Waughter

Volume 1 : Edition 6 – Ion Exchange, Resin, Softening, DM Plant & CPU , and Regeneration *June 30, 2021*

Dear Water Warriors,

Once we are done with particulate impurities, we are ready to get into inter molecular space to find “Cations”, “Anions” and molecules e.g. SiO_2 and remove them from water making it perfect H_2O; free of all impurities sans gases.

IX process (De-mineralization) thus become essential technology to the armoury of a water engineer as you can literally play with “Resins” to produce what you want.

This issue of **‘Waughter’**, lets focus on Ion Exchange, Resin, Softening, DM Plant & CPU, and Regeneration.

Sanjeev Srivastava
– Lead Technology

While we cover Ion Exchange, IX Resin and DM Plant based on user feedback we also ATTACH the link to the relevant design file in XLS that may useful to reader.

Link : DM Plants Design in XLS

This file Includes:

1. Treated Water Quality Data
2. Process Calculation
3. Mixed Bed Regeneration Design
4. SBA Column Design
5. SAC Column Design

Just Input your data in a yellow cell in the Input Data sheet then select others accordingly. Then you have to design your own Plant. Please feel free to ask us if you have any doubts technology@aktionindiaa.com

Refresh before we proceed

Let’s remember **Waughter** Volume 1 Edition 1. Where we covered Ionic Impurities and definitions such as TA, TC, EMA etc.

Impurities (i.e. Ionic Impurities) which are not removed in pre-treatment are removed by ion exchange only or separated in Reverse Osmosis...

These are the Ionic Impurities which are present in water that shall be removed by Ion Exchange and non-ionic impurity e.g. SiO_2 is an additional material to remove.

H^+	OH^-
Na^+ K^+	$HCO3^-$ $CO3^{--}$
Ca^{++} Mg^{++}	Cl^- $SO4^{--}$ $NO3^-$
$Fe^{++}Mn^{++}$ → 3 Val.	$PO4^{---}$

As per rules of electro neutrality, ions though free entity must have a relation with counter ion to balance its charge. One of the common most example of a relation is Na^+ & Cl^-.

So, a good engineer will walk 11 steps on the water analysis report before doing anything, to be sure he/she is working in right direction.

Step 1 : Check Adequacy of Data
Step 2 : Convert Impurities to $CaCO_3$, if not reported as $CaCO_3$
Step 3 : Calculate EMA
Step 4 : Calculate Total Anion (= EMA + M-Alkalinity)
Step 5 : Calculate Total Cation (TC = TA, H2O is Electro neutral)
Step 6 : Find $Na^+ + K^+$ = TC – Total Hardness
Step 6A : If you get – Ve Value, it indicates error in report
Step 7 : Observe M and P Value
Step 8 : Report $HCO3^-$, $CO3^{--}$ and OH^-
Step 9 : Observe Total Hardness and M-Alkalinity
Step 10 : Report Temporary and Permanent Hardness
Step 11 : Report Sodium Alkalinity

Once done, pay an attention to dosing in Pre-Treatment Section of the plant. Remember to correct your water analysis for dosing of Alum and Lime.

Each ppm of Alum will decrease alkalinity by 0.45 ppm and increase SO_4 (EMA) by 0.45 ppm. *(Expressed as $CaCO_3$)*

Each ppm of lime will increase alkalinity by 1.8 ppm and increase Ca (Hardness) by 1.8 ppm. *(Expressed as $CaCO_3$)*

It’s time to know about DM Plant…

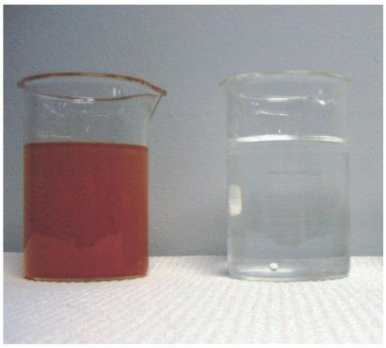
PURE WATER

suez

IMPROVE THE EFFICACY OF COLOR & COD REMOVAL IN WASTEWATER

SUEZ'S TRUE NANOFILTRATION MEMBRANES (NF)

Proprietary NF membrane with a 3 layer flat sheet construction resulting in a smooth surface reducing fouling. This minimizes the CIP frequency and increases water production yield. True NF Membrane-preferential rejection of multivalent ions over monovalent ions- operate at relatively low feed pressure.



INDUSTRIES

Textile, Petrochemical , Chemical, Pharma.

APPLICATIONS

COD removal, Color removal, Sulphate removal, Acid purification.

FOULING RESISTANCE

Superior resistance due to three layered membrane.

HIGH PERFORMANCE

Longer membrane life, reduced CIP frequency and reduced opex.

ROBUST ELEMENTS

For challenging wastewater streams.

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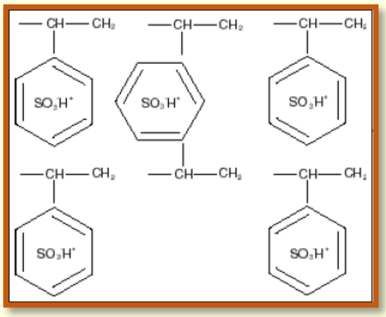
Resins are Key to Demineralization, lets understand them:

Strong Acid Cation (SAC) Resin

SAC resin beads are made from styrene and divinylbenzene. They are known as DVB-S (divinylbenzene-styrene) resins.

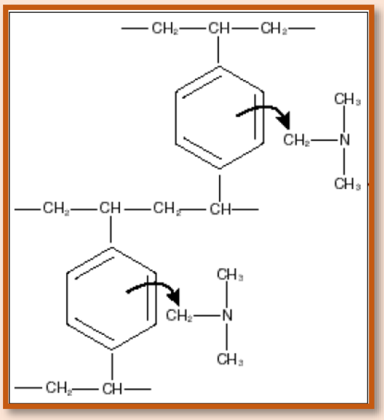
DVB-S resins are produced by suspension copolymerization. This process starts with the addition of two non-polar liquids, styrene and divinylbenzene, to water. These two oil-like substances mix with each other but are insoluble in water. A small amount of detergent is added and the solution is agitated, causing the divinylbenzene and styrene mixture to form small droplets in the water.



The performance of SAC resins is reduced by chlorine, iron, manganese, aluminium, and calcium in the feed water. SAC Resin can exchange (Na Ca & Mg)

Weak Acid Cation (WAC) Resin

WAC resin in the hydrogen form removes an amount of cations from the process water equal to the alkalinity (amount of bicarbonate, carbonate, and hydroxide ions) of the process water.



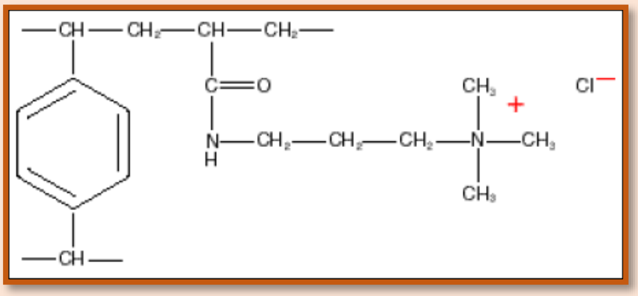
If the process water contains 30 ppm of cations and 20 ppm of alkalinity, the WAC resin removes 20 ppm of cations. WAC resin is not used in the sodium form.

The performance of WAC resin is reduced by chlorine, iron, manganese, aluminium, or calcium in the process water.

Iron, manganese, and aluminium foul the resin by forming hydroxide precipitates. Calcium sulphate precipitate forms in the resin during sulphuric acid regeneration if the regenerant chemical concentration is too high. (Temporary Hardness)

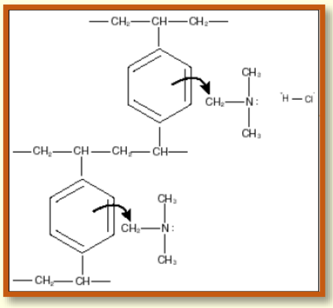
Strong Base Anion (SBA) Resin

SBA resin bead functional groups are added in a two Step process: chloromethylation followed by amination.



SBA resin in the hydroxide form removes both strong acids (sulfuric and hydrochloric) and weak acids (carbonic and silicic) from decationized (cation exchange unit effluent) process water. Sulphate (present as sulfuric acid), chloride (present as hydrochloric acid), and bicarbonate (present as the bicarbonate ion after the conversion of carbonic acid) are removed by ion exchange. (EMA.M-Alk, SiO2)

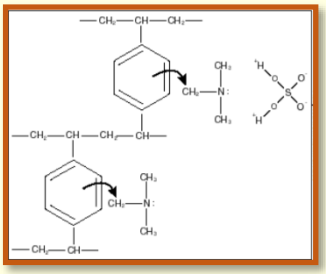
Weak Base Anion (WBA) Resin



The production of WBA resin beads and SBA resin beads differ in the chloromethylation and amination steps.

The free base functional group removes strong acids from the process water by molecule exchange; individual water molecules are exchanged for individual acid molecules, as shown in figure.

(FMA = Cl, SO_4 NO_3)



I think that was a bit Hi-Fi, so let's understand Resin from basics:

H.Cl + Na.OH → Na.Cl + H.OH

Is a simple acid and base reaction. Both HCl and NaOH above are liquid. Imagine we have them as Solids.

R.H → Is Cation Exchange Resin where H is free to reactor and R is an inert Solid.

R.OH → is Anion Exchange Resin where OH is free to react.

If they come in contact with water that has cation or anion "willing" to react, the EXCHANGE takes place. See below

R.H + NaCl → R.Na + H.Cl (Service)

In above reaction the Na present in water has relaced H ion of Resin, it's possible because R loves Na more then H. <u>This is selectivity of Resin</u>. Each resin has certain liking and disliking SAC resin explained in previous page love Ca most, Mg Next and Na least. This is the reason when we apply SAC resin in DM plant, Na Slips and governs the termination of service cycle.

In a given resin voulme we have fixed no of Resin Sites that have H on it to get exchanged. Sum of total no of such sites is know as Total Excahnge Capacity and is expreesed a kg $CaCO_3$/ m^3 of Resin.

Once Na Slips beyond the normal slip during the entire process, it's an indication that H sites are reducing in Nos and resin is getting EXHAUSTED. Once the resin is exhausted we need to regenerate the same by giving very high concentration of H ion (Remember SAC resin does not like H), thus higher concentrations of H ion typically by 3-5% H_2SO_4 or HCl is required:

R.Na.Ca.Mg + HCl → R.H + Na.Mg.Ca.(Cl) (Regeneration)

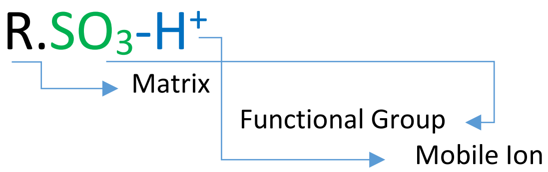
Thus, during regeneration the IONs exchanged during previous cycles are released from resin, making it fresh again for next cycle. Spent Acid flushes the ions and then water rinses the resin to make it fit for next cycle.

Resincan not remove more Kgs of Impurity than its Op Exchange Capacity and thus we talk of Efficiency η.

Let's get into Resin a bit deep inside into it

Resin has a base material that is a 3D Co-Polymer. We call it MATRIX.

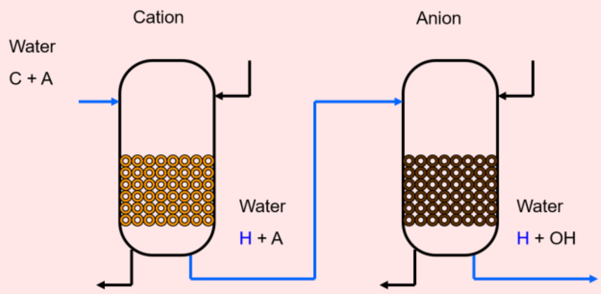
On matrix we introduce a Functional group e.g. the Functional group in SAC resin is $-SO_3H^+$, where H^+ is the mobile ion that will react with any Cation Na, Ca or Mg.



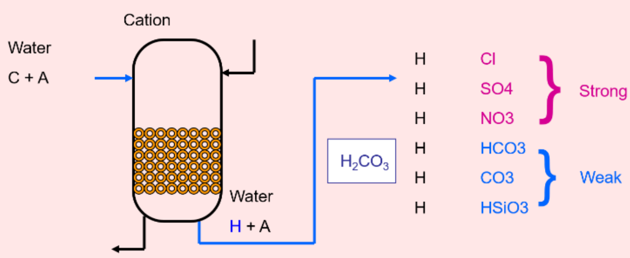
On matrix we introduce a Functional group e.g. the Functional

DM Process & Need of Degasser..1

DM plant has a Cation & Anion Exchanger as below:



If you look above, once cations are exchanged we produce Acid (HCl), therfore the EMA present in water is known as FMA after cation exchanged (Equivlant becomes Free). This free acid can react with WBA resin and Cl, SO_4, NO_3 etc would be held onto resin and OH will be released, making water DM water.



A closure look at SAC outlet suggests we produce Carbonic acid that justifies Degasser. SiO_2 now behaves as an acid to be removed by SBA resin.

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AKTION CONSULTANCY

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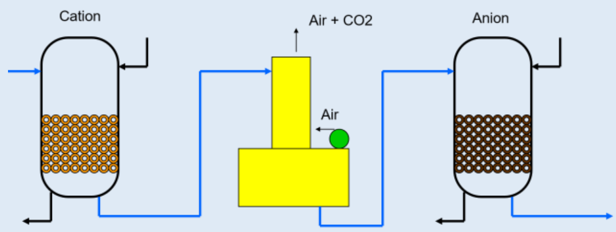
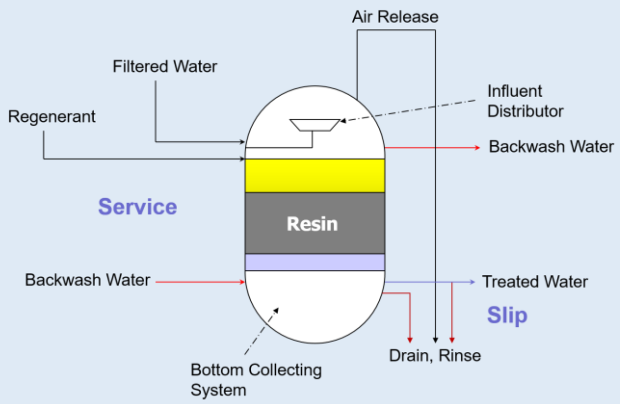
DM Process & Need of Degasser..2

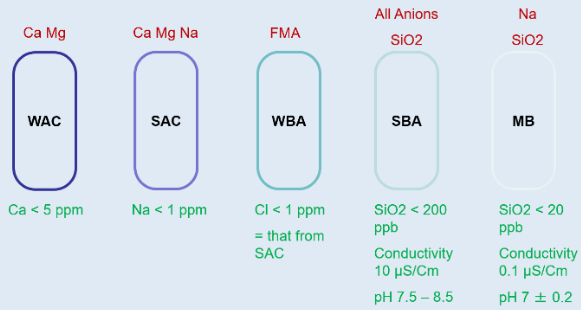
H_2CO_3 in its form has CO_2 gas that can be blown in a DG Tower. If not, HCO_3 will be exchanged by SBA resin (No problem), but NaOH required for regeneration is expensive, so we prefer a DG Tower in between Cation and Anion.



For DM plant thus we need vessels where resin is filled. The inside of vessel looks like:

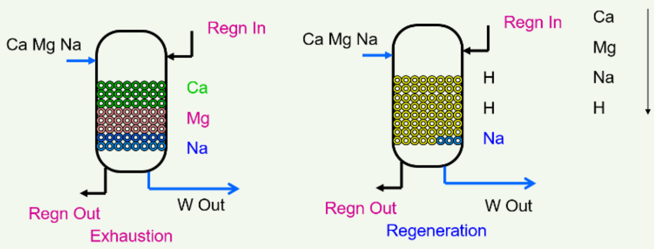


Depending upon treated water quality desired several combinations of exchangers are possible like, SAC-DG-SBA, SAC-DG-WBA-SBA, and WAC-SAC-DG-WBA-SBA and in some cases WAC-SAC-WBA-DG-SBA etc. If treated water quality is very stringent and further polishing is needed, one may use 1 or 2 Mixed Bed exchangers in Series MB1, MB2. Usually MB2 is needed only in high purity water production for *Semiconductor Manufacturing* where treated water quality requirement may be > 10 mega Ω.Cm resistivity.

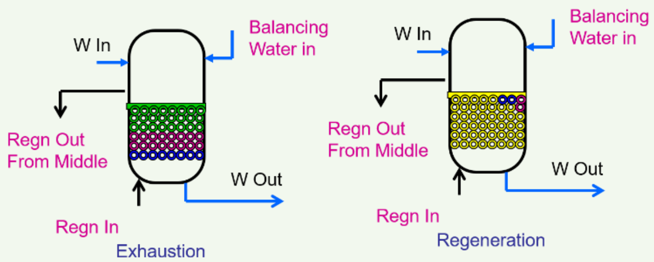


Regeneration Techniques

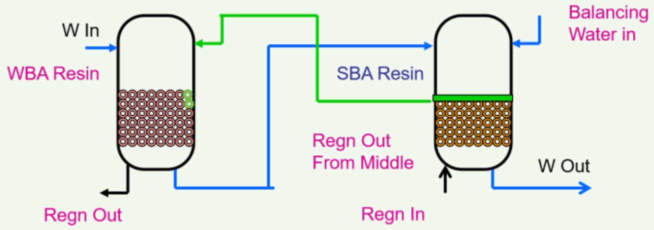
HCl/H_2SO_4 for Cation and NaOH for Anion is usually employed as the chemicals for regeneration. If the REGENERANT is flowing in the same direction as that of service water it's called Co-Current Regeneration.



Selectivity of Resin as explained previously results in layered exhaustion of Resin Red in a typical exchanger. If we deploy Co-Current Regeneration method, the last layer from where Na may slip is not fully regenerated and we may have to add additional HCl to regenerate last resin layer properly. This problem is solved by employing counter current regeneration technique as hereunder:



While the last layer is best regenerated layer, the CCR technique creates an additional problem to deal in form of FLUIDIZATION of resin due to reverse flow. This is avoided by suppling the service water from top to counter FLUIDIZATION, and an additional opening in the vessel is needed to take both regenerant and balancing water out of vessels through a system called Middle collecting system. Similarly, we deploy thoroughfare regeneration technique to optimize HCl/NaOH consumption in a DM Plant:



The Design of IX Process

The simplest design is a Softener where Ca & Mg are exchanged with Na.

R.Na + Ca,Mg → R.Ca,Mg + Na.Cl (Service) + H_2O

R.Ca,Mg + NaCl → R.Na + Mg,Ca.Cl (Regneration) + H_2O

Let's do a calculation and understand basic terms in CAPS. If we have to remove 200 mg/l Hardness, the

LOAD = 200 Hardness i.e sum of Ca & Mg (mg/l or ppm)

Flow rate = 10 m^3/h

EXHUASTION = 10 hrs Service + 2 hrs regn (12 hrs i.e. 2 Cycle)

Output between Regeneration(OBR) = Flow rate* Exhaustion Hours
10 m^3/h * 10 h = 100 m^3

WORK DONE/Cycle = Load * OBR
200 gm/m^3 * 100 m^3

= 20000 gm = 20 kg

What it means in every cycle 20 kg of Ca + Mg (Hardness) shall be exchanged.

In Softener we use strong Acid Cation Exchange Resin in Na Form. Resin have an exchange capacity and it depends upon several things;

1. Rate of Exhaustion ($m^3/h.m^3$ of resin)
2. End Water Quality , Slip < Na 5 ppm
3. Na/TC ratio ~ 23% (In Our Case)
4. Regeneration Level – kgs of Salt NaCl/m^3 of Resin usually 130 – 180 kg NaCl /m^3 of Resin.

The exchange capacity of resin can be obtained from resin characteristics curves supplied by Resin manufacturers e.g. Purolite. A designer must learn how to see those curves.

As such it's very simple for an engineer with little bit patience.

From one such graph we achieve:

Op. exchange capacity at RL (160) = 55 kgs Hardness as CaCO3/m^3 of Resin

Resin Volume Needed = Word Done ÷ Op EC

= 20 kg ÷ 55 kg/m^3

= 0.364 m^3 = 364 l

Salt Consumption = Resin Volume * RL

= 0.364 m^3 * 160 kg / m^3

= 58.3 kg

If saturated with water concentration of salt is usually 30% w/v.

Brine Measuring tank volume = 58.3 kg ÷ 0.30

= 194 l

Thus to summarize for 10 m^3/h softener, that produces 200 m^3 water in a day and removes Hardness from 200 ppm to 5 ppm, we require 364 lit of Cation Exchange Resin that would need reaeration with 58 kg of Salt.

PROCESS CALCULATION - Sample Softner

Softener	Unit	Parameter
Streams	Nos	1
Flow	m3/h	10
Operating Hrs.	h	10
Cycle	Nos	2
Ionic Load	ppm as CaCO3	200
OBR		**100**
Work done	kg as CaCO3	**20**
Regeneration level (100%)	kg NaCl /m3	160
Operating Exchange capacity	CaCO3/m3 of Resin	61
Na/TC correction factor	-	1
Corr. Factor for Hardness	-	1
Mech Correction Factor	-	0.9
Design Exchange Capacity	kg CaCO3 /m3	55
Effective Resin Volume	m3	0.363
Effective Resin Volume	lit	362.5
Salt Consumption	kg	58.0025

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From the Desk of Editor

We have been issueing this magazine since January 2021 and this one is the 6th edition. We are getting several responses from the readers and shall improve our coverage as per their suggestions.

De-mineralization has become a science that is almost extint other than the Power sector. Most of our teams are not knowlegeable on this subject and thus we wished our Lead Technology Sanjeev Srivastava to develop the content for this edition. We hope you like it.

Further, the readers wish:

1. Narration shall be simple
2. Examples shall be offered to explain a subject
3. XLS tool shall be available to perform design calculations.
4. Easy Excess to previous editions shall be available

We have upladed all the previous issues as well as XLS tools on our website www.aktionconsultancy.com for free download and distribution.

Nidhi Jain – Editor Waughter

Feed Back of the Month

Mr Pradeep Chandanan, the Managing Director of Inhibeo Water Solutions Pvt Ltd and is a regular reader of Waughter.

Sir, your feed back to create a "Pocket Book" for Service and Installation technicians is well appriciated by the editorial team.

We promise our "Deepawali Edition", being released in October shall be focused on Erection, Installations, Servinging, Commissioning engineers and shall have the content suitable for them.

Thank you Pradeep Ji.

वन और हम !!

Our world is Waughter

The technical knowledge share attempt of Aktion Consultancy and the contents in the magazine shall be qualified by Sanjeev Srivastava our Technology Lead.

Our next edition focuses on: Desalting – RO & SWRO with Special Pre-treatment Needs.

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