Crits Notes on Water and Ion Exchange

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Ion-Exchange Technology and Water Treatment

by George J. Crits

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This book is dedicated to my wife, Thetis, and to the Crits-Christoph triplet grandchildren—Alex, Nick, and Avery, and to the many friends who helped with my knowledge of ion exchange and water treatment: S.B. Applebaum, Frank N. Kemmer, Dick Hetherington, Irv. Abrams, Frank X. McGarvey, Cal Calmlon, John Sloan, Sallie Fisher, Louis Wirth, Don Crane, Mike Gottlieb, Peter Meyers, Ken Frederick, Chet Parks, Al Preuss, Fred Pocock, Bruce McKinney, Jack Pratt, Ed Davis, Bill McIntire, Ed Heller, Ralph Johnson, Bill Runyan, George P. Simon, Phil DeAngelo, L. Van Halteren, Ed Nace, Bob Kunin and others of Rohm and Haas, Ted Begg and others of Purolite Co., Dave Dally, Dwight Tamaki and others of Sybron Corp., many of the Permutit Co., the Dow Co., Duolite Chemical Process Co., and the many other ion-exchange resin equipment suppliers and Cochrane representatives from around the globe.

Contents

Introduction

The following foreword by Mikhail Gorbachev, as president of Green Cross International, is taken from Peter Swanson's book *Water, the Drop of Life* (NorthWord Press, 2001); also a Public Television series.

Water, like religion and ideology, has the power to move millions of people. Since the very birth of human civilization, people have moved to settle close to it. People moved when there is too little of it. People moved when there is too much of it. People journey down it. People write, sing, and dance about it. People fight over it. And all people, everywhere and every day, need it.

We need it for drinking, for cooking, for washing, for food, for sanitation, for industry, for energy, for transport, for rituals, for fun, for life. Not only humans need it; all life everywhere is dependent on water to survive. But we stand today on the brink of a global water crisis. Although certain parts of the world have abundant water, supplies of drinking water are inadequate in many regions . . .

Fortunately we have a history of meeting great challenges using imagination and our irrepressible capacity to adapt, and thousands of talented people around the world are already mobilized to the cause of preserving water for future generations.

Biographical Sketch of George J. Crits (Critsimilios)

Crits acquired a B.Sc. in Chem. Engr. Degree in 1943 from Penn State University, and an M.S. in Chem. Engr. from Columbia University in 1950. He has been a registered Professional Engineer in Pennsylvania since 1950.

During the war he was employed in 1943 by Kellex Corp, NYC, and at Kellex in Jersey City on the Manhattan Project, and at Los Alamos, NM with the U.S. Army (as a Gadget engineer), and later with the University of California, operator of Los Alamos until 1947.

The greater part of his career, from 1950, was with the Cochrane Corporation, later Cochrane Environmental Systems, Crane Co., King of Prussia, PA. He was the technical director when he retired from Crane/Cochrane in 1988. Crits visited Cochrane representatives and customers in England, Holland, France, Italy, Switzerland, Germany, South Africa, Japan, and the Philippines.

His expertise is in water, wastewater treatment, and ion-exchange technology. He holds 13 U.S. patents and many more foreign ones (over 50 patents), has contributed to three technical books, and has published or presented over 150 papers.

From 1962 until 2000, he was a course director of the Liberty Bell Corrosion Course, and was the principal in obtaining John C. Vaaler Awards at Cochrane for Ammonex Process, Cation Modified Mixed-Bed Demineralizer Process, Packaged Tube Settler Clarifier Module. He developed the Crits Ring Test, a simple test for trace detergents in water. In 1981, he was named Honorary Member of AMFESAAC, the Mexican Water Treatment and Manufacturers Association. At the International Water Conference, 1983, he was awarded the Annual Merit Award in recognition of outstanding contributions to the water-related field of activity. In 1989, he was inducted into the Norristown (Class of 1940) Hall of Fame for his success in industry.

He is listed in *Men of Achievement*, *Who's Who in the East*, *American Men of Science*, *Who's Who in Technology Today*, and *Empire Who's Who*. He is also a life member of AWWA, ASTM, NACE, ACS, and the Franklin Institute.

In January 1988, Mr. Crits announced the formation of Aqua-Zeolite Sciences, Inc. offering technical consulting services training, equipment improvement in water treatment, and ion-exchange technology.

George Crits is now operating as the Aqua-Zeolite Sciences Co. or George J. Crits Co.

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Ardmore, PA 19003
Phone 610 649 0372

A

ABRO—"Air Bump Rinse Operation"—A procedure in filters or mixed beds (in CPP) loaded with fine crud, iron oxides, copper oxides, etc. Where at first, the partially drained tank (minimum 2 ft water above bed) is air scrubbed and rinsed as follows:

1. air mixed/scrubbed with air applied at 5 to 7 scfm/sq ft for 1 minute or less,
2. then drained or preferably rinsed for 2 to 3 min,
3. refilling with some water, then repeating air scrubbing rinse steps 1, 2, & 3 a number of times, perhaps 30 times for a dirty resin bed.

This is more effective than a normal backwash and saves water and time. This prevents loss of resin when using the conventional backwash. Also more effective and economical than ultrasonic resin cleaning.

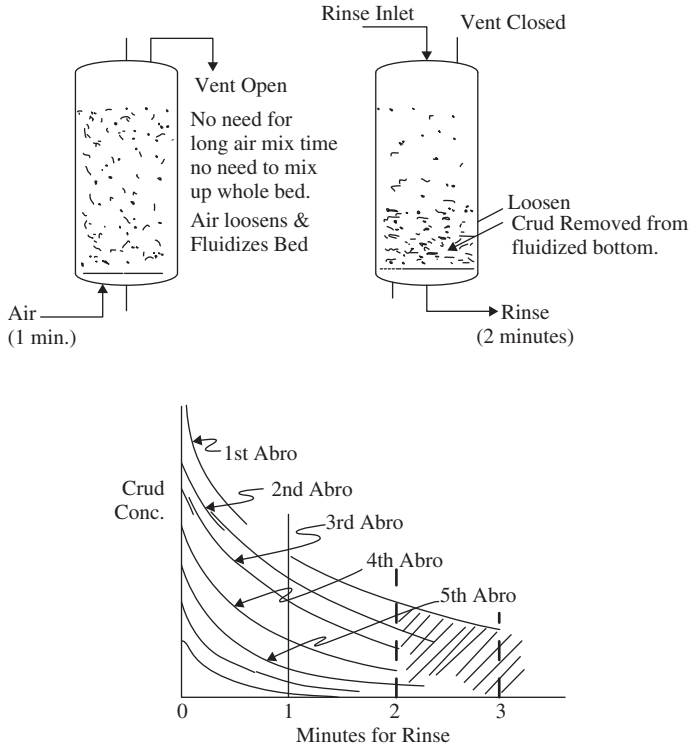
– However, it is important to have plenty of water above the bed for the scrubbing action or for the resin-mixing action. The level of water above the bed must be minimum 24" (610 mm) but better to have 36" (916 mm) or more for best fluidization and mixing action.

– The reason for the high air rate 6 to 7 cfm/sq ft is so that all parts of the tank are fluidized to remove resin dead spots that may have residual crud trapped there.

– Crits, G.J.—U.S. Patent #3,455,819, ABRO Patent

– Users—Most Cochrane CPP supplied plants: S. Calif. Edison, Penn. Electric/Conemaugh Station, Oyster Creek, Escom SA, Peter Myers/ ResinTech will recommend it.

– George Flynn patented process, U.S. #4,065,388, 1977, that features an air injection at the top portion of a bed to provide an air scrubbing, pressurizing the dome of the tank, then rinsing from this same port—without disturbing the lower resin/filter layers. This will remove the crud from upper parts of an ion-exchange mixed bed or filter. This requires a inlet/ outlet collector or distributor added to the filtering or ion-exchange tank.



Abro in the external regeneration tank (Air Bump Rinse Operation).
Note: Shaded Area after 2nd minute shows much reduced quantity of Crud being removed per unit Tile-Volume, therefore both time & rinse volume can be saved by repeating short Abros rather long ones.

– S.B. Applebaum in the 1960s had the same idea and applied it to the "Filterex" hot zeolite condensate polishers in industrial boilers.

– It was also applied to mixed beds by applying air into the interface (regen.) collector and rinsing out this same port in the same manner practiced by Flynn.

– *JOBW is a modified ABRO method incorporating a side blow from a sub-surface screened collector. Called "Japan Organo Backwash"(JOBW). Promoted by Japan Organo of Japan. This employs two sequential methods to liberate and separate crud from exhausted resins: Fine crud*

particles are removed by a side blow of the supernatant water, and the other crud is removed by "Down Blow," similar to ABRO. Air is allowed to pressurize in the freeboard prior to the Down Blow to create higher down flows.

Examples: *One application that was cited required 2 Side Blows and 14 Down Blows. (7) In another application—4 Side Blows and 40 Down Blows. If side blow is so important, why were only 2 or 4 blows required? It would appear that the Side Blow is limited in use and of little advantage for the extra cost of adding the in-bed collector. ABRO is not a drain step as claimed by the above reference. The rinse step in ABRO is a forced downflow rinse, and some pressurization during the air bump takes place when closure of the vent is delayed before the opening of the rinse outlet valve. If more air pressure is necessary, this added pressurization may be programmed by adding an extra step to ABRO.*

"ABSOLUTE FILTER RATING"—A filter rating meaning that 99.9% or essentially all of the particles larger than a specified micron rating will be trapped on or within the filter. "Nominal Filter Rating"—A filter rating indicating the approximate-size particle, the majority of which will not pass through the filter, or that 85% of the particles of the size equal to the nominal filter rating will be retained.

ACETIC ACID—BLENDED WITH HYDROGEN PEROXIDE is an effective sterilizing solution suitable for soiled piping, reverse osmosis (RO) systems, etc. See VINEGAR file. Mixing one bottle of 5% white vinegar, and one bottle of 3% hydrogen peroxide (available in drug-stores), and one bottle of water makes 1.66% Acetic and 1.0% hydrogen peroxide—suitable for sterilizing high-purity system components: piping/loops, membrane filters, RO systems, cartridge filters, etc. Contact time should be as long as possible—2 to 24 hrs. For TFC membranes, the peroxide must be lowered to 0.1% by further dilution. Caution—transitional metals (Fe, Cu, etc.) must first be removed from membranes by an acid wash to avoid catalyzed oxidation/degradation by the metals that are usually deposited or accumulated there.

– Acetic acid is removed from water by WBA or SBA resins. The order of affinities with WBA resins in the free base form: HCl = HNO_3 < H_2SO_4 < H_3PO_4 < benzoic < oxalic < formic < acetic = Citric < salicylic

In the Chloride form: F– < Cl– < Br– = Iodide = acetate < molybdate < phosphate < arsenate < Nitrate < tartrate < citrate < chromate < sulfate < hydroxide

– Absorption of Acetic acid, 2N, or intrusion into SAC H+ form resins:

Ratio of molal inside to outside of the resin gel-

5% DVB	10% DVB	15% DVB
0.8	0.6	0.45

– n-Butyric acid 2M:

0.95	0.55	0.30

– Excellent separations by ION EXCLUSION of HCl from acetic, chloroacetic, and dichloroacetic acids by columns of SAC H+ form—50/100 mesh, 8% or lower cross linkage SAC resins. See ION EXCLUSION file.

Ref. Calmon & Kressman, "Ion Exchangers in Organic & Biochemistry," pp. 181–183, Interscience 1957.

– Recovery of dilute acetic acid by Duolite A-375 (a WBA resin) regenerated with lime solution. The calcium acetate is quite soluble, so when treated with sulfuric acid, calcium sulfate crystals form (which can be filtered out) and acetic acid solution, which can be recovered. Exchange capacity was about 1.2 eq./l (vs. total capacity for this resin of 1.4). The capacity was flat at 1.2 eq./l for influents 0.01 eq./l to 0.05 eq./l acetic acid.

This process may be done in a fluidized reactor-type operation: The resin can be fully exhausted within 40 to 60 min and eluted by calcium hydroxide within 10 to 20 min.

Ref. Cloete & Marais, "IX Process for Recovery of Very Dilute Acetic and Related Acids," pp. 452–459; ION EXCHANGE DEVELOPMENTS & APPLICATIONS; Proc. of IEX '96, Cambridge, UK.

– Acetic acid Process: acetic/nitrate pickling of magnesium sheet

Ion Exchanger/Adsorbent: SA Cation, minimum bed: 30"

Regeneration/Elution Dosage: 7 lbs/cu ft H_2SO_4 20%

Column Cap. 1 lb/cu ft Mg

Theoretical Cap. 1.5 lb/cu ft

Process Info: Solution bath—28% acetic acid and 8% sodium nitrate

Capacity is low because Mg is a divalent, which is the ion exchanged on cation resin.

– Type 316 stainless steel and Monel 400 are safe with acetic acids.

ACID EYE protection in acid/caustic mixing systems: Splash Guards—a lucite or polycarbonate clear ¼" thick sheet (18" × 24" or so) mounted before a set of acid/NaOH control valves to prevent chemical leaks/squirts to an operators face. Placed so that one can reach behind to set the valves.

ACID RECLAIMING—Reclaiming excess acid from regenerants when applied.

Co-current cation regenerations are practical when excessive regenerant dosages are used above 200% of theoretical. Reclaiming hydrochloric and nitric acid is possible because generally the chlorides and nitrates salts in the regenerant effluent are soluble. However, with spent sulfuric acid, when calcium is present on the resin, calcium sulfate precipitation or crystallization occurs, which must be filtered out before reuse of the reclaimed acid. Polypropylene cartridge filters (10 or 50 micron) may be used to filter the reclaimed acid.

Also, the tenacious $CaSO_4$ crystals will coat and grow on the reclaiming tank walls, requiring frequent scraping, etc. See Figure**.**

– But reuse of the last 25 or 30% of the acid does have its penalties: IX leakage will be a little higher and capacity slightly lower. Also, an acid reclaiming pump or extra eductor and extra processing steps will be required, thus complicating the simple regeneration procedure.

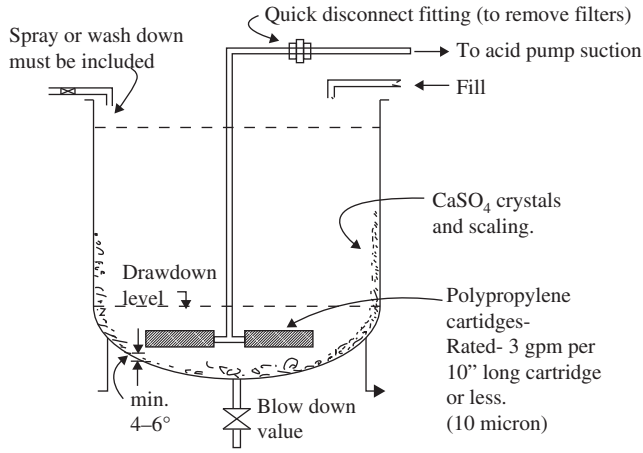
– Acid reclaiming is not generally practiced with countercurrent or pack bed regenerations because acid utilization is generally below 175% of theory. But more important, one does not apply contaminated water or regenerants to the bottom or exit end of the operating bed, which might lead to increased equilibrium leakage.

Reclaiming Sulfuric Acid from Cation Regenerations

Reclaiming HCL receneration effluents poses no problem and need not be filtered. However, with the reclaiming of sulfuric acid when calcium is present in the raw water (even with calcium less than 5%), there is always the problem with $CaSo_4$ precipitation or crystallization in the reclaim tank. Also the $CaSo_4$ crystals build up on the sides of this tank to hinder desludging or blow off. Also, the crystals must be filtered from the reclaim acid to avoid fouling of the cation resin bed. The exchange capacity of the cation resin will most certainly decrease when the $CaSo_4$ crystals redissolve to add to the calcium fraction in the resin.

THEREFORE: every effort must be made to design the tank to facilitate the following:

1) Utilize polypropylene cartridge filters within the bottom of the reclaim tank so that they can be easily flushed, cleaned, or replaced.
2) Use a cone or ellipitical heads at the bottom to aid in flushing out the $CaSo_4$ crystals.
3) Open top tank for observation and ease of cleaning.



– On the plus side, reclaiming acid may reduce waste treatment neutralization costs (provided caustic from normal anion regenerations is present for the neutralization).

– With CCCR (Co-Counter Flow Regeneration), the spent or reused acid may be applied only to the top part of the bed and fresh acid to the bottom.

ACIDS (and alkali) molar solutions:
Molar solution of acids and alkali: ml of concentrated chemical (by Baker Chemical) taken and made up to one (1) liter to make 1 molar solution:

HCl–(32%)	82.5 ml
H_2SO_4–(98%)	55.5 ml
CH_3COOH–	57.5 ml
HNO_3–	63.0 ml
NH_4OH–(28%)	69.0 ml
NaOH–(50%)	51.5 ml
KOH–(45%)	85.5 ml

ACID REGENERATION Injection or mixing-station system:

1. Simplest for small or large units is the use of eductors for Conc. HCl or 10 to 20% H_2SO_4 (educting concentrated H_2SO_4 is not recommended because of the excess heat of dilution generated at the point of mixing).
2. Mixing station using acid metering pumps for Conc. H_2SO_4 requires the following array of valves, for the three-valve leak-off system at maximum pressure of 125 psi (1999) (for 75 gpm dilution water and 1.3 gpm H_2SO_4)
   a. Two AR-1 & AR-2 Acid supply valves (¾"), Spring to close, Close-coupled Saunders, Carpenter 20 or Durimet 20, with TFE Diaphragm.
   b. One AR-3, ¾", Acid leak off, Spring to close, close-coupled Saunders type valves, Carpenter or Drurimet #20, TFE Diaphragm.
   c. AR-4, Dilution Water Supply, 2", Air/air close-coupled Saunders type, Body CI/PPL, Std. with limit stop.
   d. ¾" Durimet or Carp. 20 check valve
   e. Check Valve, 2" steel/brass for water supply.
   f. Acid supply Pressure Switch, Barksdale or equal to be placed before the back-pressure valve
   g. Back-pressure valve—Durimet 20

      To be sized & set 10 psi below maximum pressure of pump
   h. Paddle wheel flow meter with alarm for water supply, 2" brass or PVC for the water

i. Mixing tee, 2" PPL, flanged PPL
   Mixing section above tee—spool pc 5 ft long
   Dilute acid piping to regeneration tank-PPL
j. Piping from AR-4 to Tee, Spool pc. 12" flanged
k. Acid fittings Durimet 20: nipple ¾" × 10" lg
   Five required threaded ends (may be back welded)
l. Acid leak off Tee, ¾" Durimet 20
m. ¾" Tee for Barksdale Pressure Switch, Durimet 20 & Bushing ¾" × ¼", diaphragm isolation TFE
n. Flanges, Seven (7) required, ¾" threaded all Durimet 20—reducing flange 2" × ¾"
o. Pulsatrol Damper for diaphragm pumps—Lapp Model No. 76
p. Milton Roy Meter pump for 1.3 gpm
q. Acid Conductivity Probe & Monitor/Signet
r. Solenoids for air control of valves, 3 reqd.
s. PLC by customer Air tubing & air supply by customer
t. Skid/assembly—labor/service

ACID RETARDATION—Strong acids are retarded relative to the movement of the salts, when the acid/salt solution is passed through a bed of Type 1 strong-base anion resin. Best to use the finer cut of resin beads—60 to 80 mesh or uniform beads. This is performed by applying a void volume of the salt/acid mixtures, then displacing with water to perform the separation.

– Examples: Separations of sodium chloride or ferrous chloride from hydrochloric acid, or ferric nitrate from nitric acid, copper from nitric acid, magnesium from acetic acid, $A_{l2}(SO_4)_3$ from sulfuric acid, ferrous sulfate from sulfuric acid, etc. *Ref. Hatch & Dillon, Independent Engineers Chemical Process Design Development 2, no. 4 (1963), p. 253.*

WEAK ACIDITY—When the pH is below 7 ranging down to 4.5, this weak acidity is due to dissolved free carbon dioxide; however, the ratio of free carbon dioxide (CO_2) to bicarbonate (HCO_3) determines the pH, such relationships are best found in *The Nalco Water Handbook*, *The Permutit Handbook*, or others.

With the absence of bicarbonate in pure water, the pH varies with CO_2 as follows:

pH	CO_2 ppm	Conductivity mmhos
5.0	10	4.2
5.5	1.4	1.4
6.0	0.2	0.44
6.5	0.02	0.14

STRONG ACIDITY, Free Mineral Acidity—
Below pH 4.5, the acidity is due to free mineral acidity* (FMA) H_2SO_4, HCl, HNO_3, etc. approx. as follows:

pH	FMA ppm as $CaCO_3$	Conductivity mmhos
5.0	0.4 ppm	3.0 mmhos
4.0	4.0 ppm	30.0 mmhos
3.0	40.0 ppm	300.0 mmhos
2.0	400.0 ppm	3000.0 mmhos

– Acids—conductivity vs. PPM of various acids are as follows:

HCl	1 ppm as $CaCO_3$	8.3 mmhos
H_2SO_4	1 ppm as $CaCO_3$	7.0 mmhos
Mix	½ ppm HCl & ½ ppm H_2SO_4	7.6 mmhos

i.e., Water containing 10 ppm HCl and 10 ppm H_2SO_4 (both as $CaCO_3$) will have a conductivity of $20 \times 7.6 = 152$ mmhos.

– The FMA in Effluents from hydrogen SAC resins and the total alkalinity (measured in the Raw Water) when added together will give

Total Anions (TA):

Alkalinity ppm as $CaCO_3$ + FMA ppm as $CaCO_3$ + leakage* = TA Then
Total Anions = Total Cations

* Cation Leakage from H+ beds, all as $CaCO_3$.

ACMITE—$Na_2O.Fe_2O_3.4SiO_2$ water-formed deposit

ACRYLIC WEAK-BASE ANION RESINS—Amberlite IRA-67RF, IRA-68, ResinTech WBACR1, Tulsion A-10X, Diaion WA10, Ionac A-265, Purolite

These are classed as non-fouling, organic releasing by caustic regeneration, etc. (Type 2 SBA may also be used as weak base anion resins with caustic dosage at 4 lbs/cu ft and are non-fouling resins.) Excess caustic dosage may cause, acrylic WBA resins, with excess rinsing problems—best to limit caustic dosage to 3.0 lbs/cu ft or 5% more than the operating capacity.

ACRYLIC, Amberlite IRA-458 Strong-Base Anion (SBA) Resins

ANION-EXCHANGE CAPACITY ratings

Table A-1
DOWNFLOW- Co-Current Operation-

DOSAGE, NaOH lbs./CF	**5% SiO_2 (15 to 45% SO_4)**	**5% SiO_2 (75% SO_4)**	**5% SiO_2 (0% SO_4)**
3	14.2 Kgrs.	15.6 Kgrs.	15.1 Kgrs.
4	15.3	16.9	16.3
5	16.3	17.9	17.4
6	17.3	19.0	18.5
8	18.3	20.0	19.5
10	18.9	–	

Silica Leakage:	**Dosage**	**at 90 F**	**at 75 F**	**at 60 F**
At 5% Silica-	3	0.93 ppm	0.10 ppm	0.198 ppm
Influents	4	0.043	0.05	0.057
	6	0.15	0.02	0.024
	8	0.015	0.015	0.020
At 15% Silica-	4	0.21	0.22	0.24
Influents	6	0.07	0.075	0.09
	8	0.04	0.050	0.07
At 25% Silica-	6	0.07		
Influents	8	0.055		
	10	0.045		

Table A-2
UPFLOW CCR/PACKED BED Capacities: with acrylic SBA
Silica leakage- below 0.025 ppm (endpt. 0.20 ppm)

DOSAGE, NaOH lbs./CF	20% Silica at 90 F Regen. Temp.		
	Weak Acids 25%	Weak Acids 50%	Weak Acids 75%
3	16 Kgrs	17.2 Kgrs	17.5 Kgrs
4	17	18.3	18.8
6	18.9	19.6	20.0

ACTIVATED ALUMINA—Alcoa F-1, 28 × 48 mesh is principle product used for removals of humic color, fluoride, silica, and arsenic from water. Reynolds Metal also has equivalent product.

1. Alcoa, 181 Thornhill Rd., Warrendale, PA; Kathy Tricarico
2. Selecto, Inc.; Source of zeolites & Activated Alumina; 800 635 4017

Clifford et al., "Act. Alumina-Rediscovered Adsorbent for Fluoride, Humic Acids, and Silica," Industrial Water Engineering, p. 6, Dec. 1978.

F—removals:

Activated alumina: Alcoa F-1, 28–48 mesh, 27' bed minimum at 1.5 ppm F, capacity is 3500 to 4000 gals/cu ft at 0.25 ppm endpoint; Regeneration 1.0–1.5 lbs NaOH/cu ft at 1%, 35 min ct; acid rinse 1.6–2.0 lbs/cu ft at 0.25% H_2SO_4;

Higher capacity is obtained at higher F influent. Leakage 0.05–0.2 ppm

(capacity at 1.5 ppm F inlets: 0.1 lbs/cu ft)

References

1. EPA /600/S2-85/094, Sept. 1985; "Pilot Study for Removal of Arsenic from Drinking Water at Fallon, Nevada Naval Air Station," Rubel Jr. & Hathaway
2. EPA /600/S2-83-107, Feb. 1984; "The Equilibrium Arsenic Capacity of Activated Alumina," Rosenblum & Clifford
3. Hathaway & Rubel Jr.; "Removing Arsenic from Drinking Water," p. 61, *AWWA Journal*, Aug. 1987
4. Choi & Chen; "Removal of Fluoride from Water by Adsorption," p. 562, *AWWA Journal*, Oct. 1979

5. Rubel Jr. & Woosley; "Removal of Excess Fluoride from Drinking Water by Activated Alumina," p. 45, *AWWA Journal*, Jan. 1979
6. Clifford, Matson, Kennedy; "Activated Alumina: Rediscovered 'Adsorbent' for Fluoride, Humic Acids and Silica," p. 6, *Industrial Water Engineering*, Dec. 1978
7. Robert W. Peters & B. Mo Kim, Editors; "Separation of Heavy Metals and Other Trace Contaminants," Symposium Series #243, Vol. 81, 1985, AICHE
8. Cochrane Lab tests by Davis, Crits, et al., eds.; see FLUORIDE file.

ACTIVATED CARBON—Activated carbon is commercially available as a powder, granular, or pellets. The powder can be applied to water in a batch/stir/settling process, in a clarifier, ahead of a filter, or precoated on septa or frame filters. The dosage of PAC (powder activated carbon) in water treatment for odor control ranges from 15 to 100 ppm. For organic, color or volatiles, the dosage may be as high as 500 ppm.

Granular carbon for water treatment is made from coal, peat, coconut shells, and wood. The coal carbons have the highest activity. The coconut carbon is stronger with less dust throw. Sizing is 8 × 30, 12 × 40, 20 × 50, mesh.

Suppliers:

– American Norit Co. (Peat)
– ICI/Hydrodarco (Lignite)
– Calgon (Coal)
– Ceca, Inc. (Coal)
– Westvaco (Coal & wood)
– Pica USA, Inc. (sales)
– Barnebey/Sutcliffe Corp; Columbus,
– ResinTech (Medical)
– Westates
– Enirotrol
– CEI
– Carbon Activated Corp., Compton, CA.
– Carbochem, Inc., Ardmore, PA
– Sinocarbon Inc. (China carbons)

– CarbonUSA

– Carbon Link Corporation, OH

– H_2O Filter Warehouse, Marietta, GA

– Macadamia Carbon

Big Island Carbon building $35 million plant to make activated Carbon from macadamia shells. Plant to produce by second half of year 2011.

– Calgon Carbon certified for activated carbon (for drinking etc.) NSF/ANSI Standard 61; *Water Conditioning & Purification*, Aug. 2010, p. 12

ACTIVATED CARBON [AQUABOND]—by Omnipure Filter Co.– Customizing Particle Bonded Media:

Binding heavy metal sorbent onto carbon to reduce:

arsenic, cadmium, chloramines, chromium, lead, mercury, THM's, uranium, volatile organic compounds, etc.

– Knowing what carbon is available: According to Neal Megonnell of Calgon Carbon Corp., one should pay attention to "getting what you pay for":

1. Buy only ISO-certified products
2. Know the base material of any activated carbon you purchase.

   Is it a high-performance, reagglomerated carbon, or the inexpensive, direct activated carbon?
3. Require vendors to disclose where and how their carbon is manufactured.
4. Select suppliers with more than 10 years experience in carbon and water treatment
5. Check out technical resources and lab supporting the supplier.
6. Request a specification.
7. Choose a vendor that offers a broad product line.
8. If a premature breakthrough/exhaustion occurs, investigate the reason—not necessarily that the water quality has changed.

Ref. Neal Megonnell, "Why some products don't measure up,"

Water Conditioning & Purification, p. 32, March 2003.

Reagglomerated vs. Direct activation carbon:

– Direct activated products may be lower than 10% in capacity.

– Less abrasive

– Ash levels may be 50 to 100% higher.
– Leachables may be higher.
– They may not be recommended for potable or food-grade applications.
– Floaters due to non-wetting may cause more losses on BW.
– They may not be certified ISO-certified.
– Reagglomerated are high-performance carbons.

Carbon—ASTM tests:	
Iodine No. AWWA B604	
Abrasion No.	” D3802
Moisture as Packed % maximum	” D2867
Apparent Density, g/cc	” D2854
Ash, maximum 1%	” D2866
Mesh—USD Sieve	
Surface Area—BET N2	

– Carbon, potable water activated carbon analysis:
  1. Surface area
  2. 72 hour DI water extraction for:
     – Iron
     – Al
     – As
     – Antimony
  3. Water extraction taste
  4. Sieve analysis
  5. Adsorption—Chloriform/VOC
     – Act Carbon Filter Cartridge Elements—
     – Test for free chlorine reduction at rated flow
     – Lead reduction at rated flow at low pH & high
     – VOC (Chloriform) at rated flow

Applications:

– Surface water organics, humic/fulvic are removed by carbon at about 50%. However, best to remove most of the easily coagulable color/

organic matter first by alum/iron coagulation, Direct filtration, or Lime precipitation process, being about 50% effective in these processes. Then the residual organic after coagulation is further reduced 50% by activated carbon, so for both processes the reduction in organics is approximately 75%.

– Organic volatile compounds such as chloroform, benzene, carbon tetrachloride, tri-chloroethylene DDT, DDE, phenol, etc. are removed by carbon to 1 ppb levels; but the influent must not contain high values above 500 ppb, which will overwhelm the carbon. Best to degasify by forced air or vacuum towers the main quantity and treat the residual with carbon. The activated carbon may be steamed to remove the volatiles to the atmosphere or to a condenser for recovery.

– See also Rohm & Haas adsorbents XAD, Ambersorb 563, etc.

– Activated carbon will also be used for:

– Removal/reduction of H2S, free chlorine, bromine, ozone

– Removal/reduction of lead, mercury, silver

– Removal/reduction of arsenic (with iron assist)

– Reduction of chromate, Cr-6

– Removal/reduction of Cd, Se, Ag, Co, Sb, Sn, Ni, Ti, V, Fe

– Removal at lower activity: Cu, Cd, Zn, Be, Mo, Mn, W

For best results and capacity, flow rates to carbon must be held to below 1 gpm/cu ft. For organic and volatiles removals, flows below 0.50 gpm/cu ft are recommended.

For these special applications pilot testing in small 1" columns is recommended.

– Surface water organic removals: (after service time as indicated)—

Flow Rate (service)	**Organic Reduction ($KMnO_4$)**
at 2.0 gpm/cu ft	25% after 4 months
at 1.0 gpm/cu ft	40% after 4 months
at 0.5 gpm/cu ft	50% after 6 months

– As a rule GAC beds should be replaced every 6 or 12 months depending on the service flows used, if organic removal is the main requirement. For chlorine removal, life extends to 3 years or more.

– Deleterious effects of inorganic compounds during thermal regeneration of GAC is covered in depth by Steve D. Lambert, G.S. Miguel, and Nigel J.D. Graham in article in *AWWA Journal*, pp. 109–119, Dec. 2002. Must read this if you are considering thermal regeneration of GAC.

– Activated carbon beds applied to special removals or reductions should be pilot tested (with various carbons) to obtain data for designing large plants.

– Crits, G.J., "Granular Activated Carbon in Water Treatment," AMFE-SAAC, 9th Annual Meeting; Mexico City, 1990

– Sigworth & Smith, "Adsorption of Inorganic Compounds by Activated Carbon," N.C. Section Meeting of AWWA, Nov. 9, 1971

– Chloramines are not effectively removed by some activated carbons, and particularly the coarse carbons larger than 12 mesh.

Leakage of chloramine may appear after 4 months or so or even with new carbons when the flow rate is above 1 gpm/cu ft.

– "Monitoring Activated Carbon Drinking Water Filters," Nowicki et al., *Water Conditioning & Purification*, Oct. 2009; pp. 40–43

– Water treated by activated carbon must not be previously softened since the organic molecule may be extended into a long-chain configuration thus preventing adsorption. The presence of hardness causes the organic molecule to curl up into a small particle form, thus aiding the removals.

– Although activated carbon requires replacement every 6 or 12 months for organic removal, its life may exceed 5 years if used primarily for chlorine or ozone removal. Exhausted carbon by chlorine capacity ranges from 1 to 2.5 grams Cl_2/gram carbon.

– Silver impregnated Activated carbon is available from Ionics, Inc. for producing "bacteria free" water, to a degree. Silver on carbon may be in the range of 0.1% to 1.0% or more.

Silver carbon is also available from NSF, NICHEM CO. and Bestech, Inc.

Silver carbon will not remove pathogenic bacteria of total coliforms. They can be used for inhibition or retardation of non-pathogenic bacteria. In-depth study.

–"Performance of Silverized GAC vs. Silver zeolite treated GAC," feature article by David Pickering, *Water Treatment*, pp. 26–28, July 2011

– Ozone-Activated Carbon treatment:

Application of ozone before GAC has been found to enhance removal of organics significantly. Not only is some of the organic matter is burned by the ozone thus lessening the organic loading on the carbon, but the carbon (TOC) leakage was lowered from the GAC beds. It was thought that the residual and cleaved organics after ozone were more adsorbable. In Culp-Hansen studies, the organic COD was reduced from 36 ppm to 6 ppm (at 10 ppm ozone feed) vs. the control carbon bed without ozone organic reduced from 39 to 11 ppm.

– Home carbon units such as POU units and industrial units are subject to sliming and accumulation of bacteria—so they must be sanitized regularly, such as every few days to 7 days. Hot water or heat above 160°F+ should be applied for a few hours.

To inspect for slime in activated carbon tanks, disassemble the piping at the bottom or exit end of the tank and feel for slime on the inner pipe walls.

ACTIVATED CARBON BLOCK FILTER: There are two types based on coconut shell or bituminous coal. Micropores present are about 50% greater than in bitumen coal-based AC.

Type Carbon	Iodine Number (mg/g)	Total Ash %
Coconut	1,100–1,300	<3
Bit. Coal	850–1,000	8–15% (<7 acid washed)

Additives: Polyphosphate silicate to prevent downstream scaling, silver for bacteriostatic properties, another uses a patented antimicrobial agent impregnated in the AC.

Since there are many types of these, one should test any for the desired results.

NSF/ANSI Std. 42 addresses reduction of aesthetic contaminants like chlorine, taste, odor, color, and particulate removal. There are various particulate reduction classes: I, II, III, —VI.

Ref. "A POU Workhorse—The Carbon Block Filter," Robert Potwora, *Water Technology*, pp. 42–43, March 2009.

Granular Activated Carbon filter CrO_4^{-6} vs. SO_2 dosages:

5 ppm	8.8: 1	380% excess
10 ppm	5.35: 1	190% excess
20 ppm	3.2: 1	95% excess
50 ppm	2.55: 1	38% excess
100 ppm	2.2: 1	19% excess
500 ppm	1.9: 1	4% excess

Theoretical SO_2/Cr = 1.85

– **Activated carbon granules added to home cation resin softeners** (0.2 cu ft carbon to 1 cu ft cation resin) has the following advantages:

1. Improves taste of the treated water due to organic substances.
2. Removes free chlorine, which is oxidative/damaging to cation resin.

These two materials have about the same density, so eveNTUally the two media will intermix. The activated carbon may exhaust in a year or, so one may have to decide on replacement of the bed.

– "Match Treatment Type to Carbon Type," Ken Schaeffer, *Water Technology*, Jan. 2008, pp. 34–36. Has much of what is reported above but worth reading. "A good activity carbon with a surface area of 1000 m^2/g would have a 125 acres of surface area per pound."

ACTIVATED CARBON REMOVAL [CHLORAMINES]—a carbon enhanced for chloramines removal, supplied by Carbon Resources Co.

ADHESIVES ADVANTAGES AND LIMITATIONS

ANAEROBICS

Advantages:

Moderately priced Limited gap cure
High strength on some substrates
Flexible for form-tough bonds, generally brittle
Good solvent & temperature resistance
Range of viscosities
Non-toxic materials
No mixing required
Single component
Indefinite pot life
Dispenses easily from package

Limitations:

Not recommended for many Easily automated plastics or rubber substrates
Won't cure where air contacts adhesive
300–400°F temperature limitation

CYANOACRYLATES

Advantages:

Rapid cure at room temperature
Single component adhesive
Excellent adhesion to rubber
Good adhesion to metal
High tensile strength
No mixing required
Indefinite pot life
Dispenses easily from package

Limitations:

Higher price
Limited gap filling & cure

Low solvent resistance

Low temp. resistance

Bonds skin

Poor impact and peel resistance

EPOXIE

Advantages:

Low price

Good gap filling

Wide range of formulations

Versatile

Good temp. & solvent resistance.

Limitations:

Creates thinning of adhesives during curing

Two components mixing and measuring required

Exact proportions required

Single component required refrigeration

Needs heat curing

Slow fixing, short pot life

Special equipment & handling

Note: Best to use the amine hardeners for chemical and water use and flame any plastic surface to carbonize for better adhesion.

HOT MELTS

Advantages:

Good gap filling

Rigid to flexible bonds available

Fast setting

Limitations:

Low strength, poor wetting

Poor creep resistance

Low solvent resistance

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Note: Entries for figures or tables are indicated with an “f” or a “t” respectively.