Technical Report

Samyang Layered Bed System
(Water Treatment)

Samyang Corporation
Ion Exchange Resin Team
31, Jongno 33-gil, Jongno-gu, Seoul, Korea
TEL) 82-2-740-7732~7, FAX) 82-2-740-7709
http://samyangtrilite.com

Samyang Corporation is the history of Ion Exchange Resin in Korea.

In 1976, Samyang Corporation successfully initiated localized production of IER in South Korea by technical cooperation with Mitsubishi Chemical Corporation, Japan. In 2011, with the successful development of UPW (Ultrapure water grade) resins, we are contributing to enhancing national competitiveness in semiconductor/LCD industries.
In 2016, Asia's largest UPS (Uniform Particle Sized) specialized IER (Ion Exchange Resin) plant; Samyang Fine Technology Corporation was founded. TRILITE is being supplied to the global market and is receiving rave reviews from the users.

Seoul(Head Office)

- **Technical sales force in 3 fields**
  - Demineralization/Ultrapure water /Condensate polishing/Catalyst
  - Food/Amino acids/Pharmaceuticals
  - Wastewater/Chelating resins /Purification
- **One Stop Service**
  - Analysis of IER
  - Equipment diagnosis and design support
  - Technical seminars and trouble shooting guides

Gusan(UPS Resin Plant)

- **Samyang Fine Technology (Joint venture with Mitsubishi Chemicals)**
- **Largest manufacturing capaicty for UPS resins in Asia**
- **Annual production capacity**
  - Cation 13,000kℓ, Anion 7,000kℓ
- **Product lines**
  - Uniform particle sized resins
  - Chromatography resins
  - Ultrapure water grade resins (OLED, LCD application)

Daejeon(R&D Center)

- **Analysis of IER**
- **Recipe improvement of IER**
- **New product development**
  - Tailored/Specialty resins
- **Application process development**
  - Pilot test
  - Engineering data gathering
  - Process proposal

Ulsan (UPW/Tailored/Specialty Resin Plant)

- **Technology licensed by Mitsubishi Chemicals & Self-development**
- **Specialized production of tailored resins**
- **Production capacity**
  - Cation 3,500kℓ, Anion 2,500kℓ
- **Product line**
  - Ultrapure water grade for semiconductor
  - Tailored resins : food, catalyst, pharmaceuticals
  - Specialty resins: chelating resins, synthetic adsorbents, refining of chemicals

No.1 Total Solution Provider

Samyang Corporation presents the full line-up of TRILITE Ion Exchange Resins from water teratement up to specialty applications. Samynag devlops Tailored resins optimized for customer needs and provoides differentiated technical services such as on-site visti for troubleshooting, technical seminars, process and design consulting, etc. Also, Samyang R&D center offers various analysis services for IERs and develops advanced application technologies.

■ Classification by IER layer

SAC	**Strongly Acidic Cation Resin : MC-08, MC-10, …**
WAC	**Weakly Acidic Cation Resin : WCA10, …**
SBA	**Strongly Basic Anion Resin : MA-12, MA-10, …**
WBA	**Weakly Basic Anion Resin : AW30, AW90, …**

(Classification by IER layer)

Single Bed	SAC, WAC, SBA, WBA
Layered Bed	WAC / SAC, WBA / SBA
Mixed Bed	SBA / SAC

■ Various combinations by Raw water and treated water quality

(Demineralization system and IER selection)

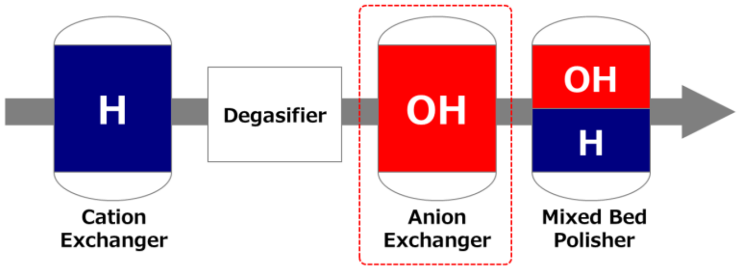
2B2T (2Bed 2Tower) Cation Exchanger + Anion Exchanger	SAC → SBA	MC-08 MC-10	MA-12 MA-20		
2B3T Cation Exchanger + Degasifier + Anion Exchanger	SAC → Degasi-fier → SBA	MC-08 MC-10	MA-12 MA-20		
Working MB (Mixed Bed)	SBA / SAC	MA-12(P) MA-20(P) MC-08 MC-10			
2B2T+MBP (Mixed Bed Polisher)	SAC → SBA → SBA / SAC	MC-08 MC-10	MA-12 MA-20	MA-12(P) MA-10(P) MC-08 MC-10	
2B3T+MBP	SAC → Degasi-fier → SBA → SBA / SAC	MC-08 MC-10	MA-12 MA-20	MA-12(P) MA-10(P) MC-08 MC-10	
3B3T+MBP	SAC → Degasi-fier → WBA / SBA → SBA / SAC	MC-08 MC-10	AW90 AW30L MA-12 MA-10	MA-12(P) MA-10(P) MC-08 MC-10	
4B3T+MBP	WAC / SAC → Degasi-fier → WBA / SBA → SBA / SAC	WCA10L MC-08 MC-10	AW90 AW30L MA-12 MA-10	MA-12(P) MA-10(P) MC-08 MC-10	
4B3T+MBP+CPP (Condensate Polisher)	WAC / SAC → Degasi-fier → WBA / SBA → SBA / SAC → Conden-ser → SBA / SAC	WCA10L MC-08 MC-10	AW90 AW30L MA-12 MA-10	MA-12(P) MA-10(P) MC-08 MC-10	MA-10OH MA-15OH MC-10H MC-14H

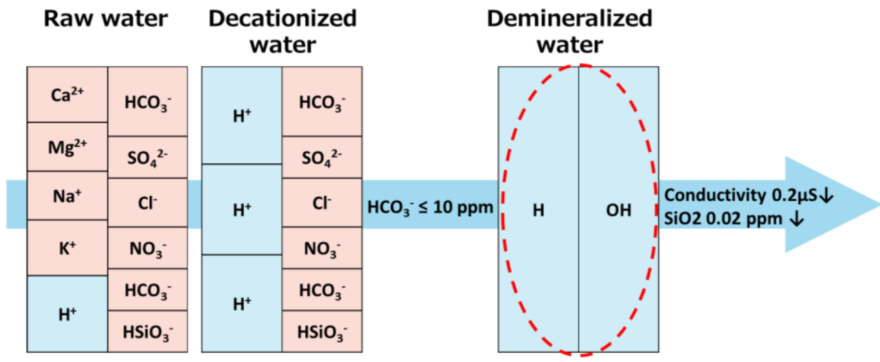
1. Overview

A Layered Bed water treatment system allows economical production of pure water through simultaneous employment of Strongly Acidic Ion Exchange Resin (SAC IER) and Weakly Acidic Ion Exchange Resin (WAC IER) for a cation exchanger; and of Strongly Basic Ion Exchange Resin (SBA IER) and Weakly Basic Ion Exchange Resins (WBA IER) for an anion exchanger. Successive regeneration of WAC or WBA ion exchange resin with regeneration waste water of SAC or SBA ion exchange resin enables high regeneration efficiency and ability to cope with the change of raw water due to a good resistance to organic fouling of resins.

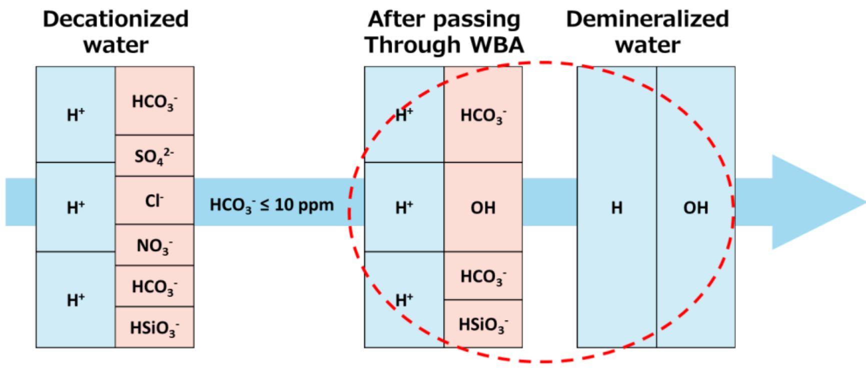
Generally, a cation exchanger is chemically stable and is strong against organic pollutants of raw water, so it is rarely constructed in layered bed; thus, it is preferable to construct a layered bed with anion exchangers only. The following figure is a diagram of Samyang Packed Bed System Process (Layered bed) that does not use intermediate plate; there are two types of resin layer in one resin tower. The separation of resin layers is performed according to the difference in the particle size and the specific gravity.

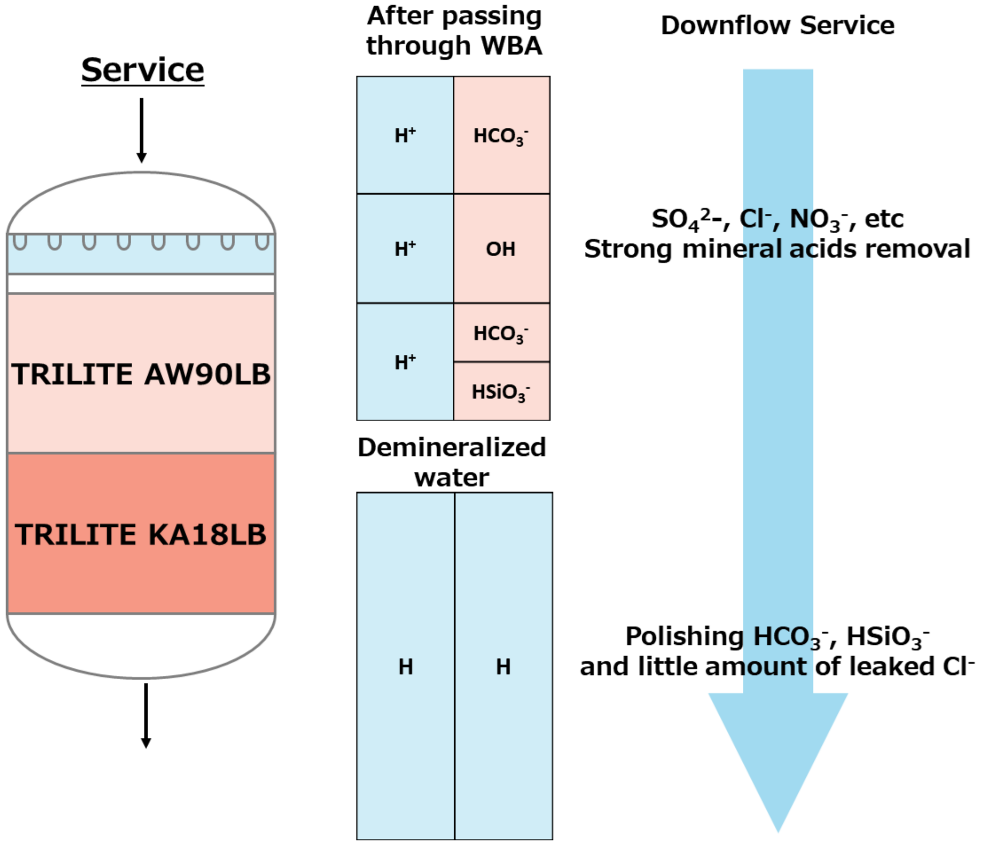
2. Understanding the layered bed pure water system (I)

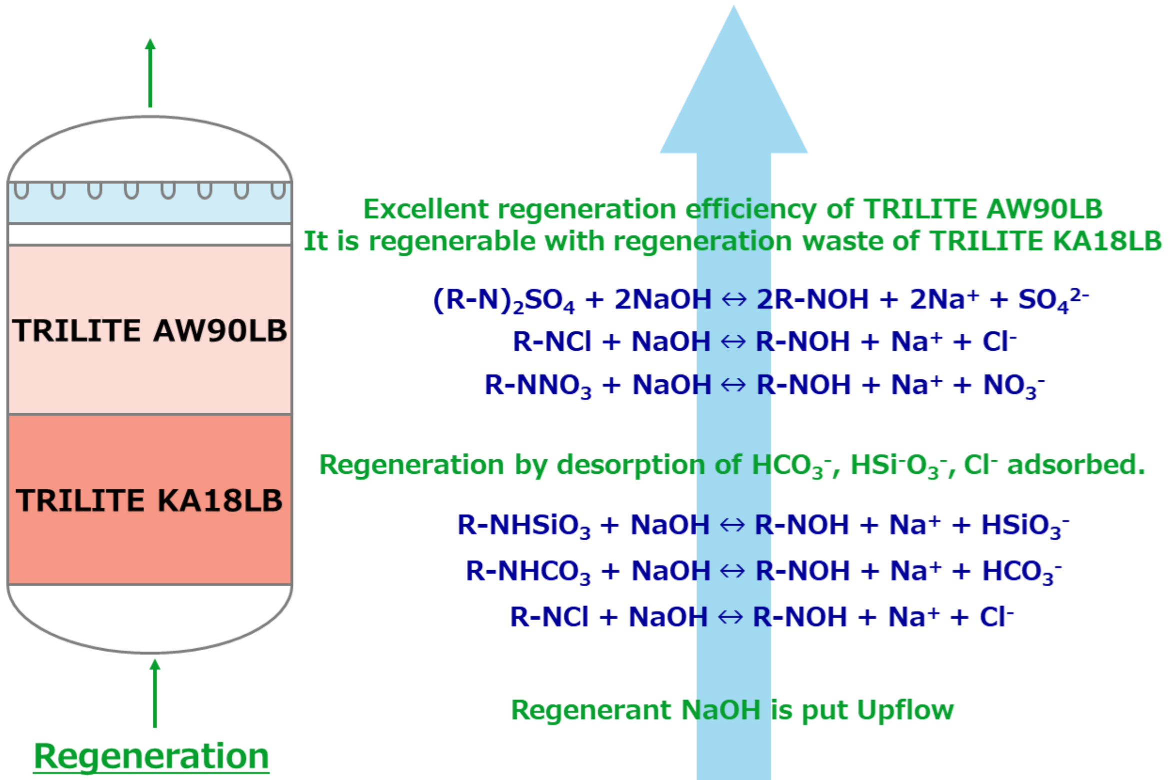




The 2B3T+MBP system, a typical demineralizer using SAC and SBA ion exchange resin, is shown in the figure above. The layered bed system employs two types of anion exchange resins in the anion exchanger.




Service
TRILITE AW90LB
TRILITE KA18LB
After passing through WBA
H^+ | HCO_3^-
H^+ | OH
H^+ | HCO_3^- | $HSiO_3^-$
Demineralized water
H | H
Downflow Service
SO_4^{2-}, Cl^-, NO_3^-, etc
Strong mineral acids removal
Polishing HCO_3^-, $HSiO_3^-$
and little amount of leaked Cl^-


TRILITE AW90LB
TRILITE KA18LB
Regeneration
Excellent regeneration efficiency of TRILITE AW90LB
It is regenerable with regeneration waste of TRILITE KA18LB
$(R\text{-}N)_2SO_4 + 2NaOH \leftrightarrow 2R\text{-}NOH + 2Na^+ + SO_4^{2-}$
$R\text{-}NCl + NaOH \leftrightarrow R\text{-}NOH + Na^+ + Cl^-$
$R\text{-}NNO_3 + NaOH \leftrightarrow R\text{-}NOH + Na^+ + NO_3^-$
Regeneration by desorption of HCO_3^-, $HSi^-O_3^-$, Cl^- adsorbed.
$R\text{-}NHSiO_3 + NaOH \leftrightarrow R\text{-}NOH + Na^+ + HSiO_3^-$
$R\text{-}NHCO_3 + NaOH \leftrightarrow R\text{-}NOH + Na^+ + HCO_3^-$
$R\text{-}NCl + NaOH \leftrightarrow R\text{-}NOH + Na^+ + Cl^-$
Regenerant NaOH is put Upflow

■ Advantage of Samyang Layered bed System

1. **Simple structure of the resin tower**
   (No intermediate plate is needed owing to the separation of resins by the difference in particle size and specific gravity)
2. **Very high regeneration efficiency (85~95%) due to the regeneration of WBA with regeneration waste water of SBA IER**
3. **Very high operating capacity of the WBA IER**
4. **Smooth desorption of silica due to the use of Type1 SBA IER**
5. **Longer life time of resins; WBA IER prevents organic contamination of SBA IER**
6. **Easy retrofit of existing resin tower; adjusting ratio of 2 types of IER (SBA, WBA)**

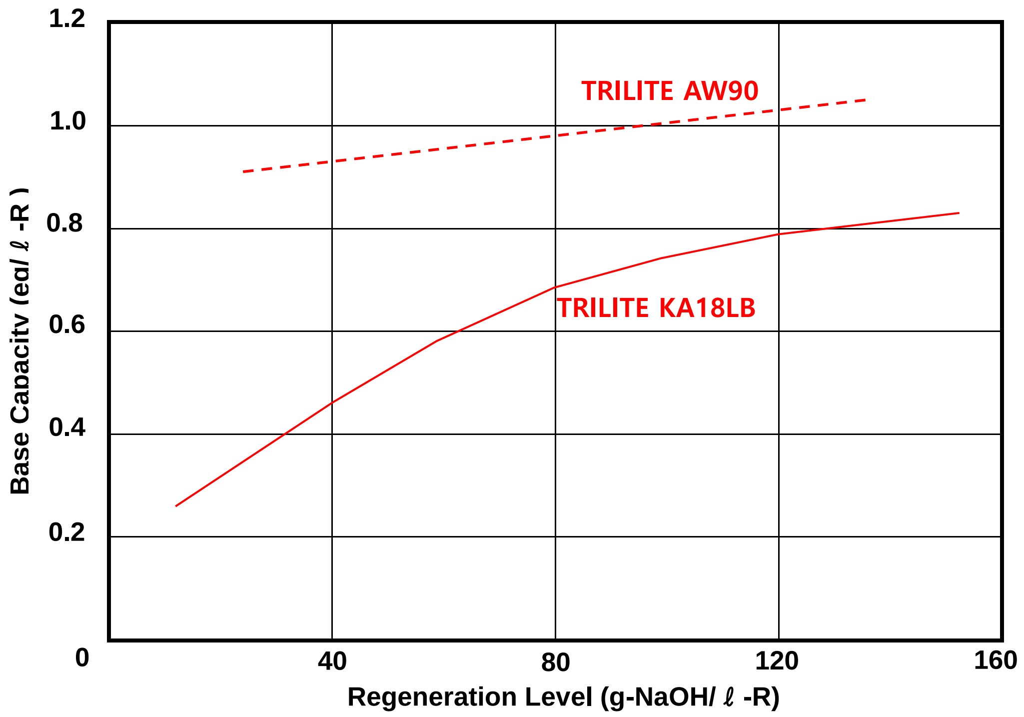
■ Disadvantage of Samyang Layered Bed System

1. **Possible SiO_2 leakage for treating water with high SiO_2%**
   - Not recommended to use when SiO_2% is above 30%
2. **Intermediate sight glass is needed to check the separation of two types of resins (SBA, WBA)**
3. **Rather high initial investment cost due to higher price of WBA IER than SBA IER**

3. Specification for SBA and WBA IER for Layered bed

Grade	TRILITE KA18LB (SBA)	TRILITE AW90LB (WBA)
Type	Strongly Basic Anion Exchange Resin (Gel type)	Weakly Basic Anion Exchange Resin (Porous type)
Matrix	Styrene-Divinylbenzene Copolymer	
Functional group	Trimethylammonium (Type1)	Dimethylammonium
Ionic form	Cl	OH
Physical form	Beige translucent spherical beads	Ivory opaque spherical beads
Specific gravity	**1.11g/mℓ**	**1.04g/mℓ**
Moisture retention(%)	43~47%	40~50%
Total capacity	1.3meq/mℓ	1.5meq/mℓ
Swelling rate	OH / Cl = 1.24	Cl / OH = 1.30
Uniformity coefficient	1.4 ↓	1.1 ↓
Particle size	**0.6~1.2mm**	**0.5~0.6mm**
Operating temperature	60℃(OH form) 80℃(Cl form)	100℃ ↓
Operating pH range	0~14	0~9

4. Regeneration efficiency comparison between SBA, WBA Exchange resins



5. Understanding the layered bed pure water system (Ⅱ)

WBA exchange resin (TRILITE AW90LB) has excellent regeneration efficiency, as shown above, and exchange capacity for multivalent ions; SBA exchange resin type 1 (TRILITE KA18LB) has low regeneration efficiency but strong basicity, allowing low ion and silica leakage.

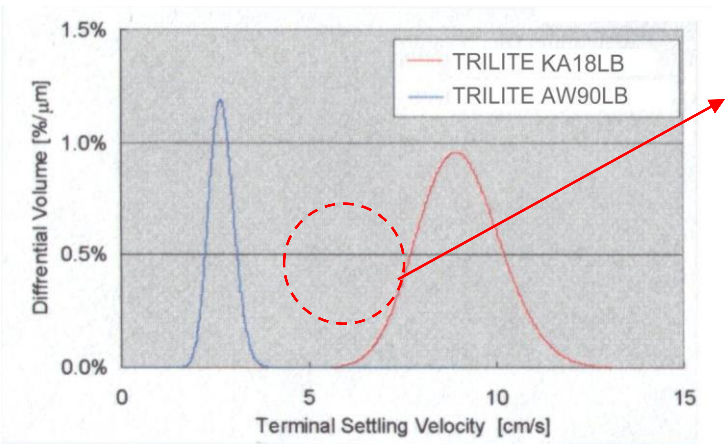
Grade	TRILITE KA18LB	TRILITE AW90LB
Regeneration efficiency	Low	High
Ion leakage	Low	High
Silica removal	High	Low
Organic fouling resistance	Low	High

As shown in the above table, two types of ion exchange resin with different characteristics are filled in one resin tower, exerting excellent performance during service. These resins are separated without an intermediate plate due to difference in specific gravity and particle size.

Type	TRILITE KA18LB		TRILITE AW90LB
Specific gravity	1.11g/mℓ	>	1.04g/mℓ
Particle size	0.6~1.2mm	>	0.5~0.6mm

While backwashing the resin tower, the resin layer is initially expanded (Bed Expansion) and settles down, the TRILITE KA18LH is located at the bottom part of the resin layer because of its high shipping density and average diameter, and the TRILITE AW90LB is located at the top, forming the layers.

At this time, the conventional products were mixed in the middle layer by separation depending on the apparent density without adjusting the particle size, but TRILITE KA18LB and TRILITE AW90LB are able to separate completely owing to their differentiation in terminal settling velocity with adjusting the particle size as shown in the figure below.



Sedimentation rate of TRILITE KA18LB is much faster than that of AW90LB. Uniformity of TRILITE AW90LB results sharp rate of differentiation for sedimentation. Hence, there is no mixture of 2 types of IERs.
→ Excellent separation efficiency

TRILITE AW90LB, a weakly basic anion-exchange resin, has high exchange capacity for free mineral acids (FMA), thus is highly economical if FMA concentration in raw water is high. Its usage is not recommended, however, if FMA concentration is relatively low and SiO_2% is high (over 30%).

※) Free mineral acid(FMA): Chloride(Cl^-), Nitrate(NO_3^-), Sulfate(SO_4^{2-})

For reference, the selection of the SBA exchange resin for the anion tower according to the quality of the raw water is as follows:

Raw water condition			Recommended IER	Grade	
TDS	**SiO_2%**	**COD**			
Total ionic contents in raw water (50ppm↓)	**30%↓**	**Low TOC in raw water**	**SBA exchange resin Gel Type2**	**Gaussian**	**TRILITE SAR20**
				UPS	**TRILITE MA-20**
		High TOC in raw water	**WBA exchange resin + SBA exchange resin Gel Type1**	**TRILITE AW90LB + TRILITE KA18LB**	
	30%↑	**Low TOC in raw water**	**SBA exchange resin Gel Type1**	**Gaussian**	**TRILITE SAR10, 12**
				UPS	**TRILITE MA-12, MA-10**
		High TOC in raw water	**SBA exchange resin Porous Type2**		**TRILITE AMP18**

Total ionic contents in raw water (50ppm↓)	30%↓	Low TOC in raw water	SBA exchange resin Gel Type2	Gaussian	TRILITE SAR20
				UPS	TRILITE MA-20
		High TOC in raw water	WBA exchange resin + SBA exchange resin Gel Type1	TRILITE AW90LB + TRILITE KA18LB	
	30%↑	Low TOC in raw water	SBA exchange resin Gel Type2	Gaussian	TRILITE SAR20
				UPS	TRILITE MA-20
		High TOC in raw water	SBA exchange resin Porous Type2	TRILITE AMP28	

※ 1g $KMnO_4$/ℓ-Resin ↓, ※※ 5g $KMnO_4$/ℓ-Resin ↓

Type			Regeneration efficiency	Organic fouling	Heat resistance	Chemical stability	Economic efficiency
SBA Gel type2	Gaussian	TRILITE SAR20	Better	Good	Good	Good	Increases with low TOC and low TDS
	UPS	TRILITE MA-20					
SBA Gel type1	Gaussian	TRILITE SAR10, 12	Good	Good	Better	Better	Increases with low TOC and low TDS
	UPS	TRILITE MA-10, 12					
WBA + SBA Gel type1	Layered bed	TRILITE AW90LB + TRILITE KA18LB	Excellent	Excellent	Better	Better	Increases with high TOC, high TDS and low SiO_2%
SBA Porous type1		TRILITE AMP18	Good	Excellent	Better	Good	Increases with high TOC, less TDS and high SiO_2%
SBA Porous type2		TRILITE AMP28	Better	Excellent	Better	Good	Increases with high TOC, high TDS and high SiO_2%

6. Layered Bed Water Treatment System: Operating condition

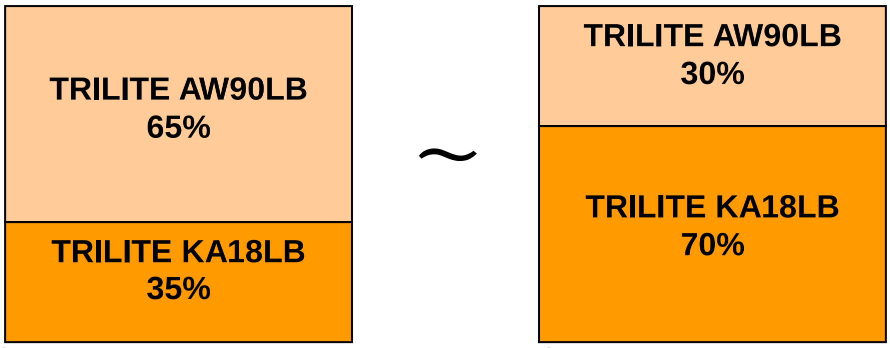
6.1 Summary

Type	Data
Service flow rate	
Maximum	50m/hr
Normal	20~40m/hr
Minimum	5m/hr
Regenerant concentration	2%↑
Injection flow rate	LV 8 m/hr↑
Injection period	20min↑
Slow rinse	3BV
Fast rinse	3~5BV
Outlet condition	2 ㎲/㎝↓
SiO_2 leakage	100~150ppb ↓

6.2 Vessel sizing Summary

Classification	TRILITE AW90LB	TRILITE KA18LB
Bed depth		
Maximum	2,000mm	1,500mm
Normal	800~1,500mm	800~1,300mm
Minimum	500mm	800mm
Regeneration level		
Maximum	90g/ℓ-Resin	120g/ℓ-Resin
Normal	50g/ℓ-Resin	80g/ℓ-Resin
Minimum	30g/ℓ-Resin	40g/ℓ-Resin
Swelling	20%	12%

6.3 Ratio of Anion Exchange Resins for Layered bed



① SiO_2 Concentration Low
② Regeneration efficiency High

① SiO_2 Concentration High
② Regeneration efficiency Low

6.4 Regeneration condition and Operating condition for Layered bed

6.4.1 When SiO_2 input is low

NaOH Concentration	NaOH Injection period	NaOH Injection flow rate
2%	20~30min	LV 8

No limit for Overrun operation (approximately, up to 50%)

6.4.2 When SiO_2 input is high

NaOH Concentration	NaOH Injection period	NaOH Injection flow rate
2%	25~40min	LV 8 ↑

Overrun operation is limited. It is desirable to control over NaOH concentration to less than 2%. When highly concentrated NaOH is put, Silica contamination may occur to WBA exchange resin while regenerating operation. Also, it is suggested to manage the temperature of regenerant lower than 35℃, to protect silica contamination of WBA.

7. Operating condition of layered bed water treatment system

The WBA exchange resin at the front of the SBA exchange resin may have an increased operating exchange capacity than the theoretical end point, which is because the SBA in the rear end polishes the ions leaking from WBA. This phenomenon is called overrun operation.

The degree of overrun operation can be expressed by the following equation.

Overrun% = 100×(overrun amount of treated water / theoretical amount of attainable water)

The higher the overrun % is, the higher the concentration of FMA leak to the SBA at the end point is, which should be considered when operating. The calculation of WBA resin amount is as follows:

WBA Volume = FMA total ion load per cycle (g/cycle) / WBA operating exchange capacity (g/L-Resin)

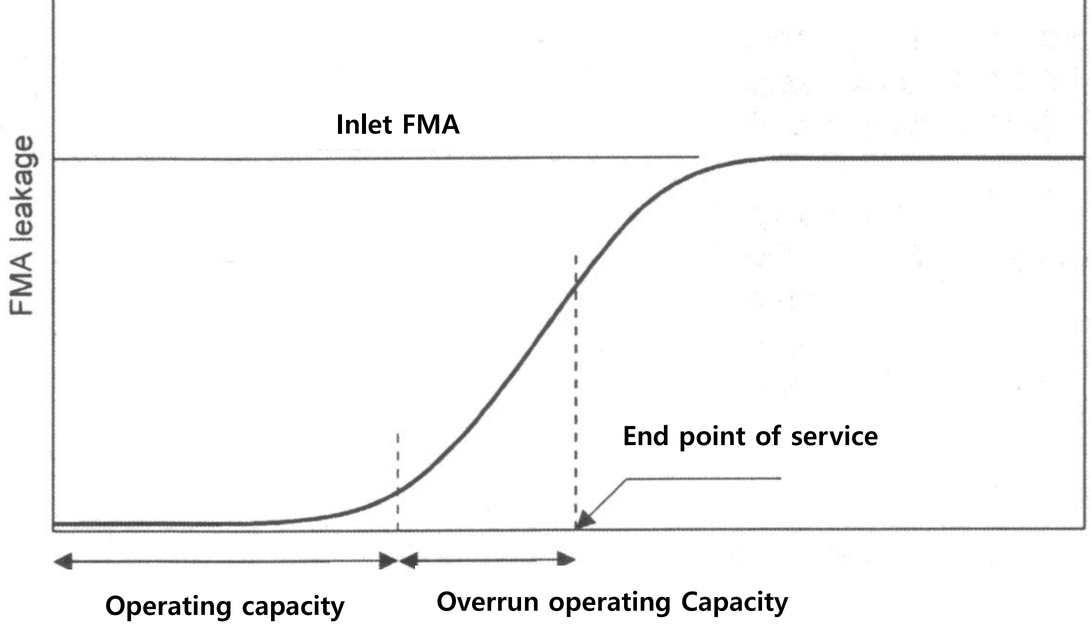
In the absence of overrun, only the SiO_2 and HCO_3^- ions should be treated by the SBA; however, when overrun operation occurs, small amount of FMA leaks and the load increases. In this case, the ion loading of SBA is as follows:

SBA ion loading = SiO_2 + HCO_3^- + FMA leakage from WBA

In conclusion, it can be seen that the resin amount of SBA increases when the overrun operation is performed a lot. Generally, when calculating the amount of ion exchange resin in a layered bed pure water system, it is common to consider a certain overrun % after calculation assuming no overrun operation.

Free mineral acid (FMA) : Chloride(Cl^-), Nitrate(NO_3^-), Sulfate(SO_4^{2-})

Overrun Operating Capacity : Operating capacity more than total capacity of anion exchange resin, when there is a SBA exchanger behind a WBA exchange resin. It is due to SBA acts as polisher at the rear end of WBA.



8. IER Charging Method for Layered Bed Water Treatment System

TRILITE KA18LB is most swelled when ionic type is OH type, and TRILITE AW90LB is most swelled when it is in exhausted form. Therefore, it should be considered that the volume is increased about 5% when charging ion exchange resin.

8.1 General counter-current regeneration Water Blocking System

① Fill resin tower with water about 50% to prevent physical crush of resins.

② Put in TRILITE KA18LB (Cl type) into tower

③ Perform backwash (LV 6-8m/hr, 30min)

④ Fill water up to approximately 1m above the charged TRILITE KA18LB, and then put in AW90LB. (It is preferable, at this time, to leave TRILITE AW90LB in water for about 8 hours, or to supply water to resins by carrying out 1 cycle operating before back wash (step ⑤) if there is no time to do so. If water supply operation is omitted, resin loss may occur during backwash because TRILITE AW90LB is porous resin and air might remain among pores.)

⑤ Conduct backwash (LV 1.5-2 m/hr, 30min).

⑥ Close the manhole and perform double regeneration.

⑦ After displacement, carry out service from the point below the specified electric conductivity.

8.2 Packed Bed System

① Calculate the freeboard above the resin layer based on the case when the resin layer is most swelled.

② Add TRILITE KA18LB followed by Inert Resin in accordance with the provision of 8.1.

③ Add TRILITE AW90LB in accordance with section 8.1.

④ The following procedures are the same as section 8.1.

9. IER Separation Method for Layered Bed Water Treatment System

Since the layered bed pure water system has 2 types of ion exchange resin charged in the tower, the separation must be smooth, which is essential for proper operation. If the separation is not satisfactory due to inadequate operating conditions or if pollutants are accumulated excessively in WBA exchange resins on upper side, follow the procedures below to induce the ion exchange separation and pollutant discharge.

① If the ion exchange resin is contaminated, perform cleaning process of the ion exchange resin. After cleaning is completed, perform double regeneration and settle the resin layer.

② Perform backwash at a flow rate of LV 1-2 m/hr for 2-4 hours (At this time, the WBA exchange resin is backwashed upward, and the SBA exchange resin is located at the bottom.)

③ Rest the resins for settlement.

④ Perform backwash at a backwash flow rate of LV 2-3 m/hr for 4 hours (At this time, the WBA exchange resin mixed in the SBA exchange resin moves upward.)

⑤ Rest the resins for settlement and perform double regeneration again.

■ Case Study1 (Co-current System → Samyang Packed Bed System) – Operating Cost Evaluation

This is a retrofit example of co-current system to Samyang Packed Bed System.

Ⅰ) Feed water analysis

Ca^{2+}	0.46 meq/ ℓ	Cl^-	0.60 meq/ ℓ
Mg^{2+}	0.30 meq/ ℓ	SO_4^{2-}, etc	0.32 meq/ ℓ
Na^+ + K^+	0.59 meq/ ℓ	HCO_3^-	0.43 meq/ ℓ
Total Cations	1.35 meq/ ℓ	SiO_2	0.12 meq/ ℓ
※Total cations = TC		Total Anions	1.47 meq/ ℓ

Ⅱ) After Degasfier Anion

Cl^-	0.60 meq/ ℓ
SO_4^{2-}, etc	0.32 meq/ ℓ
HCO_3^-	0.20 meq/ ℓ
SiO_2	0.12 meq/ ℓ
TEA	1.24 meq/ ℓ

※FMA = 0.60 + 0.32 = 0.92meq/ ℓ , Cl / FMA%=65.2%
※Cl% = 0.60 / 1.24 = 48.4%
※Weak Acid = TEA – FMA = 1.24–0.92 = 0.32
※SiO_2% = 0.12 / 1.24 = 9.7%
※FMA / Weak Acids = 2.88

※TEA(Total Exchangeable Anions)

※FMA(Free Mineral Acids) = Total sum of ions; Cl^-, SO_4^{2-}, NO_3^- ,F^- ,PO_4^{3-}, etc from organic contents

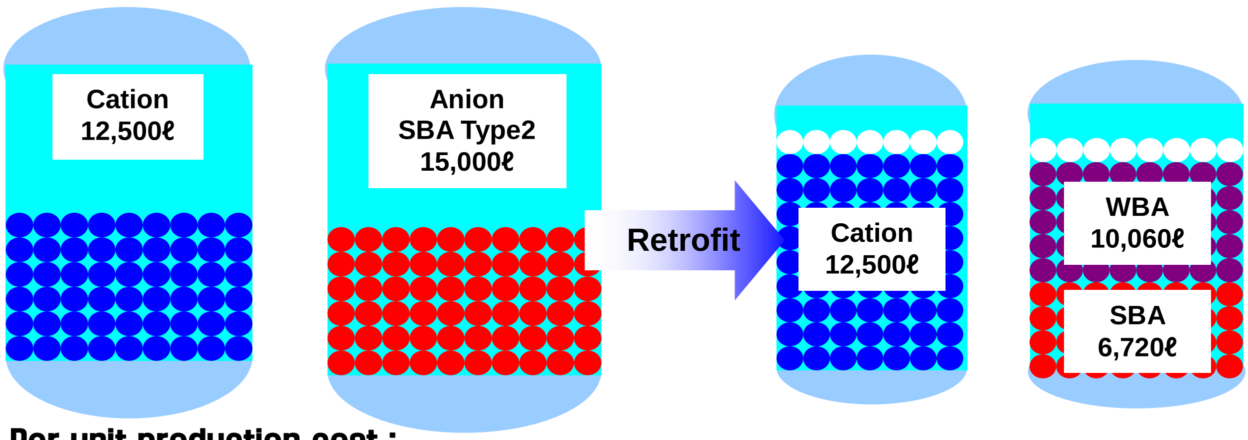
※Weak Acids = Total sum of ions; HCO_3^-, acetic acid, citric acid, silica, etc mostly resulted from organic contents. It is generally calculated by TEA – FMA.

Ⅲ) Requirements

2B3T(2Bed 3Tower) system(Cation exchanger → degasfier → anion exchanger)
Flow Rate = 450 ㎥/hr, Running Time = 20hr
Operating Temperature = 15℃, Regeneration Temperature = 35℃
Required SiO_2 Leakage = 150ppb as SiO_2

Ⅳ) Cationic load(eq/cycle) = TC × 450 ㎥/hr × 20hrs = 12,150eq/cycle
Anionic load(eq/cycle) = TEA × 450 ㎥/hr × 20hrs = 11,160eq/cycle

Ⅴ) Cation exchange resin regeneration level = 100.0g as 100% HCl/ ℓ -R ,
Anion exchange resin regeneration level = 100.0g as 100% NaOH/ ℓ -R



Per unit production cost :

457 Won/Ton **424 Won/Ton**

Annual save on Operating Cost : 100,355,623 WON / Year

Ion Exchange Resin Demineralizer Operating Cost Wise Comparison (Co-current →Layered Bed)

■ Calculation of production capacity

Type	Unit	Conventional		Layered Bed		Remarks
		Cation resin	Anion resin	Cation resin	Anion resin	
IER Grade		TRILITE SCR-B	TRILITE SAR20	TRILITE MC-08	TRILITE AW90LB TRILITE KA18LB	Layered Bed
Raw water ionic load	(eq/m^3)	1.35	1.24	1.35	1.24	
Hourly production	(m^3/hr)	450	450	450	450	
Raw water ionc load/ hr	(eq/hr)	607.5	558	607.5	558	
Effective quantity	(ℓ)	12,500	15,000	12,500	16,780	
Regeneration level	(g/ℓ)	100.0	100.0	62.0	89.4	
Operating capacity	(meq/ℓ)	0.90	0.73	1.08	0.97	
Safety factor & Loss rate	(%)	1.05	1.10	1.05	1.10	
Total operating capacity	(eq)	10,714	9,955	12,857	14,788	
Gross service quanity per cycle	(m^3/cycle)	7,937	8,028	9,524	11,926	
Regeneration waste per cycle	(m^3/cycle)	63	75	63	84	5BV of resin
Net service quanity per cycle	(m^3/cycle)	7,874	7,953	9,461	11,842	
Service hours per cycle	(hr/cycle)	17.5	17.7	21.0	26.3	Select lower quanity between Cation & Anion
Actual production per cycle	(m^3/cycle)	7,874	7,953	9,461	11,842	
Annual cycle (a)	(cycle/year)	391		336		1cycle = service time + regeneration time (4hrs)
Annual production quanity(b)	(m^3/cycle)	3,076,672		3,175,807		

■ Calculation of regenerant usage and netralization cost

Regenerant unit cost — HCl: ₩75/kg (35%); NaOH: ₩170/kg (25%)

Type	Unit	HCl	NaOH	HCl	NaOH	Remarks
Regenerant used per cycle	(kg/cycle)	1,250.0	1,500.0	775.0	1,500.0	100% Regeneration
Regenerant cost per cycle	(₩/cycle)	267,857	1,020,000	166,071	1,020,000	
Total cost per cycle (c)	(₩/cycle)	1,287,857		1,186,071		

Acid excess	(keq/cycle)	23.1		7.8		HCl MW 36.5
Alkali excess	(keq/cycle)		29.9		26.2	NaOH MW 40.0
Regenerant used per cycle	(kg/cycle)	709.7		1,913		
Neutralizer cost per cycle(d)	(₩/cycle)	53,229		143,507		

■ Calculation of IER cost

IER unit price

Conventional Cation resin	₩1,900/ℓ	Price of TRILITE SCR-B
Conventional Anion resin	₩4,500/ℓ	Price of TRILITE SAR20
New Cation resin	₩2,200/ℓ	Price of TRILITE MC-08
New Anion resin	₩6,500/ℓ	Average price of TRILITE AW90LB, KA-18LB

Type	Unit	Cation resin	Anion resin	Cation resin	Anion resin	Remarks
Annual replacement rate	(%/year)	5%	20%	5%	10%	
Annual replacement quanity	(ℓ/year)	625ℓ	3,000ℓ	625ℓ	1,687ℓ	
Annual IER cost (e)	(₩/year)	14,687,500		12,282,000		

■ Calculation of Wastewater treatment cost

Wastewater treatment unit cost: ₩500/m^3

Type	Unit	Conventional	Layered bed	Remarks
Wastewater per cycle	(m^3/cycle)	138	146	
Treatment cost per cycle	(₩/cycle)	68,750	73,200	

■ Calculation of annual operating cost and purewater production cost

Industrial water unit cost(g): ₩250/m^3

Type	Unit	Conventional	Layered bed	Remarks
Annual operating cost	(₩/year)	1,404,695,278	1,304,339,655	Without UT cost, for same amount of production
Save on annual operating cost	(₩/year)	100,355,623		
Purewater production unit cost	(₩/m^3)	457	424	

The said production cost of pure water does not include energy and other UT costs, so the actual unit price may increase. It is compared with existing facilities, on the same conditions of resin amount and recycling; if the amount of resin is increased by utilizing the freeboard space above the existing resin tower, capacity will increase more than twice, and the operational cost saving will also increase.

■ Case Study2(Water Block Count-current → Samyang Packed Bed System)

– Operating Cost Evaluation

This is a retrofit example of water block count-current system to Samyang Packed Bed System.

Ⅰ) Feed water analysis

Ca^{2+}	0.46 meq/ ℓ	Cl^-	0.60 meq/ ℓ
Mg^{2+}	0.30 meq/ ℓ	SO_4^{2-}, etc	0.32 meq/ ℓ
$Na^+ + K^+$	0.59 meq/ ℓ	HCO_3^-	0.43 meq/ ℓ
Total Cations	1.35 meq/ ℓ	SiO_2	0.12 meq/ ℓ
※Total cations = TC		Total Anions	1.47 meq/ ℓ

Ⅱ) After Degasfier Anion

Cl^-	0.60 meq/ ℓ
SO_4^{2-}외	0.32 meq/ ℓ
HCO_3^-	0.20 meq/ ℓ
SiO_2	0.12 meq/ ℓ
TEA	1.24 meq/ ℓ

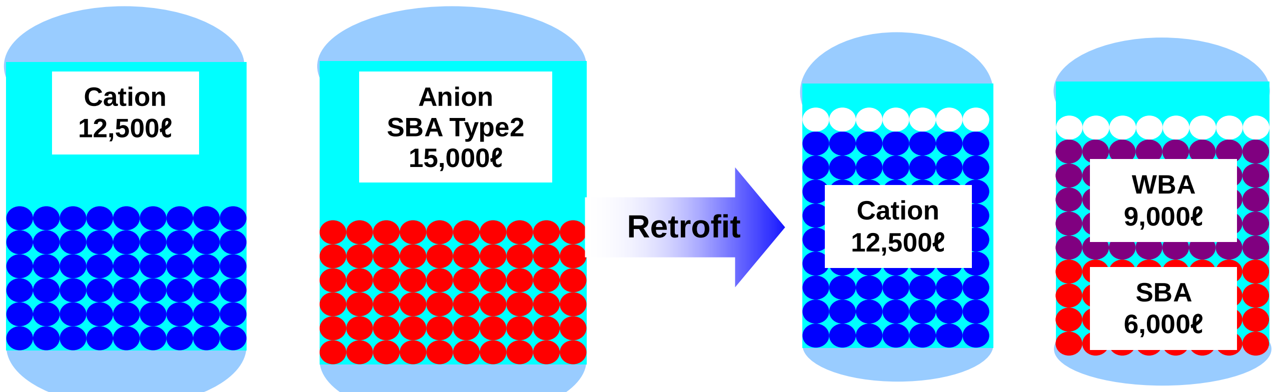
※FMA = 0.60 + 0.32 = 0.92meq/ ℓ , Cl / FMA%=65.2%
※Cl% = 0.60 / 1.24 = 48.4%
※Weak Acid = TEA – FMA = 1.24–0.92 = 0.32
※SiO_2% = 0.12 / 1.24 = 9.7%
※FMA / Weak Acids = 2.88

Ⅲ) Requirements

2B3T(2Bed 3Tower) system(Cation exchanger → degasifier → anion exchanger)
Flow Rate = 450 ㎥/hr, Running Time = 20hr
Operating Temperature = 15℃, Regeneration Temperature = 35℃
Required SiO_2 Leakage = 150ppb as SiO_2

Ⅳ) Cationic load(eq/cycle) = TC × 450 ㎥/hr × 20hrs = 12,150eq/cycle
Anionic load(eq/cycle) = TEA × 450 ㎥/hr × 20hrs = 11,160eq/cycle

Ⅴ) Cation exchange resin regeneration level = 42.0g as 100% HCl/ ℓ -R ,
Anion exchange resin regeneration level = 50.0g as 100% NaOH/ ℓ -R



Per unit cost : 364 Won/Ton **353 Won/Ton**

Annual save on Operating Cost : 34,804,007 WON/Year

In this case, total capacity can be increased more than twice by increasing resin amount and modifying upper distributor, given the same area. Economic increase in capacity can be derived for an existing facility.

Ion Exchange Resin Demineralizer Operating Cost Wise Comparison (Water block count-current →Layered Bed)

■ Calculation of production capacity

Type	Unit	Conventional		Layered Bed		Remarks
		Cation resin	Anion resin	Cation resin	Anion resin	
IER Grade		TRILITE SCR-B	TRILITE SAR20	TRILITE MC-08	TRILITE AW90LB TRILITE KA18LB	Layered Bed
Raw water ionic load	(eq/m³)	1.35	1.24	1.35	1.24	
Hourly production	(m³/hr)	450	450	450	450	
Raw water ionc load/ hr	(eq/hr)	607.5	558.0	607.5	558.0	
Effective quantity	(ℓ)	12,500	15,000	12,500	15,000	
Regeneration level	(g/ℓ)	42.0	50.0	42.0	50.0	
Operating capacity	(meq/ℓ)	1.08	0.86	1.08	0.97	
Safety factor & Loss rate	(%)	1.05	1.10	1.05	1.10	
Total operating capacity	(eq)	12,857	11,727	12,857	13,222	
Gross service quanity per cycle	(m³/cycle)	9,524	9,457	9,524	10,663	
Regeneration waste per cycle	(m³/cycle)	125	150	63	75	5BV of resin
Net service quanity per cycle	(m³/cycle)	9,399	9,307	9,461	10,588	
Service hours per cycle	(hr/cycle)	20.9	20.7	21.0	23.5	Select lower quanity between Cation & Anion
Actual production per cycle	(m³/cycle)	9,399	9,307	9,461	10,588	
Annual cycle (a)	(cycle/year)	340		336		1cycle = service time + regeneration time (4hrs)
Annual production quanity(b)	(m³/cycle)	3,167,440		3,175,807		

■ Calculation of regenerant usage and netralization cost

Regenerant unit cost	HCl	₩75/kg	(35%)
	NaOH	₩170/kg	(25%)

Type	Unit	HCl	NaOH	HCl	NaOH	Remarks
Regenerant used per cycle	(kg/cycle)	525.0	750.0	525.0	750.0	100% Regeneration
Regenerant cost per cycle	(₩/cycle)	112,500	510,000	112,500	510,000	
Total cost per cycle (c)	(₩/cycle)	622,500		622,500		
Acid excess	(keq/cycle)	1.1		1.0		HCl MW 36.5
Alkali excess	(keq/cycle)		9.8		8.6	NaOH MW 40.0
Regenerant used per cycle	(kg/cycle)	916.0		798		
Neutralizer cost per cycle(d)	(₩/cycle)	68,702		89,812		

■ Calculation of IER cost

IER unit price	Conventional Cation resin	₩1,900/ℓ	Price of TRILITE SCR-B
	Conventional Anion resin	₩4,500/ℓ	Price of TRILITE SAR20
	New Cation resin	₩2,200/ℓ	Price of TRILITE MC-08
	New Anion resin	₩6,500/ℓ	Average price of TRILITE AW90LB, KA-18LB

Type	Unit	Cation resin	Anion resin	Cation resin	Anion resin	Remarks
Annual replacement rate	(%/year)	5%	20%	5%	10%	
Annual replacement quanity	(ℓ/year)	625ℓ	3,000ℓ	625ℓ	1,687ℓ	
Annual IER cost (e)	(₩/year)	14,687,500		12,282,000		

■ Calculation of Wastewater treatment cost

Wastewater treatment unit cost ₩500/m³

Type	Unit	Conventional	Layered bed	Remarks
Wastewater per cycle	(m³/cycle)	275	138	
Treatment cost per cycle	(₩/cycle)	137,500	68,750	

■ Calculation of annual operating cost and purewater production cost

Industrial water unit cost(g) ₩250/m³

Type	Unit	Conventional	Layered bed	Remarks
Annual operating cost	(₩/year)	1,153,157,314	1,118,353,307	Without UT cost, for same amount of production
Save on annual operating cost	(₩/year)	34,804,007		
Purewater production unit cost	(₩/m³)	364	353	

The said production cost of pure water does not include energy and other UT costs, so the actual unit price may increase.

■ Case Study3(Samyang Packed Bed System Set-up 1)
– Operating Cost Evaluation

This is an example of operating cost evaluation for setting up a Samyang Packed Bed System (Layered bed).

Ⅰ) Feed water analysis

Ca^{2+}	0.80 meq/ ℓ	Cl^-	1.00 meq/ ℓ
Mg^{2+}	0.60 meq/ ℓ	SO_4^{2-}, etc	1.00 meq/ ℓ
$Na^+ + K^+$	1.00 meq/ ℓ	HCO_3^-	0.40 meq/ ℓ
Total Cations	2.40 meq/ ℓ	SiO_2	0.20 meq/ ℓ
※Total cations = TC		Total Anions	2.60 meq/ ℓ

Ⅱ) After Degasfier Anion

Cl^-	1.00 meq/ ℓ
SO_4^{2-}, etc	1.00 meq/ ℓ
HCO_3^-	0.20 meq/ ℓ
SiO_2	0.20 meq/ ℓ
TEA	2.40 meq/ ℓ

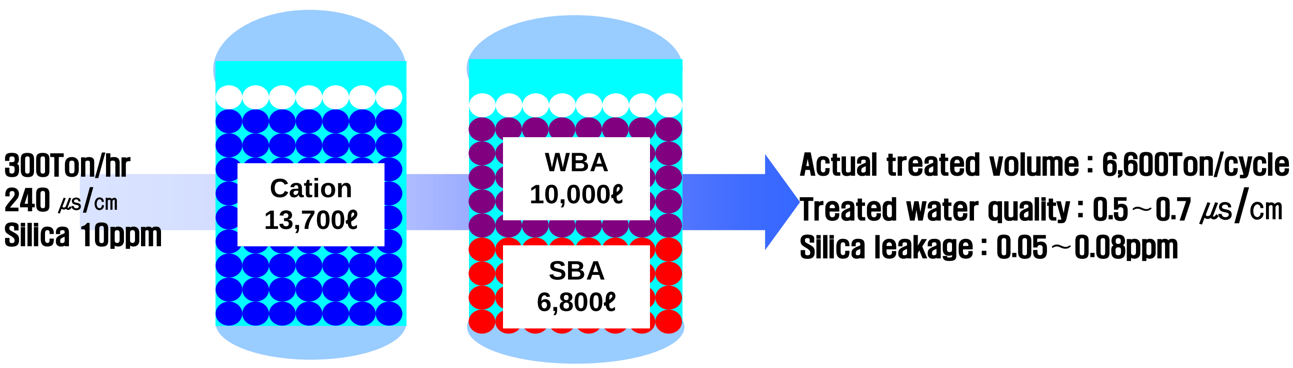
※FMA = 1.00 + 1.00 = 2.00meq/ ℓ , Cl / FMA%=50.0%
※Cl% = 1.00 / 2.40 = 41.7%
※Weak Acid = TEA – FMA = 2.40–2.00 = 0.40
※SiO_2% = 0.20 / 2.40 = 8.3%
※FMA / Weak Acids = 5.00

Ⅲ) Requirements

2B3T(2Bed 3Tower) system(Cation exchanger → degasifier → anion exchanger)
Flow Rate = 300 ㎥/hr, Running Time = 20hr
Operating Temperature = 15℃, Regeneration Temperature = 35℃
Required SiO_2 Leakage = 150ppb as SiO_2

Ⅳ) Cationic load(eq/cycle) = TC × 300 ㎥/hr × 20hrs = 14,400eq/cycle
Anionic load(eq/cycle) = TEA × 300 ㎥/hr × 20hrs = 14,400eq/cycle

Ⅴ) Cation exchange resin regeneration level = 50.0g as 100% HCl/ ℓ -R ,
Anion exchange resin regeneration level = 41.2g as 100% NaOH/ ℓ -R



The unit cost for pure water production is 312 won/Ton, which is more economical when packed bed system is newly installed than water block counter-current system. The reduction of annual operating cost is expected to be 9,454,161 won/year.

The case above does not include the reduced unit cost for construction; the construction cost is low due to the reduction of actual vessel size and the simple structure of resin tower.

Ion Exchange Resin Demineralizer Operating Cost Wise Comparison (Layered Bed Set-up1)

■ Calculation of production capacity

Type	Unit	Conventional		Layered Bed		Remarks
		Cation resin	Anion resin	Cation resin	Anion resin	
IER Grade		DIAION SK1B	DIAION SA20AP	TRILITE MC1	TRILITE AW90LB TRILITE KA18LB	Layered Bed
Raw water ionic load	(eq/m^3)	2.40	2.40	2.40	2.40	
Hourly production	(m^3/hr)	300	300	300	300	
Raw water ionc load/ hr	(eq/hr)	720.0	720.0	720.0	720.0	
Effective quantity	(ℓ)	13,700	16,800	13,700	16,800	
Regeneration level	(g/ℓ)	50.0	41.2	50.0	41.2	
Operating capacity	(meq/ℓ)	1.05	82.00	1.11	95.00	
Safety factor & Loss rate	(%)	1.05	1.10	1.05	1.10	
Total operating capacity	(eq)	13,700	12,524	14,483	14,509	
Gross service quanity per cycle	(m^3/cycle)	5,708	5,218	6,035	6,045	
Regeneration waste per cycle	(m^3/cycle)	69	84	69	84	5BV of resin
Net service quanity per cycle	(m^3/cycle)	5,640	5,134	5,966	5,961	
Service hours per cycle	(hr/cycle)	18.8	17.1	19.9	19.9	Select lower quanity between Cation & Anion
Actual production per cycle	(m^3/cycle)	5,640	5,134	5,966	5,961	
Annual cycle (a)	(cycle/year)	368		352		1cycle = service time + regeneration time (4hrs)
Annual production quanity(b)	(m^3/cycle)	1,891,587		2,098,009		

■ Calculation of regenerant usage and netralization cost

Regenerant unit cost HCl ₩72/kg (35%)
NaOH ₩155/kg (50%)

Type	Unit	HCl	NaOH	HCl	NaOH	Remarks
Regenerant used per cycle	(kg/cycle)	685.0	692.2	685.0	692.2	100% Regeneration
Regenerant cost per cycle	(₩/cycle)	140,914	214,570	140,914	214,570	
Total cost per cycle (c)	(₩/cycle)	355,484		355,484		
Acid excess	(keq/cycle)	4.6		3.7		HCl MW 36.5
Alkali excess	(keq/cycle)		6.6		4.9	NaOH MW 40.0
Regenerant used per cycle	(kg/cycle)	215.9		122		
Neutralizer cost per cycle(d)	(₩/cycle)	15,544		8,796		

■ Calculation of IER cost

IER unit price
Conventional Cation resin ₩1,700/ℓ Price of TRILITE SK1B
Conventional Anion resin ₩4,500/ℓ Price of TRILITE SA20AP
New Cation resin ₩1,700/ℓ Price of TRILITE SK1B
New Anion resin ₩7,000/ℓ Average price of TRILITE AW90LB, KA-18LB

Type	Unit	Cation resin	Anion resin	Cation resin	Anion resin	Remarks
Annual replacement rate	(%/year)	5%	20%	5%	10%	
Annual replacement quanity	(ℓ/year)	685ℓ	2550ℓ	685ℓ	1,680ℓ	
Annual IER cost (e)	(₩/year)	12,504,500		12,924,500		

■ Calculation of Wastewater treatment cost

Wastewater treatment unit cost ₩500/m^3

Type	Unit	Conventional	Layered bed	Remarks
Wastewater per cycle	(m^3/cycle)	153	153	
Treatment cost per cycle	(₩/cycle)	76,250	76,250	

■ Calculation of annual operating cost and purewater production cost

Industrial water unit cost(g) ₩250/m^3

Type	Unit	Conventional	Layered bed	Remarks
Annual operating cost	(₩/year)	664,378,671	654,924,510	Without UT cost, for same amount of production
Save on annual operating cost	(₩/year)	9,454,161		
Purewater production unit cost	(₩/m^3)	351	312	

The said production cost of pure water does not include energy and other UT costs, so the actual unit price may increase. It is compared with existing facilities, on the same conditions of resin amount and recycling; if the amount of resin is increased by utilizing the freeboard space above the existing resin tower, capacity will increase more than twice, and the operational cost saving will also increase.

■ Case Study4(Samyang Packed Bed System Set-up 2) -Construction Cost Evaluation

This is an example of operating cost evaluation for setting up a Samyang Packed Bed System.

Ⅰ) Feed water analysis

Ca^{2+}	1.00 meq/ ℓ	Cl^-	1.00 meq/ ℓ
Mg^{2+}	1.00 meq/ ℓ	SO_4^{2-}, etc	1.00 meq/ ℓ
Na^+ + K^+	1.00 meq/ ℓ	HCO_3^-	1.00 meq/ ℓ
Total Cations	3.00 meq/ ℓ	SiO_2	0.14 meq/ ℓ
※Total cations = TC		Total Anions	3.14 meq/ ℓ

Ⅱ) After Degasfier Anion

Cl^-	1.00 meq/ ℓ
SO_4^{2-}, etc	1.00 meq/ ℓ
HCO_3^-	0.20 meq/ ℓ
SiO_2	0.14 meq/ ℓ
TEA	2.34 meq/ ℓ

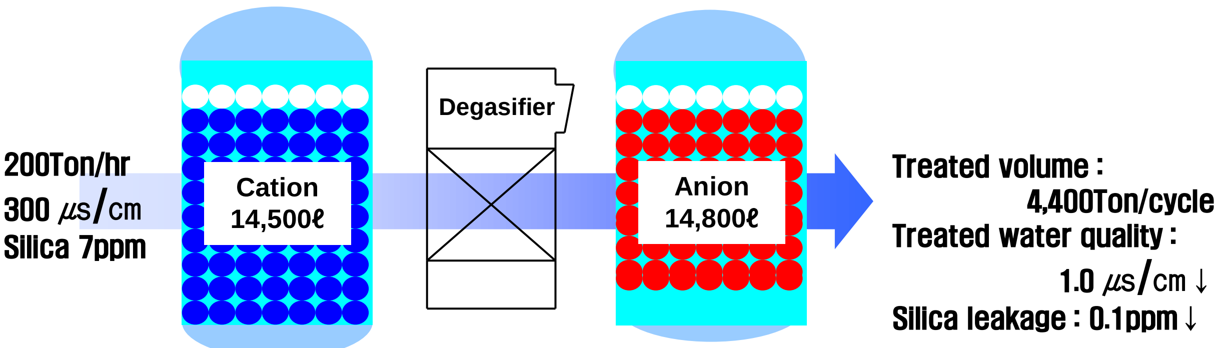
※FMA = 1.00 + 1.00 = 2.00meq/ ℓ , Cl / FMA%=50.0%
※Cl% = 1.00 / 2.34 = 42.7%
※Weak Acid = TEA – FMA = 2.34–2.00 = 0.34
※SiO_2% = 0.14 / 2.34 = 6.0%
※FMA / Weak Acids = 5.88

Ⅲ) Requirements

2B3T(2Bed 3Tower) system(Cation exchanger → degasifier → anion exchanger)
Flow Rate = 200 ㎥/hr, Running Time = 22hr
Operating Temperature = 15℃, Regeneration Temperature = 35℃
Required SiO_2 Leakage = 150ppb as SiO_2

Ⅳ) Cationic load(eq/cycle) = TC × 200 ㎥/hr × 22hrs = 13,200eq/cycle
Anionic load (eq/cycle) = TEA × 200 ㎥/hr × 22hrs = 10,296eq/cycle

Ⅴ) Cation exchange resin regeneration level = 50.0g as 100% HCl/ ℓ -R ,
Anion exchange resin regeneration level = 40.0g as 100% NaOH/ ℓ -R



Ⅵ) Equipment and Volume of Fillings

Equipment	Dimension	Filling Material	Volume	Reference
Cation exchanger	2,700 D x 2,875 H	TRILITE MC-08	14,500ℓ	Cation exchange resin
		TRILITE TR70	1,475ℓ	Inert resin
Anion exchanger	3,000 D x 2,900 H	TRILITE MA-20	14,800ℓ	Anion exchange resin
		TRILITE TR70	2,000ℓ	Inert resin

Ⅶ) Construction Cost

Description	Prices(₩)
1. Mechanical & Piping Part	**350,000,000**
Cation exchanger(SS41, Rubber lining)	
Anion exchanger(SS41, Rubber lining)	
Degasfier & tank(SS41, Rubber lining)	
HCl measuring tank	
NaOH measuring tank	
Fan blower	
Piping material & erection work	
Engineering & drawing	
2. Electric & Instrument Part	**180,000,000**
Instruments	
Automatic valves	
PLC panel	
MMI system	
Solenoid panel	
Installing work	
Engineering & drawing	
3. Filling Media	**100,000,000**
TRILITE MC1	
TRILITE MA2	
TRILITE TR70	
4. Overhead & Profit	**50,000,000**
Total amount	**680,000,000**

Note 1) Estimated amount may change if there is a sudden price fluctuation or exchange rate change.

Note 2) If there is a design change on your request, the amount of the quotation and the delivery date may change.

Note 3) The above quotation is a reference value; actual estimation may vary depending on the situation of the site.

Samyang Corporation, 31 Jong-ro 33-gil, Jongno-gu, Seoul, Korea Tel: (02)740-7732~7, Fax: (02)740-7140