Waughter

AKTION CONSULTANCY

Volume 3 : Edition 1 – DM Plant Design

Feb 01, 2023

Dear Water Warriors,

With Narmada water now available in Gujarat in many industrial clusters, designers are moving from the RO-MB option to conventional Demineralization.

Cation Exchange – Degasification & Anion Exchange column design calculations are now are in demand.

The issue of 'Waughter', let's understand DM Plant Design using Ion Exchange Resins.

Nidhi Jain – Civil Engineer

Ion Exchange Resin – Refresh it again.

IX Resins are produced by "Copolymerization" of Styrene with DVB. This forms the "Matrix" (core) of the resin. The sulphonation of this Matrix results in Strong Acid Cation Exchange Resin. $R\text{-}SO_3H$

Here $-SO_3H$, is known as functional group and H is the mobile ion willing to exchange other Cations.

For SAC application, the resin is used inH form and appears as $R\text{-}SO_3H$, where H is replaced with Ca & Mg, Na and H is released into water.

For Anion Exchange the Resin is in R.OH form where OH is released on exchange of Cl, SO_4, NO_3, HCO_3 and $HSiO_3$.

IX DM Reactions & Regeneration

To simplify the understanding, we are now dealing with Ca only when we see equations. One can easily write the same with Mg and Na as indicated below.

Process is as below:

$R\text{-}SO_3H$	+	Ca	=	$R\text{-}SO_3Ca$	+	H
		Mg		$R\text{-}SO_3Mg$		H
		Na		$R\text{-}SO_3Na$		H

Regeneration with HCl is as below:

$R\text{-}SO_3Ca$	+	H	=	$R\text{-}SO_3H$	+	Ca
$R\text{-}SO_3Mg$		From				Mg
$R\text{-}SO_3Na$		HCL				Na

As we can see that the Acid (HCl) is used for regeneration. One can also use H_2SO_4 or HNO_3

Design of DM Plant with CDA-MB Scheme

To start, you must have a water analysis. And correct the same wrt to chemicals dosed in clarification plant before filtered water is available.

Raw Water Analysis				Chemical Dose, mg/l	
				20	7
Sl No	Parameter	Unit	As CaCO3	Corr. Alum	Corr. Lime
1	Calcium mg/l	mg/l	50.00	50.0	62.5
2	Magnesium	mg/l	22.00	22.0	22.0
3	Total Hardness	mg/l	72.00	72.0	84.5
4	Temp Hardness	mg/l	72.00	72.0	73.5
5	Permanent Hardness	mg/l	0.00	0.0	11.0
6	Na+K	mg/l	79.00	79.0	79.0
7	Total Cation	mg/l	151.00	151.0	163.5
8	Chloride	mg/l	40.00	40.0	40.0
9	Sulphate	mg/l	30.00	39.0	39.0
10	Nitrate	mg/l	10.00	10.0	10.0
11	Fluoride	mg/l	1.00	1.0	1.0
12	Total EMA	mg/l	81.00	90.0	90.0
13	M-Alkalinity	mg/l	70.00	61.0	73.5
14	P-Alkalinity	mg/l	0.00	0.0	0.0
15	Total Anion	mg/l	151.00	151.0	163.5
16	Silica Reactive,	mg/l	25.00	25.0	25.0

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DM Design – User Requirement

The design of DM plant is based on DM water required Ex-MB per day. Our client wants ~ 1000 m3 DM water per day.

User Requirement				
Client		ABC Limited		
Consultants		Aktion Consultancy		
Parameter	Symbol	Unit	Formula	Value
Scheme Selected				CDA_MB
Out between regeneartaion - DM Plant	OBR_{DM}	m^3/h	Input	1000
Operating Cycle	O_p	h	Input	24
No of Regn /day for DM	Reg_{DM}	Nos	Input	1
MB Regn Frequency	Reg_{MB}	d	Input	7
Regeneration Time DM	R_T	h	Input	4
Working Time	W_T	h	$= O_T - R_T$	20
OBR for Mixed Bed, if Provided	OBR_{MB}	m^3	$= OBR_{DM} * Reg_{MB}$	7000
Plant Flow Rate	Q	m^3/h	$= OBR_{DM} / O_T$	50

The Cation & Anion Column, need to be regenerated every day or even twice a day if we have multiple chains and automated regeneration.

Another point the user must confirm is treated water quality expectation. Typically, 1 ppm of Na Slip as NaOH is responsible for Conductivity of 6 µS/Cm.

End Point Ionic Slip			
Exchanger	What's Typical Slip from Exchanger	Unit	CCR Regen
SAC	Na (1-2)	mg/l	2
Degasser	Alkalinity (5-8)	mg/l	6
SBA	Silica (0.1 - 0.5)	mg/l	0.2
MB Cation	Na (0.1 - 0.3)	mg/l	0.1
MB Anion	Silica (0.01 - 0.05)	mg/l	0.02
Loads			
Exchanger	What's Load	Unit	CCR Regen
SAC if NO WAC	TC	mg/l	163.5
Degasser	M-alkalinity	mg/l	73.5
SBA if NO WBA	Silica+EMA + Slip Alka	mg/l	121.0
MB Cation	Na Slip from SAC	mg/l	2
MB Anion	Silica Slip from SBA	mg/l	0.2
Design Ratios and Applicability			
Specific Ratio	Applicable to Resin	Unit	Value
Alk/TC	SAC	%	45
SiO2/TA	SBA	%	21
Ca/TC	SAC for H2SO4 Regeneration	%	74

Generally, Customers expect 1 µS/Cm conductivity, pH around 7.00 and SiO_2 < 0.02 mg/l after mixed bed.

The table above gives a view about end point ionic slip and the load (ions) removed by a specific Exchanger.

CDA MB Design XLS Sheet

To understand IX Colum design for DM Plant one has to go through the table below in sequential order.

Process Calculation for DM Plant

Production Data

Sl No	Description	Unit	MB Cation	MB Anion	SBA	SAC
1	Regeneration Mode		Co	Co	CCR	CCR
2	Chemical for Regeneration		HCl	NaOH	NaOH	HCl
3	Type of Resin - INDION Brand		225H	FFIP	FFIP	225H
4	Temperature	Deg C	25	25	25	25
5	Flow rate (Avg)	m3/h	50	50	50	50
6	Working Hrs	h	140	140	20	20
7	Out Between Rgeneration, nett	m3	7000	7000	1000	1000
8	Waste Water for Self	m3	14.23	14.23	21.98	12.96
9	Waste Water for Upstream	m3	153.84	153.84	0.00	0.00
10	Waste Water for Down Stream	m3	0.00	0.00	5.01	63.36
11	Gross Output BR, Gross	m3	7168.07	7168.07	1026.99	1076

The important thing above is to understand that each unit produces extra water for regeneration of either Self or Down Stream or Upstream columns. So, one must check in XLS as Options → Formulas → Enable Iterative Calculations. To start with you can imagine it "Zero", but remember or note down formula to loop back once you complete the design.

The next thing is obtaining "Operation Exchange Capacity" from resin characteristics curves. This has several steps:

1. Select Regeneration Level
2. Select Op Exchange Capacity from Curve
3. Do correction for Ions as suggested in Curves
4. Apply general reduction of 10% from the capacity obtained.

IX Exchange Resin Design

Sl No	Description	Unit	Mixed Bed		SBA	SAC
1	Ionic Load	mg/l	2.00	0.20	121.00	163.53
2	Ionic Load per Cycle (Work Done)	Kg	14.34	1.43	124.27	176.01
3	Regeneration Level	kg/m3	60.00	60.00	40.00	77.49
4	Exchange Capacity of Resin from Graph	Kg/m3	39.00	3.00	26.00	67.00
5	Gen Correction Factor		0.70	0.90	0.90	0.90
6	CF for Na/TC		1.00	1.00	1.00	0.97
7	CF for alk/TC		1.00	1.00	1.00	0.99
8	CF for Bed depth		1.00	1.00	1.00	1.00
9	CF for Silica over end pt. Silica		1.00	1.00	0.98	1.00
10	Corrected exchnge capacity	kg/m3	27.30	2.70	22.93	57.91

MB Cation, if regenerated once in 7 days the Cation Exchange Capacity is reduced by 30% while designing.

The Blue Cell above is to adjust Acid Injection in SAC to obtain self-neutralizing effluent. Means on Mixing the pH of regeneration effluent in Neutralizing Pit is Neutral.

IX Column Design

It must satisfy the criteria of Bed Depth (Governs DP across column < 0.5 kg/Cm2), Surface Velocity m3/h.m2 < 40 and minimum bed depth (0.5 m for each resin in MB and 1m in Cation or Anion column in CCR mode.

Resin Calculated = Work Done ÷ Corrected Exch Cap.

Self- Neutralization : Regenerant?

One must provide regenerant sufficient enough as per the regeneration level considered for obtaining the “Operation Exchange Capacity” from the curves. You can add extra chemicals to regenerate better and self-neutralize effluent from two columns.

IX Exchange Column Design

Sl No	Description	Unit	Mixed Bed		SBA	SAC
1	Resin, Calculated	m3	0.53	0.53	5.42	3.04
2	Resin, Inert		0.00	0.00	0.57	0.30
3	Resin , Buffer		0.24	0.24	0.00	0.00
4	Resin, Provided		0.77	0.77	5.99	3.34
5	Resin , Active		0.77	0.77	5.42	3.04
6	Dia Based on min BD	mm	1159.89	1159.89	2627.36	1967.77
7	Dia Based on Maximum BD		1159.89	1159.89	2145.23	1244.53
8	Resin Based on Min BD		0.7693	0.7693	3.7994	2.0096
9	Dia selected		1400.00	1400.00	2200.00	1600.00
10	Revised area		1.5386	1.5386	3.7994	2.0096
11	Bed Depth		1000.00	1000.00	1426.24	1512.54
12	% free Board		120.00	120.00	100.00	100.00
13	Unit HOS Calculated		2200.00	2200.00	2852.48	3025.08
14	Unit HOS Selected		2200.00	2200.00	3000.00	3000.00
15	Check BV/h		32.50	32.50	9.23	16.45
16	Check M3/h-m2		32.50	32.50	13.16	24.88
Chemicals Required						
Sl No	Description	Unit	Mixed Bed		SBA	SAC
17	Chemical, as Such		46.16	46.16	216.75	235.54
18	Chemical as CaCO3		63.24	57.70	270.94	322.69
19	Regn Efficiency	%	22.67	2.48	45.86	54.55
20	Chemical Wasted	kg	48.90	56.26	146.68	146.68
21	Effluent Genearted	kg		7.36		0.00
22	Neutralising Chemical,CaCO3	kg	7.36		0.00	
23	Neutralising Chemical, as such	kg	5.37		0.00	

Regeneration Steps

The Mixed bed unit shall be designed first and designer shall calculate the waste water required for the regeneration of the Mixed bed Exchanger.

Mixed Bed Regeneartion(Sequential)			Acid Conc %	4.00	Alkali Con %	4.00
Sl No	Operation	Basis	Flow m3/h	Time(min)	Volume m3	Water Source
1	Middle Coll. Flush ,9m/h	9	13.85	5.00	1.15	DM
2	Backwash ,9m/h	9	13.85	5.00	1.15	DM
3	Bed settlement			5.00		
4	Acid injection (1.5-5%)	w/v	6.92	10.00	1.15	DM
4	Down flow, 1.5 m/h	1.5	2.31	10.00	0.38	DM
5	Acid rinse, 2 BV	2	6.15	15.00	1.54	DM
5	Downflow, 1.5m/h	1.5	2.31	15.00	0.58	DM
6	Alkali injection	w/v	4.62	15.00	1.15	DM
6	Upflow	4.5	6.92	15.00	1.73	DM
7	Alkali Rinse	4	9.23	20.00	3.08	DM
7	Upflow	4.5	6.92	20.00	2.31	DM
8	Drain Down			10.00		
9	Air Mix	2.0 m3/min/m2	184.63	10.00		
10	Final Rinse (10-30 min)	Service flow	50.00	25.00	20.83	SBA
11	Check Acid	> 4.5	4.50			
12	Check Alkali	> 3.0	3.00			
13	Total	< 120 min		120.00	20.83	SBA
					14.23	MB
	Rinse Time depends upon Final quality (10 Min, 1 MicroS/Cm, 30 min 0.2 micro Siemnes)					

The Point to remember are:

1. Backwash flow is calculated based on Sp. Gr. of Resin. In mixed bed Cation and Anion are mixed together. So, for separation, we need 40% expansion of Cation. The corresponding water velocity at 25^0C is 9 m/h.

2. At this velocity Anion expands a lot further, thus MB shall have 120% freeboard above resin level.

3. Channelling shall be avoided while injecting the Acid or Alkali so that the regenerant can impregnate the entire volume of resin rathe than channelize through some section. To obtain the same

   a. Minimum injection velocity for HCl shall be 4.5 m/h (Upwards)
   b. Minimum Injection velocity for Anion shall be 3.0 m/h (downwards)

4. Final Rinse water may be recycled for preparation of chemicals for SAC/SBA etc to reduce water losses.

5. Rinse duration depends upon end water conductivity.

Regeneration Steps

The SBA Regeneration

Injection concentration 3-5% need to be adjusted so as to have ~ 4.5 m/h upward velocity of alkali during injection.

Fast Rinse water ~ 12.5 m3, can be recycled back to Degassed Water Tank as recovery water as it's quality is always better then that obtained from SAC.

SBA Regeneration			Alkali Con %	3	(3-5%)	CCR
Sl No	Operation	Basis	Flow m3/h	Time(min)	Volume m3	Water source
1	Backwash, 3m/h	3	11.40	5.00	0.95	DG
2	Middle Coll. Flush, 3 m/h	3	11.40	5.00	0.95	DG
3	Alkali Pre Inject, 5/6 of Inj	5/6 of InJ	14.45	5.00	1.20	MB
3	Down Flow, 5/6 of DF	5/6 of DF	14.45	5.00	1.20	DG
4	Alkali injection, 4.5 - 18 m/h	4.5-18 m/h	17.34	25.00	7.23	MB
4	Down Flow, inj flow	inj flow	17.34	25.00	7.23	DG
5	Slow Rinse (2.5 BV)	5/6 of InJ	14.45	56.25	13.55	MB
5	Down Flow	5/6 of DF	14.45	56.25	13.55	DG
6	Final Rinse	Ser Flow	50.00	15.00	12.50	DG
	Total			111.25	36.38	on SAC
					21.98	on MB/SBA
	Check AlkaliInjection	4.5-18 m/h	4.56			

The SAC Regeneration

Middle collector flush is an important step, not to be ignored. The fine particles of resin block the Middle collector strainers. During flushing they are released and allow for proper exit of Injection Flow + Downflow flow.

SAC Regeneration			Acid Con %	5	(3-5%)	CCR
Sl No	Operation	Basis	Flow m3/h	Time(min)	Volume m3	Water source
1	Backwash	9	18.09	5.00	1.51	Fil
2	Middle Coll. Flush	9	18.09	5.00	1.51	Fil
3	Acid Pre Inject	5/6 of InJ	7.85	5.00	0.65	DG
3	Down Flow	5/6 of DF	7.85	5.00	0.65	Fil
4	Acid injection	4.5-18 m/h	9.42	30.00	4.71	DG
4	Down Flow	inj flow	9.42	30.00	4.71	Fil
5	Slow Rinse (2.5 BV)	5/6 of InJ	7.85	58.07	7.60	DG
5	Down Flow	5/6 of DF	7.85	58.07	7.60	Fil
6	Final Rinse	Ser Flow	50.00	15.00	12.50	Fil
	Total			118.07	28.48	Fil
					12.96	DG (SAC)
	Check Acid Injection	4.5-18 m/h	4.69		12.96	DG (SAC)

Slow Rinse of $5/6^{th}$ of the injection flow is obtained by using a 1:5 ejector for Acid Injection. Power water is used to set $5/6^{th}$ flow and simple opening of Acid valve at the suction of ejector completes the $1/6^{th}$ part of Acid.

Simply closing this valve post injection means the slow Rinse step starts. For Final Rinse, stop the Down Flow and start normal service with drain valve open.

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March 22, 2023

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Venue

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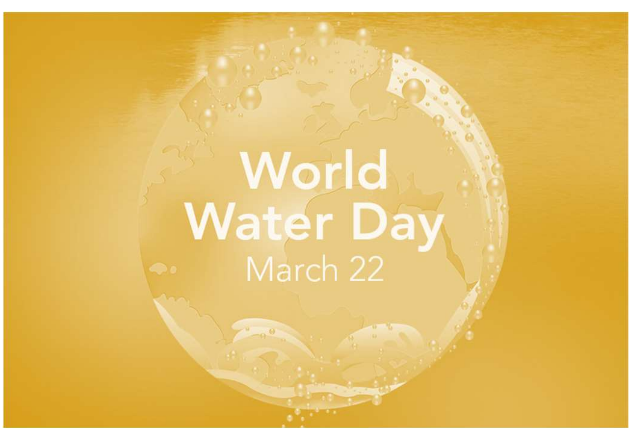

Complimentary Lunch & Tea
Register with Ms Nidhi Jain
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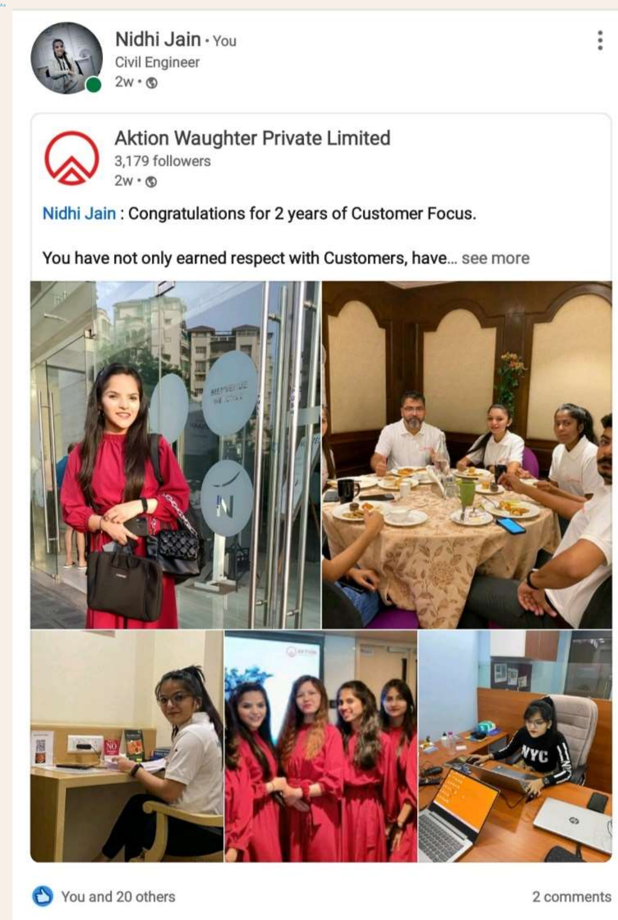

Our world is Waughter

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: "How to Study a Plant systematically for Performance or other Objectives"

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