO_4 required:	87,914	kg	193,816	lb
Chemical cost per kg H_2SO_4:	$0.05		$0.02	$/lb
TOTAL CHEMICAL COST PER YEAR:	$823,075			
Chemical concentration:	14	percent		
Regeneration fluid req'd :	628	m^3	166	kgal
STORAGE TANK COST:	$156,990			

Backwash Water		
Resin Bed Expansion (<40%)	20	%
Number of backwash cycles (1-3)	2	
Total vol. of backwash water (m^3)	1450	m^3
Vol. of backwash water per year	251417	m^3
Backwash water cost per year	$166,042	

Pumping				
Height DIfference	25	m	80.50	ft
Pipe Diameter	0.22	m	0.73	ft
Length of Pipe	10	m	32.81	ft
Efficiency	78			
Number Transfer Pumps	1			
Pressure Differential	100	kPa	14.5	psi
Capacity per Pump	0.461	m^3/s	7309.9	gpm
Size	246.0	hp		

REGENERATION/BACKWASHING PUMP:

Filter area (m^2):		29.55	Applicable Range: 13-2600 m^2
	Percentages		
1978 Capital Cost:		$72,958	
Manufactured & Electrical Equipment	0.69	$96,402	
Housing	0.00	$0	
Excavation, Site Work & Labor	0.07	$5,847	
Piping and Valves	0.24	$18,089	
Steel	0.00	$0	
Concrete	0.00	$0	
April, 2002 Capital Cost $:	1.00	$120,337	Regeneration & Pump
1978 O&M Cost:		$3,129	
Materials	0.24	$752	
Energy	0.52	$3,797	
Labor	0.24	$923	
April, 2002 Operation & Maintenance $:	1.00	$5,471	Ion Exchange O&M

Total Construction Cost:		$2,993,489	
Manufactured & Electrical Equipment	0.80	$2,477,289	
Housing	0.01	$30,188	Added to above cost
Excavation, Site Work & Labor	0.03	$95,653	Added to above cost
Piping and Valves	0.20	$559,414	
Steel	0.00	$0	Added to above c
Concrete	0.00	$0	
April, 2002 Capital Cost $:	1.04	$3,162,544	Resin w/ Tank & Regeneration
1978 O&M Cost:		$989,117	
Materials	0.24	$218,119	
Energy	0.52	$514,341	
Labor	0.24	$194,505	
April, 2002 Operation & Maintenance $:	1.00	$926,965	Annual Regenaration Chemical

Total Annual Cost

Capital Recovery	$286,217
O&M	$932,436
Annual Cost	$1,218,653

Figure 5. WaTER Program Results for Permutite Resin**.**

Process	Cost Parameter	Units		Construction Cost Total $1000	Construction Cost $/m^3 Cap	Construction Cost $/kgal Cap	Operating Cost $1000/yr	Operating Cost $/m^3	Operating Cost $/kgal
Anion Ion Exchange 5mgd Thermal Regeneration				$9410	$497	$1,882	$2838	$0.43	$1.64
Anion Equivalents/L Resin	3.75								
$/m^3 Anion Exchange Resin	$4,225		45 ft^3						
Anion Resin Volume:	580	m^3	20,716 ft^3						
To Remove Anion Equivalents/L:	4.79E-02								

Anion Ion Exchange With Thermal Regeneration Hydrotalcite

Desired Flow Rate :		219.0	L/s
Equiv/L , ANION		4.79E-02	equiv/L
Equiv/L , ANION		4.79E-02	equiv/L
Service Flow Rate :	Range = 16 - 40	20	L/(hr*L resin)
Anion Equivalents/Liter of Resin		3.75	equiv/L
			equiv/L
Desired Run Cycle:		2	days

Medium:	**Anion**		
Min Volume:	39.4		m^3
Time until exhaustion of min volume:	0.2		days
Resin for desired Run Cycle:	483.38		m^3
Resin Expansion Coefficient	1.2		
Total Vessel Volume	580		m^3
Nominal Resin Price $/m^3	$4,225		
Resin Cost:	$4,084,644		

Vessel:			
Aspect ratio:		4	height/dia
Bed area :		25.47	m^2
Base pressure vessel correlation:			
Number of Vessels (Reality check)	Height is 22.8 m		
(446 kPa/ 50 psig)	b=	3.446	
log($) = b + m*log(m^3)	m=	0.562	
Cost factor for operating pressure:		2	
Tank cost at base pressure:		$99,652	
TOTAL TANK COST (2 vessels):		$398,609	

Thermal regeneration using a fluidized-bed furnace	
Gas Reclaim - dry wt. (tons/cy)	40
Scrubber O&M	$46,963
Fluidized-Bed O&M	$2,100,000
Fluidized-Bed O&M fuel cost/yr	$1,172,000
Annual Regeneration O&M	$2,146,963
Capital Cost	$4,800,000

Total Construction Cost:		$9,283,254	
Manufactured & Electrical Equipment	0.44	$4,243,313	
Housing	0.01	$93,618	Added to above cost
Excavation, Site Work & Labor	0.03	$296,636	Added to above cost
Piping and Valves	0.56	$4,776,642	
Steel	0.00	$0	
Concrete	0.00	$0	
April, 2002 Capital Cost $:	1.04	$9,410,208	Resin tank & Fluidize-Bed Furn

1978 O&M Cost:		$3,031	
Materials	0.24	$728	
Energy	0.52	$3,678	
Labor	0.24	$894	
April, 2002 Operation & Maintenance $:	1.00	$5,300	Ion Exchange O&M

O&M Cost:		$2,146,963	
Materials	0.24	$473,447	
Energy	0.52	$1,116,421	
Labor	0.24	$422,189	
April, 2002 Operation & Maintenance $:	1.00	$2,012,057	Thermal Regeneration O&M

Total Annual Cost	
Capital Recovery	$820,425
O&M	$2,017,356
Annual Cost	$2,837,781

Figure 6. WaTER Program Results for Hydrotalcite Resin.

Summary:

Reverse osmosis is the current state-of-the-art desalting technology for brackish water and can generally be performed at a cost of $1-2/kgal. The WaTER program gives an estimate of $1.16/kgal for RO treatment of the Tularosa Basin water considered here. Scenarios wherein permutite and hydrotalcite ion exchangers are used in a once-through process and disposed of, or are chemically regenerated, are non-competitive with RO on a cost basis. Other factors such as costs and regulations associated with waste disposal may influence the decision to consider these options, in which case additional analysis should be performed. Specifically, the use of these (and other currently commercially available) inorganic exchangers should be compared to the use of commercial organic ion exchange resins, wherein final disposal options include burning the resin to yield a dry salt product. The scenario where acid regeneration of the permutite is combined with high temperature thermal regeneration of the hydrotalcite also appears to be non-competitive with RO as a cost of $2.34/kgal was calculated using very optimistic assumptions. Refinements to the calculation would be expected to significantly increase the cost estimate. A low temperature, in-situ regeneration process that limits materials handling and heat loads, such as the hot water regeneration employed in the Sirotherm process [13-19], would be preferable.

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