Water
Industrial and Potable Water Treatment.

INDUSTRIAL AND POTABLE WATER TREATMENT

Water is one of the most versatile liquids in the world. It is used for human consumption, in households, as a solvent in the industry, for power generation, as cooling and cleaning agent, to purify microchips and flat screens, and many more.

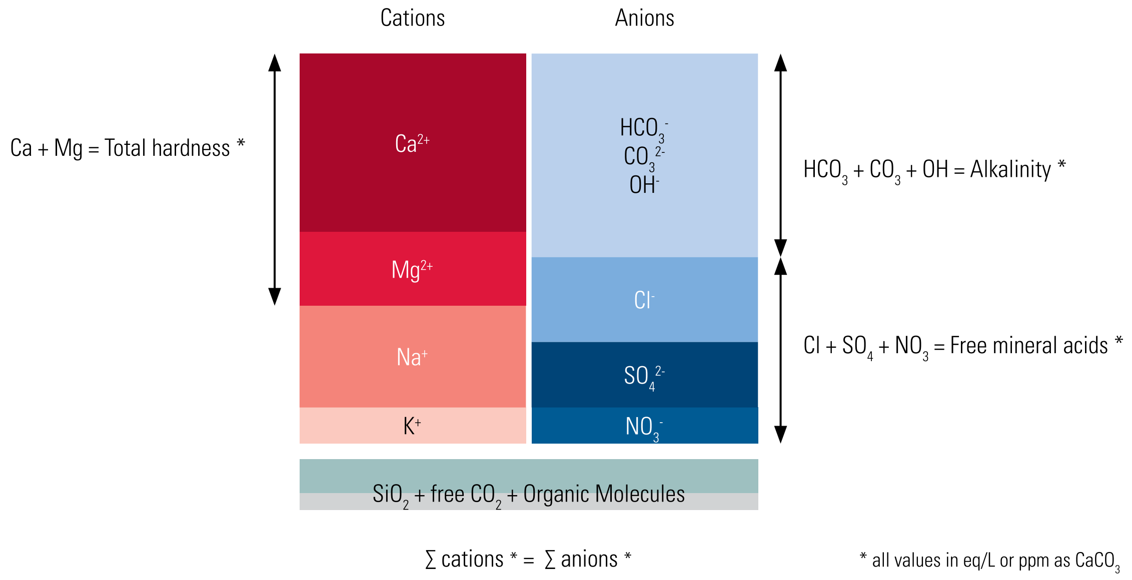
Natural water contains many contaminants which have to be removed to make it usable in different applications. Contaminants can be of natural origin or pollutants from human activity. Ion exchange resins, adsorbents and chelating resin can be used to remove some of the contaminants, particularly if they are ionic or larger organic molecules. Solids, colloids, and some large organic molecules can be trapped by filtration media.

Different applications require different water qualities. The following describes which methods can be applied for water purification or modification.

WATER COMPOSITION

In general, water may contain cationic, anionic, and neutral molecules. Depending on the usage of the water, these molecules must be removed or exchanged. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) are described as hardness leading to precipitates when heated. If they are balanced with HCO_3^- and CO_3^{2-} they are described as alkalinity or temporary hardness.

Depending on the application of the water different treatments are required.



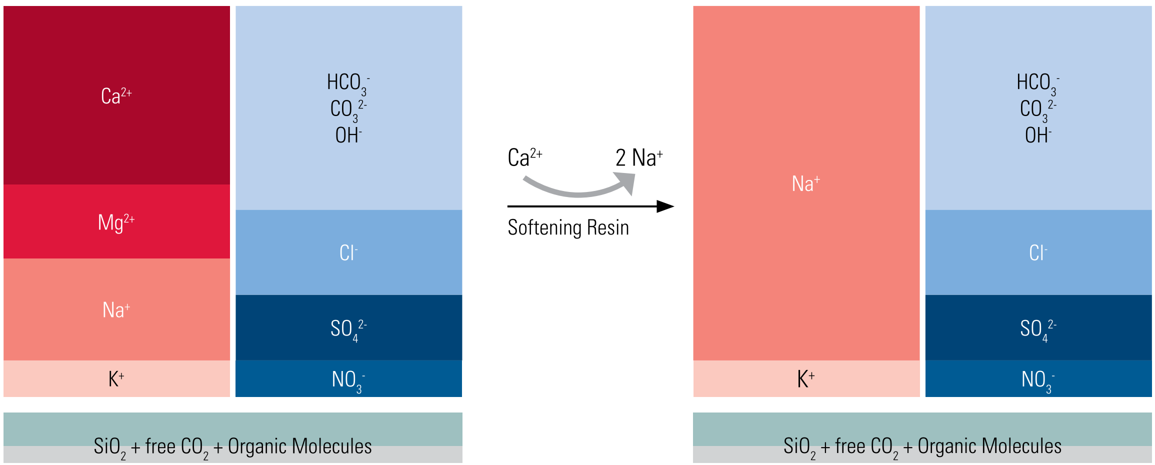
WATER TREATMENT PROCESSES

WATER SOFTENING

The following describes major water treatment methods and the major processes involving ion exchange resins, adsorbents and chelating resins.

Hard or alkaline water can lead to insoluble precipitation of Ca^{2+} and Mg^{2+} when heated. To avoid such precipitates the divalent ions Ca^{2+} and Mg^{2+} are usually exchanged for the monovalent ions Na^+ or K^+.

Water softening is often used when water is used for cleaning purposes in households, for industrial cleaning or low-pressure steam generators and low-pressure power plants. Regeneration is generally done with a 10% NaCl solution.



Water composition before and after softening

Depending on the application different ion exchange resins can be used [1]:

	Type	Trademark	Capacity [eq/L]	UC	Remarks
Industrial softening	SAC	TREVERLITE[2] IXC100/Na	≥ 1.9	≤ 1.6	Standard softening (also in UN particle size)
	SAC	TREVERLITE IXC120/Na	≥ 2.0	≤ 1.6	High performance resin for softening
	SAC	TREVERJET[2] IXC120/UN/Na	≥ 2.0	≤ 1.4	High performance resin for softening
	SAC	TREVERJET IXC1200/Na	≥ 2.0	≤ 1.2	High performance resin for softening, all type of systems
Household, potable water	SAC	TREVERLITE IXC110/Na	≥ 2.0	≤ 1.6	High performance resin for softening, co-current systems
	SAC	TREVERLITE IXC110/UN/Na	≥ 1.9	≤ 1.4	High performance and UN resin for softening, counter-current systems
	SAC	TREVERJET IXC1110/Na	≥ 2.0	≤ 1.2	High performance and high UN resin for softening, all type of systems

[1] for the complete product range refer to our brochure *Ion Exchange resins in Water treatment/CS-BRO-0005*
[2] TREVERLITE = standard particle size, TREVERJET = monodisperse

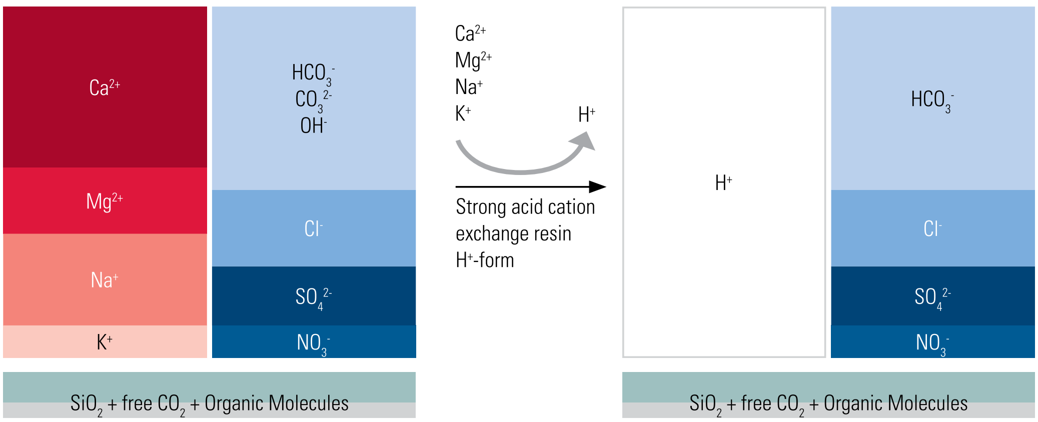
WATER DEMINERALISATION

Demineralisation means the removal of total dissolved solids (TDS) contained in water. This might be necessary because these minerals may cause problems in downstream applications and water purity levels required.

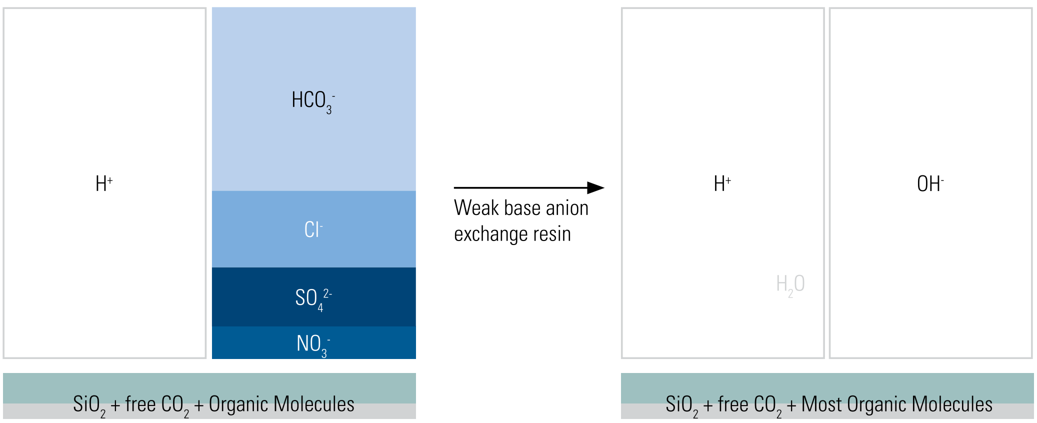
DEMINERALISATION OF PROCESS WATER

For process water the major cations and anions have to be removed. Depending on the process requirements anionic exchange can be made on a weak base and/or strong base resin.

In case of using water for processing of food, a specific range of food grade resins can be provided.

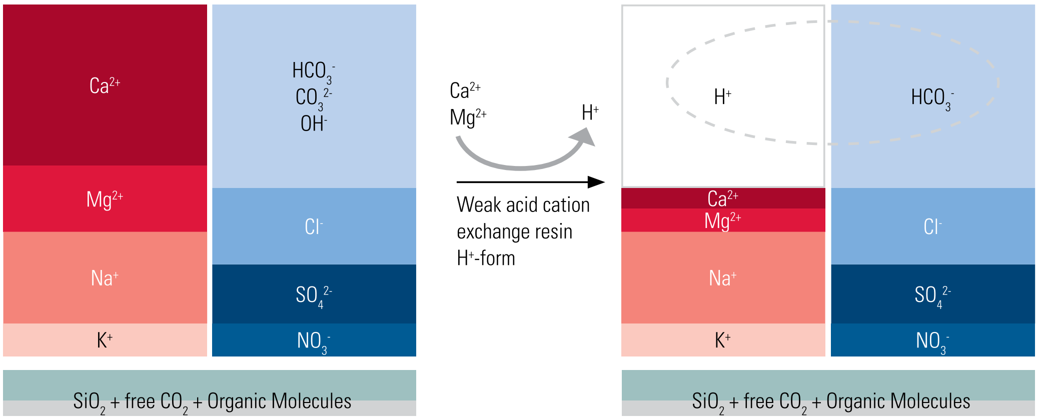


Cation exchange with a strongly acidic cation exchange resin



Anion exchange with a weak basic anion exchange resin

Some water contains a very high amount of temporary hardness. In modern plants the reduction of waste water is required. Therefore, the combination of a weakly acidic resin (which will remove temporary hardness) with a strongly acidic resin (to remove the remaining cations) can be advisable. The weakly acidic resin can be regenerated with a significantly lower amount of acid compared to a strongly acidic resin. These two resins could be in the same vessel in two layers (carbomix systems) or in separate compartments.



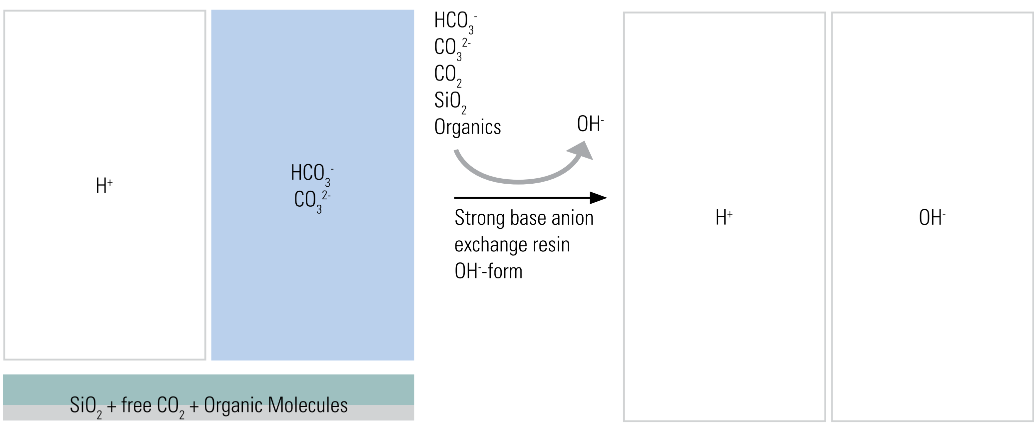
Hardness removal with a weakly acidic cation exchange resin (dealkalisation)

WATER FOR POWER PLANTS

Modern power plants which use high pressure boilers generally need highly purified water. Furthermore, frequent regeneration and the need for reduced water and chemicals consumption requires the combination of weakly/strongly acidic cation exchange resins with weakly/strongly basic anion exchange resins especially in large plants.

Besides mineral acids, strongly basic resins can also remove traces of silica, CO_2 and natural organic molecules. These can be degraded at elevated temperatures and can cause corrosion in a power plant. Depending on the required water quality, styrenic strong base anion Type 1 (trimethylamine) or Type 2 (dimethyl-ethanolamine) anionic resins are used. Type 1 resins have a higher basicity and can more efficiently remove Silica and organic substances. It should be noted that Type 1 resins will require more regenerants compared to Type 2 resins and are also subject to fouling. Water with high organic load can be efficiently treated with organic scavanger, upstream to the demineralisation unit.

Traces of organic and mineral impurities can be further removed to reach the highest water quality in polishing mixed beds consisting of high quality strong acid and strong basic resins. Such mixed beds are also polishing water after RO (reverse osmosis) plant for highest quality and resistivity.



Anion exchange with a strong base anion exchange resin after a weak base resin

Regeneration chemicals

The concentration of regeneration chemicals ranges between 0.5-6%. In situations when H_2SO_4 is used for regeneration the regeneration is done with a gradient between 0.5-6% to avoid the precipitation of gypsum ($CaSO_4$).

For detailed information about the regeneration chemicals and the required purity please check the CHEMRA technical guide *Regeneration of Chemicals/CS-TDS-0007*.

Selection of resins for water demineralisation [1)]

	Type	Trademark	Capacity [eq/L]	UC	Remarks
Organic scavanger	SBA	TREVERLITE SCA100	≥ 1.1	≤ 1.6	Styrenic, for raw water
	SBA	TREVERLITE SCA200	≥ 0.8	≤ 1.6	Acrylate, for raw water with high organic load
	SBA	TREVERLITE SCA300	≥ 0.6	≤ 1.6	Styrenic, for polishing
Cation removal	WAC	TREVERLITE IXC300/H	≥ 4,3	≤ 1,6	Weak acid for temporary hardness removal, dealkalinisation
	SAC	TREVERLITE IXC100/UN/Na TREVERLITE IXC100/UN/H	≥ 1,9 (Na^+)	≤ 1,4	Standard softening & demineralisation, counter-current systems
	SAC	TREVERJET IXC1200/Na TREVERJET IXC1200/H	≥ 2,0 (Na^+)	≤ 1,2	High performance softening & demineralisation, uniform for all systems and mixed bed
Anion removal	WBA	TREVERLITE IXA600/FB	≥ 1,4	≤ 1,6	Weak base anion for free mineral acid removal
	WBA	TREVERJET IXA6000/FB	≥ 1,4	≤ 1,6	Weak base anion for free mineral acid removal
	WBA	TREVERLITE IXA702/FB	≥ 1,4	≤ 1,6	Acrylic weak base anion for free mineral acid removal, high organic fouling resistant
Silica removal	Please refer for the complete product range to our brochure *Ion Exchange resins in Water treatment/CS-BRO-0005*				

CONDENSATE POLISHING

Condensate polishing is a process to maintain a proper water quality by removing impurities from the return feed to the boiler. It is required in the power industry for high pressure boilers both in fossil and nuclear power plants. Cations and anions have to be removed to very low levels to avoid corrosion of boiler tubes and deposits within the turbines. Cations and anions can come from water, corrosion and natural organics, but also from conditioning chemicals and their degradation products.

Principally strong acid cation and strong base anion resins are used. They can be gel type or macroporous. Gel type resins generally have a higher capacity, porous resins are physically more stable and less subject to organic fouling. The flow rates are in the range of 100-150 m/h. CHEMRA can supply cationic and anionic mixed bed resins for all kind of applications in condensate polishing.

Typical resins for condensate polishing [1)]

	Type	Trademark	Capacity [eq/L]	UC	Remarks
Cation removal	SAC mr	TREVERLITE IXC250/UN/H TREVERJET IXC2000/H	≥ 1.7 (H^+)	≤ 1.4	High cross linking resin, uniform and high strength
Anion and silica removal	SBA mr	TREVERJET IXA3050/SO_4 TREVERJET IXA3050/OH	≥ 1.4 (Cl^-)	≤ 1.2	Superior strength uniform particle size for mixed beds

ULTRAPURE WATER

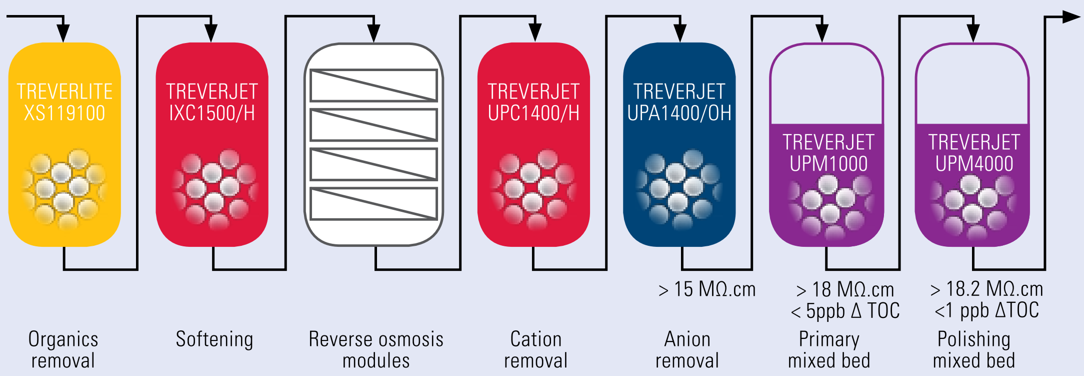
Ultrapure water (UPW) is treated to the highest level of purity for all contaminant types (e.g. organic and inorganic compounds, dissolved gases). It is required in laboratories and in the semiconductor industry as a solvent to prepare solutions and to clean surfaces.

Ionic and non-ionic contaminants can lead to defects in today's high performance integrated circuits. Therefore, the industry sets premium purity standards and requires very fast rinse profiles to reduce down times of the plant.

CHEMRA mixed bed resin for ultrapure water have been optimised for fast and short rinse. Boron removal is also an increasing requirement in this industry. CHEMRA offers an extensive range of products and its expertise to assist the end user in the phases of UPW production - from primary treatment to final polishing.

Typical resins for ultrapure water

	Type	Trademark	Capacity [eq/L]	UC	Remarks
Organic scavenger	SBA	TREVERLITE SCA300	≥ 0.6	≤ 1.6	Removal of organics
Boron removal	CHE	TREVERLITE CHE750	≥ 0.7	≤ 1.6	Removal of boron
Cation removal	SAC	TREVERJET IXC1500/H	≥ 2.0	≤ 1.2	High performance resin, uniform
	SAC	TREVERJET UPC1400/H	≥ 1.8	≤ 1.2	Ultrapure grade, low rinse, uniform
Anion removal	SBA	TREVERJET IXA1500/OH	≥ 1.0	≤ 1.2	High performance resin, uniform
	SBA	TREVERJET UPA1400/OH	≥ 1.0	≤ 1.1	Ultrapure grade, low rinse, uniform
Mixed bed	SAC/SBA	TREVERJET UPM1000		≤ 1.2	Ultrapure grade
	SAC/SBA	TREVERJET UPM4000		≤ 1.2	Ultrapure grade, highest purity, ready to use
	SAC/SBA	TREVERJET UPM4100		≤ 1.2	Ultrapure grade, highest purity, ready to use



The process flow shows the different involvement of ion exchange resins in the process of semiconductors – starting with a scavenger resin for the removal of organics, a softener to protect to RO plant, followed by a semiconductor grade clean strong acid and strong base resin.

The two following mixed bed filters with ultrapure grade resins are the last line of protection from trace of chemical contaminants. Silica and Boron are not well removed by membranes, but will be reduced below 1ppb on subsequent ion exchange resins.

POTABLE WATER

Meeting the increasing demand for high quality drinking water is one of today's challenges. More and more contaminants can be found in drinking water and have to be removed. Ion exchange resins and adsorbents have shown their ability to remove contaminants from drinking water to very low levels.

CHEMRAs wide portfolio of resins and adsorbents, along with their applications expertise, can assist you in addressing the most challenging drinking water quality directives. CHEMRA is able to provide the necessary technical support as well as offer solutions to minimise waste generation.

Nitrates (NO_3^-)

CHEMRA offers nitrate selective resins like TREVERLITE IXA810/Cl and a strong base anionic resin Type 1 like TREVERLITE IXA110/Cl – depending on the composition of the water to be treated, operating conditions and intended plant size. These anionic resins are supplied in chloride form and are regenerated with brine.

Natural Organic Matter (NOM)

Surface water contains many natural organic compounds, mainly humic acids. These are typically large molecules which can be trapped on specific macroporous strong base anionic resins such as TREVERLITE SCA100, TREVERLITE SCA300 (both styrenic) or TREVERLITE SCA200 (acrylic).

These resins work as "scavengers" to remove these acids or to "polish" the water, and can be regenerated with brine. Their high loading capacity allows for long cycles and reduces the overall environmental footprint.

Perchlorates (ClO_4^-)

Perchlorates are present in groundwater in many regions at concentrations above the regulated limits (6 ppb in USA, 10 ppb in Europe).

CHEMRA offers different treatment solutions depending on the local regulations. These resins can either be regenerable or "single-use". They are strong base anionic resins, with hydrophobic surface properties. The residual perchlorate concentrations after treatment can be below 1 ppb.

Boron $B(OH)_3$

Boron is naturally present in groundwater and seawater as boric acid $B(OH)_3$. Boron levels cannot exceed the recommended World Health Organization guideline of 0.5 ppm to be considered suitable for human consumption.

CHEMRA provides a simple and economical solution using TREVERLITE CHE751, a chelating resin with N-Methyl-D-glucamine functionality which selectively removes boron even in a high salt background. The regeneration can be performed in co-flow mode in two steps, and is regenerated using dilute acid followed by conversion using caustic soda.

Uranium (UO_2^{2+})

Uranium is a natural radionuclide generally present at trace levels in groundwater. It is typically found as anionic uranyl complexes. In several European regions groundwater exceeds the European guideline of 30 ppb as U (new water directive (EU) 2020/2184).

Strong base anionic resins or medium base anionic resins efficiently remove uranyl complexes with an efficiency of more than 99%. Removal efficiency depends on the concentration of background anions of the raw water. Maximum removal may be constrained by local regulatory limits for the allowable limit of uranium on the resin. Regeneration is possible, but most applications are "single-use, once through" to avoid the release of concentrated effluent in environment and drinking water. Disposal and transportation of spent resin is subject to local, state and federal regulations.

Chromium (Cr VI)

While trivalent chromium (Cr^{3+}) is not considered as harmful, hexavalent chromium (Cr^{6+}) is a carcinogen and emerging health concern with new European directive targeting a limit of less than 50 ppb today and 25 ppb in 2036. US EPA has fixed the maximum contaminant level (MCL) of total chromium at less than 100 ppb, with California even lower at 50 ppb.

CHEMRA offers TREVERLITE IXA110/Cl, a strong base anionic resin which can remove more than 99% of the chromium from raw water. This resin is regenerable. Operating conditions depend on the water composition and plant layout.

Bromide (Br^-)

Bromide is typically present in fresh water at trace level of 0.5 mg/L and near 1 mg/L in desalinated water. Bromide can be involved in the interaction between chlorine and Natural Organic Matter (NOM) forming toxic by-products such as trihalomethanes (THM), haloacetic acids (HAA5), or can react with ozone to form bromate.

CHEMRA offers selective and regenerable resins such as TREVERLITE XS145200 to remove traces of bromide to prevent the formation of these harmful and regulated compounds in drinking water.

Major water contaminants and typical ion exchange resins for their removal

	Type	Trademark	Capacity [eq/L]	UC	Remarks
Organic scavenger	SBA	TREVERLITE SCA300	≥ 0.6	≤ 1.6	Removal of organics
Boron	CHE	TREVERLITE CHE751	≥ 0.7	≤ 1.6	Removal of boron
Bromide	SBA	TREVERLITE XS145200	≥ 0.9	≤ 1.6	Removal of bromide
Nitrate	SBA	TREVERLITE IXA810/Cl	≥ 0.9	≤ 1.6	Selective removal of nitrate
Heavy metals	CHE	TREVERLITE CHE710/Na	≥ 2.5	≤ 1.6	Selective removal of heavy metals
Perchlorate	SBA	TREVERLITE XS133100	≥ 0.8	≤ 1.6	Selective to perchlorate
Uranium	WBA	TREVERLITE IXA720/FB	≥ 2.4	≤ 1.6	Uranyl removal, regenerable
	SBA	TREVERLITE IXA410/Cl	≥ 1.2	≤ 1.6	Uranyl removal, regenerable
Point of use	WAC	TREVERLITE IXC330/H	≥ 4.3	≤ 1.6	Ready to use, for small cartridges
	WAC	TREVERLITE IXC330/Mg	≥ 4.3	≤ 1.6	Ready to use, for small cartridges, partially in Mg form

GROUNDWATER AND SOIL REMEDIATION

Contamination of soil and groundwater with organic compounds and metals from either naturally occurring or man-made industrial (anthropogenic) sources is a matter of high concern for the public health. Ion exchange and adsorbent resins play an important role in the efficient remediation of these natural resources by selectively removing harmful contaminants which are often present at very low concentration.

Heavy Metals (Hg, Cu, Zn, Ni, Cd, Pb, Cr, …)

CHEMRA offers a range of chelating resins developed with a wide variety of functional groups for selective uptake of metals. The most useful type for soil remediation is IDA (iminodiacetic) resin with TREVERLITE CHE710/Na, and the AMP (aminophosphonic) resin TREVERLITE CHE720/Na.

To remediate pollution by mercury or cadmium, a thiol resin as TREVERLITE CHE730 removes those metals and is capable of reducing them to concentrations to below 10 ppb.

Per- and Polyfluorinated Compounds (PFAS) and Perchlorate

The family of synthetic compounds known as per- and polyfluoroalkyl substances (PFAS) is composed over >3000 PFAS used in several applications and products for more than 70 years, predominantly aqueous film forming foam used to in trainings to combat aviation fuel fires. These compounds are difficult to remove from water in traditional treatment. They are not biodegradable and, therefore, are persistent in the environment. They are a contaminant of high concern at ng/L levels in drinking water.

CHEMRAs TREVERLITE XS130800 (gel) and TREVERLITE XS133100 (macroporous) are available depending on the application, and are functionalised by a hydrophobic active site improving the selectivity of the resin towards halogenated contaminants over other competing anionic compounds in the water.

In some regions perchlorate is exceeding the threshold values. CHEMRA offers TREVERLITE XS133100 for this application.

Aromatic and/or Chlorinated Hydrocarbons

The increasing presence of organic pollutants (chlorinated compounds, pesticides, cleaning solvents) has led to an increase in global regulation and implementation of evermore efficient and cost-effective means of remediation of contaminated groundwater.

CHEMRA offers efficient alternatives to more commonly used adsorbents such as granular activated carbon (GAC). The product range covers a wide variety of polymer chemistries, surface areas, and pore sizes. Further, hydrophobic or hydrophilic surface activities are tailored for better adsorption and easy regeneration on site if necessary or for recycling purpose.

Adsorbents from the TREVERLITE ADS800 series, synthetic carbonaceous adsorbents, are very efficient for the removal of trace amounts of pesticides, chlorinated hydrocarbons, and solvents. TREVERSORB ADS100 has proven extremely efficient in the removal and recovery of phenolics and BTEX compounds from groundwater and in oil and gas applications.

ION EXCHANGE PLANT DESIGN

Operating mode

Depending on the layout, water treatment plants with ion exchange resins can be operated in down-flow and up flow mode. Most modern sophisticated demineralisation plants are regenerated in a counter current mode which means that loading the resins is done in a different flow direction than the regeneration. This allows a very efficient usage of the regenerants and is minimising the chemicals consumption thus reducing the CO_2 footprint of the process.

Taking all parameters of a unit into account, modern and efficient ion exchange plants can compete with reverse osmosis. This is particularly true when waste water disposal and fresh water consumption are important. The overall salinity of the water also plays a big role in deciding which technology is a better fit to the needs.

Large plants are mostly operated in a counter current mode. In this case the resin vessels are filled to a maximum to avoid dead space and inefficiency during regeneration. Depending on the ionic form resin are more or less swollen. This has to be considered when designing the resin columns. In general, weak acid and weak base resins are swelling more (up to 50%) compared to strong acid (5-10%) and strong base resins (15-25%). In many cases counter current operating columns use an inert resin, which has a low density and is floating above the ion exchange resin. It is protecting the filter nozzles of the column plate.

WASTE WATER

Industries like power generation, oil refining, chemical manufacturing, electroplating and mining have historically been sources of soil and water pollution. Their wastewaters and runoff can contain heavy metals and organic compounds which can pose long term health risks through pollution of rivers, lakes, groundwater and drinking water. Many of these pollutants can be removed or recovered by CHEMRAs ion exchange resins, adsorbents and applications knowledge.

Phenol

Polymeric adsorbents such as TREVERSORB ADS100 and TREVERSORB ADS150 are being used for the removal and recovery of phenolic compounds from wastewater. These adsorbents can reduce influent concentrations from 5,000 ppm down to less than 1 ppm in the effluent. If necessary, the phenol can be recovered using acetone.

Chlorinated Hydrocarbons (THM)

Chlorinated hydrocarbons can be removed from aqueous streams with synthetic carbonaceous adsorbents such as TREVERSORB ADS800 and ADS810. Single pass removal efficiencies of up to 99% are achievable at throughputs of up to 20 BV per hour, 4 to 5 times that of activated carbon. Regeneration is accomplished with steam.

BTX

Benzene, toluene and xylene (BTX) can be adsorbed on polymeric adsorbents such as TREVERSORB ADS100 and TREVERSORB ADS150. These products have loading capacities of more than 30 g/L.

Contaminated waters with an inlet concentration of 300 ppm BTX can cleaned to 1 ppm in the effluent. In-situ regeneration with either solvents or steam allow for an effective treatment of wastewater, e.g. in oil or gas field applications.

Metals (Fe, Cu, Hg, Cd, Pl, Ni, Zn,…) and Cyanides

Most effluents containing heavy metals are treated with classical methods such as flocculation and sedimentation. Divalent ion selective chelating resins such as TREVERLITE CHE710/Na (in the sodium form) have a very high affinity to many metals and are currently used for the polishing of wastewater. These materials allow the removal of heavy metals below the required regulatory limits.

Cyanides in the effluents of plating or mining operations can be easily removed using a weak base or strong base anionic resin.

CO- AND COUNTER CURRENT OPERATING SYSTEMS

In the following, standard types of softeners and demineralisers with TREVERLITE and TREVERJET ion exchange resins are described. Depending on the plant size and water composition many different plant variations are possible.

WATER SOFTENING WITH CO- AND COUNTER-CURRENT REGENERATED COLUMNS

Fig. 1 shows a co-current operated water softener and Fig. 2 a counter current operated softener. Notice the inert resin (INR100) on top of the cationic resin in the counter current model.

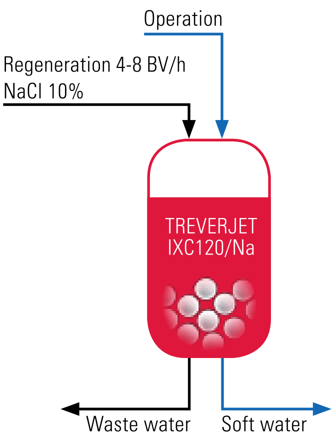


Fig. 1 Water softener with co-current operational modes.

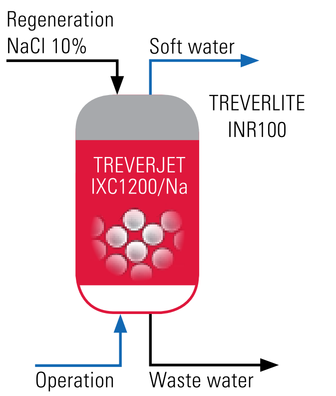


Fig. 2 Water softener with counter-current operational modes.

WATER DEMINERALISATION WITH COUNTER-CURRENT REGENERATED COLUMNS

Most modern demineralisation plants use a counter-current flow. These plants produce higher quality water by using the regeneration chemicals more efficiently and need less service water compared to the more simple co-current operating plants.

Many modern ion exchange plants operate in the upflow loading and downflow regeneration mode. Long term experience has shown that the upflow mode of an ion exchange plant has a lower tolerance for suspended solids (TSS). Furthermore, the upflow introduction of regenerants is a better displacement of the lighter water by the heavier chemicals than it is if the chemicals are introduced from above and causes the lighter water to "float" past the chemicals that are introduced from above.

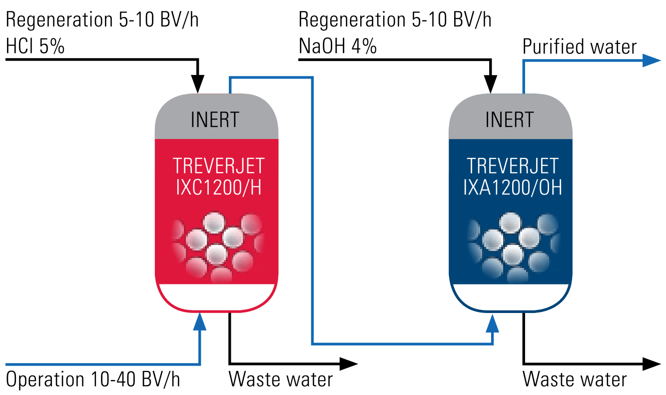


Fig. 3 Water demineralisation with strong acid and strong basic resins counter-current upflow mode

Figures 4 and 5 describe a plant which is upflow operated and downflow regenerated. The resin beds are separated in chambers which have a nozzles plate on top and on the bottom. The filter nozzles can be protected against clogging by a thin layer of inert material (TREVERLITE INR100) which is floating on top of the resin (see Fig. 4 for the cation exchangers – TREVERJET 1200/H and TREVERLITE IXC300/H).

In some cases inert material is not used (Fig. 5). The advantage of such a compact system (Schwebebett™ of Lanxess, Amberpack™ of Dupont) is that each resin can be exchanged at the end of its lifecycle. Furthermore, each chamber can be separately cleaned in case of a pressure drop problem or channelling. This kind of layout is very robust in operation. For more information on TREVER®PACK please contact CHEMRA.

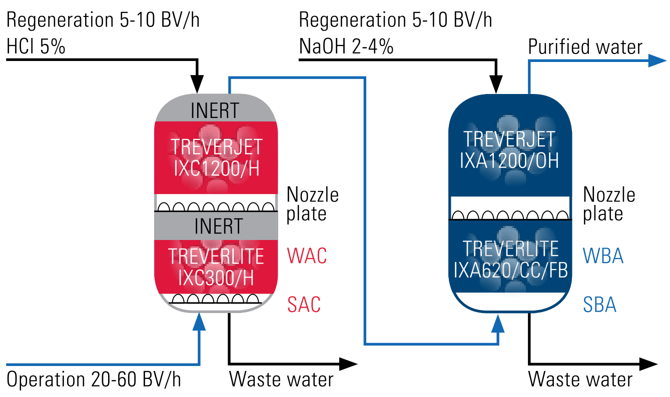


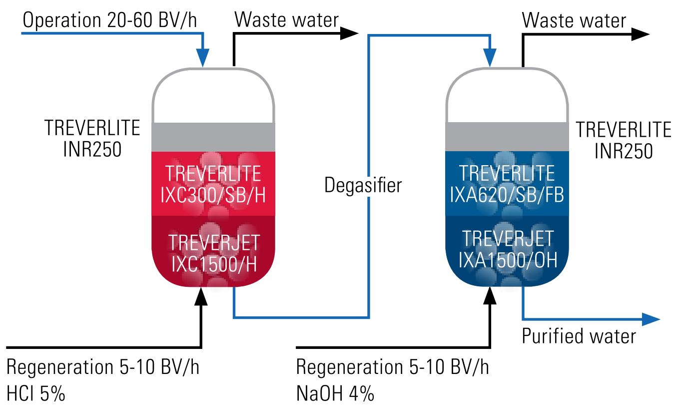
Fig. 4 Water demineralisation with weak and strong acid resins counter-current upflow model

Fig. 5 Water demineralisation with weak and strong basic resins counter-current upflow model

In case of high alkalinity, CO_2 is removed by a degasifier to reduce the ionic load on the anionic resins. The figure on the right shows a counter current regenerated plant which is operated downflow and regenerated upflow. The weak and strong acid resins and the weak and strong basic resins are in the same chamber and are kept separated through difference in particle size and density (stratified bed).

Downflow operation has the advantage of greater operating flexibly, eliminating the need for recycling streams to maintain bed compaction.

For safety and economical reason, H_2SO_4 may be preferred to HCl. In such cases, regeneration of cationic resins are repeated in two steps in accordance with the hardness in raw water, to avoid precipitation of gypsum ($CaSO_4$).



Water demineralisation with weak and strong acid and weak and strong basic resins in downflow operation and upflow regeneration including degasifier

CHEMRA provides three different types of inert resins:

- TREVERLITE INR100 for upflow operated plants (Amberpack™ [1]), Schwebebett™ [2]....)
- TREVERLITE INR200 for mixed beds (Triobed™ [1])....)
- TREVERLITE INR250 for downflow operated plants (UPCORE™ [1]))

[1]) Trademark of Dupont
[2]) Trademark of Lanxess

MIXED BED OPERATIONS

In water demineralisation plants, a polishing mixed bed can be used following a first step of ion exchange resins or reverse osmosis membranes primary unit to achieve higher water quality. Generally, the mixed bed consists of strong acid cationic and strong basic anionic resins, they can be gel or macroporous type. They are generally regenerated in the same column they are operated in. In some cases, external regeneration is done for easier and safer operations.

Mixed beds could also be used as working mixed beds when the inlet water is clean enough to allow a long cycle, for a low demand or simple systems.

The figures below show the 2 different types of mixed beds. Fig. 6 shows a mixed bed without inert resin, the column in Fig. 7 shows a mixed bed with inert to allow a better separation of cationic and anionic resins. The mixed bed in Fig. 6 is in the operation mode, in Fig. 7 in regeneration.

Both systems are widely used. The system without inert needs high performing and optimised resins which allow a good in situ separation during a long lifetime such as TREVERJET IXC1500/H and TREVERJET IXA1500/Cl. In condensate polishing external regeneration is often selected due to a lower investment, easier regeneration and lower conductivity. In this case two or three mixed bed columns are installed and the resins are removed for external regeneration.

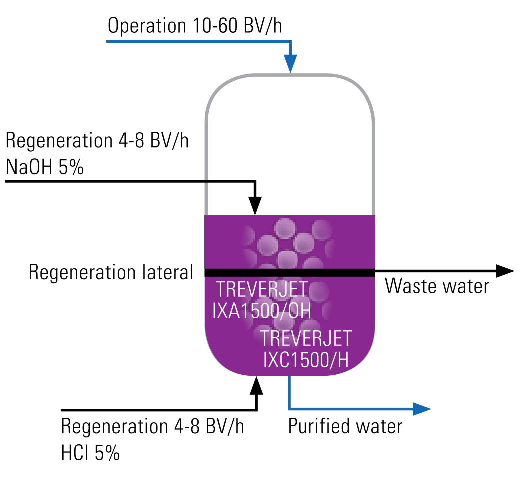


Fig. 6 Mixed bed column without inert resin

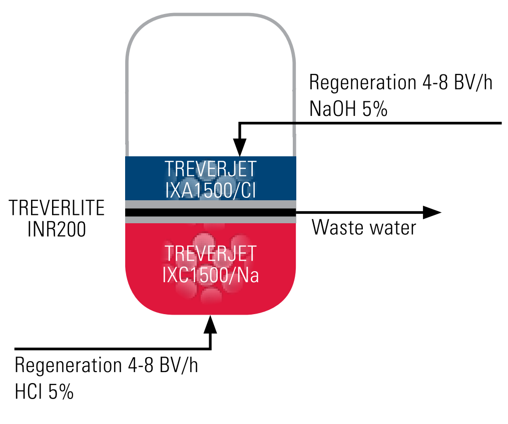
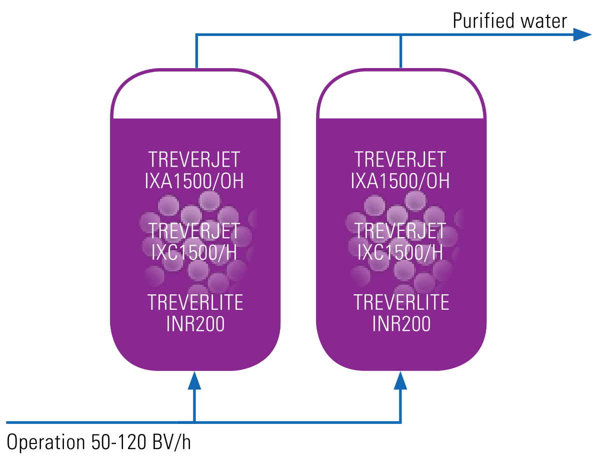
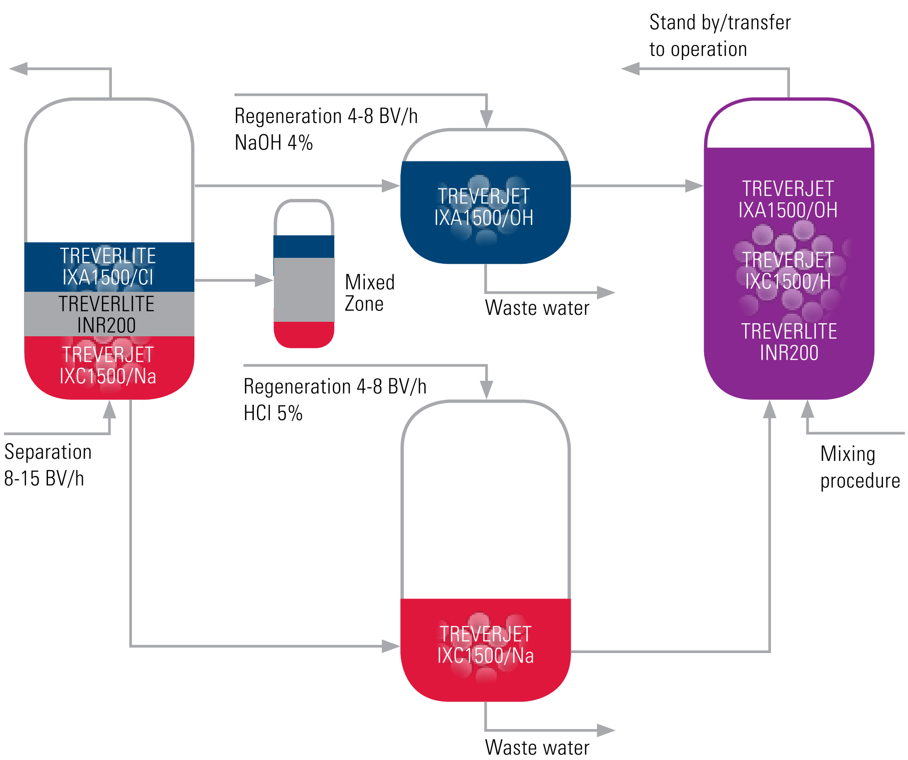


Fig. 7 Mixed bed column with inert resin



Mixed bed in condensate polishing with external regeneration. The different resins are mixed during operation and are well separated during regeneration.



CHEMRA supplies ready to use mixed beds for all kind of operations or separate cationic or anionic resins for mixed bed operations, both gel and macroporous type. The resin choice depends on the quality target and raw water to purify.

TECHNICAL SERVICE

Trouble shooting

Poor water quality and reduced water throughput can have many different reasons.

If an operational problem occurs in an ion exchange plant, our team of experts offers an initial check by telephone. Step by step, control measures can be carried out on the failing running system.

In most cases, the problems are not directly related to the use of resins. In case of doubt, however, a resin analysis can be carried out in our laboratory. A report shows possible errors and offers potential solutions.

Laboratory test

For special water applications, such as the removal of impurities or organics, CHEMRA offers a column and pilot testing service to validate the right choice of resin and define the best operating parameters, including regeneration and plant design.

Laboratory analysis

Ion exchange resins are very stable over time and can perform many cycles with consistent results. However, some substances in the feed water may suddenly affect the performance by fouling or oxidizing the resin.

CHEMRA recommends monitoring the key resin parameters of the resins on site to determine the nature of the problem and potential solutions.

Our standard report compares these parameters to the specifications of the resins, such as optical appearance, total exchange capacity, moisture holding capacity, swelling, presence and type of visible fouling or internal precipitates (iron, oil, gypsum, natural organics and others).

Our first recommendations can be supported by further analysis.

Plant Design

For new projects, CHEMRA reviews water conditions and targets and make recommendations for resin selection, plant layout, vessel design, and operating conditions (e.g. flow rate, cycle time, regenerant ratio)

The same service applies to replacing resins with the aim of saving costs, improving quality or extending the life of the resins. In this case, an on-site audit might be advisable.

In some cases, the composition of the water may change over time, requiring an adjustment to the operating conditions of the plant and/or the choice of resin. CHEMRA helps to recalculate the system and its parameters.

Warranties

CHEMRA warranties that the ion exchange resins and adsorbents will meet the specifications.

The resins will have a long service life as long as they are stored in good condition before use and are used within the recommended operating conditions.

Typical operating conditions and their limits such as temperature, flow rate, pressure drop, oxidant content, water composition, or regenerant quality can be provided on request.

The plant design is valid within the recommended range of operating conditions. For better performance check with TREVER®CALC, CHEMRAs newly developed simulation software.

CONVERSION TABLES [1)]

REGENERATION DATA

Sulfuric Acid

% H_2SO_4	Grams H_2SO_4/L	Normality	Specific gravity	°Baumé	Pounds/U.S. gallon
1	10.05	0.205	1.0051	0.7	0.08388
2	20.24	0.413	1.0118	1.7	0.1689
3	30.55	0.623	1.0184	2.6	0.2550
4	41.00	0.836	1.0250	3.5	0.3422
5	51.59	1.05	1.0317	4.5	0.4305
6	62.31	1.27	1.0385	5.4	0.5200
8	84.18	1.72	1.0522	7.2	0.7025
10	106.6	2.17	1.0661	9.0	0.8897
12	129.6	2.64	1.0802	10.8	1.082
15	165.3	3.37	1.102	13.4	1.379
20	227.9	4.65	1.1394	17.7	1.902
50	697.6	14.2	1.3951	41.1	5.821
96	1762.0	35.9	1.8355	66.0	14.71
100	1831.0	37.3	1.8305	65.8	15.28

Hydrochloric acid

% HCl	Grams HCl/L	Normality	Specific gravity	°Baumé	Pounds/U.S. gallon
1	10.03	0.275	1.0032	0.5	0.08372
2	20.16	0.553	1.0082	1.2	0.1683
4	40.72	1.12	1.0181	2.6	0.3399
6	61.67	1.69	1.0279	3.9	0.5147
8	83.01	2.28	1.0376	5.3	0.6927
10	104.7	2.87	1.0474	6.6	0.8741
12	126.9	3.48	1.0574	7.9	1.059
16	172.4	4.73	1.0776	10.4	1.439
20	219.6	6.02	1.0980	12.9	1.833
30	344.8	9.46	1.1492	18.8	2.877
40	479.2	13.1	1.1980	24.0	3.999

Sodium Hydroxide

% NaOH	Grams NaOH/L	Normality	Specific gravity	°Baumé	Pounds/U.S. gallon
1	10.1	0.262	1.0095	1.4	0.08425
2	20.41	0.511	1.0207	2.9	0.1704
3	30.95	0.774	1.0318	4.5	0.2583
4	41.71	1.04	1.0428	6.0	0.3481
5	52.69	1.32	1.0538	7.4	0.4397
6	63.89	1.60	1.0648	8.8	0.5332
8	86.95	2.17	1.0869	11.6	0.7256
10	110.9	2.77	1.1089	14.2	0.9254
12	135.7	3.39	1.1309	16.8	1.333
16	188.0	4.70	1.1751	21.6	1.569
20	243.8	6.10	1.2191	26.1	2.035
50	762.7	19.1	1.5253	49.9	6.365

Ammonia

% NH_3	Grams NH_3/L	Normality	Specific gravity	°Baumé	Pounds/U.S. gallon
1	9.939	0.583	0.9939	10.9	0.08294
2	19.79	1.16	0.9895	11.5	0.1652
4	39.24	2.31	0.9811	12.7	0.3275
6	58.38	3.43	0.9730	13.9	0.4872
8	77.21	4.53	0.9651	15.1	0.6443
10	95.75	5.62	0.9575	16.2	0.7991
12	114.0	6.70	0.9501	17.3	0.9515
16	149.8	8.79	0.9362	19.5	1.250
20	184.6	10.8	0.9229	21.7	1.540
30	267.6	17.0	0.8920	27.0	2.233

Sodium chloride

% NaCl	Grams NaCl/L	Normality	Specific gravity	°Baumé	Pounds/U.S. gallon
1	10.05	1.0053	0.8	0.0839	0.08372
2	20.25	1.0125	1.8	0.169	0.1683
4	41.07	1.0268	3.8	0.3428	0.3399
6	62.48	1.0413	5.8	0.5214	0.5147
8	84.47	1.0559	7.7	0.705	0.6927
10	107.1	1.0707	9.6	0.8935	0.8741
12	130.3	1.0857	11.5	1.087	1.059
16	178.6	1.1162	15.1	1.49	1.439
20	229.6	1.1478	18.7	1.916	1.833
26	311.3	1.1972	23.9	2.598	2.877

CONVERSION FACTORS IN ION EXCHANGE CALCULATIONS

To convert from	to	multiply by
Bed volumes/hr	gallons/min/ft^3	0.1247
Bed volumes/min	gallons/min/ft^3	7.481
Centimeters	inches	0.3937
cm^2	ft^2	0.001076
cm^3	ft^3	3.5314 x 10-5
cm^3	gallons (U.S.)	2.6417 x 10-4
Equivalents/L	kilograins/ft^3 as $CaCO_2$	21.85
Feet (U.S.)	centimeters	30.48
Feet (U.S.)	meters	0.3048
Feet of water	pounds/in^2.	0.43352
Feet of water	inches of mercury	0.88265
Feet/min	cm/sec	0.508
ft^2	cm^2	929.034
ft^3 (U.S.)	gallons	7.481
ft^3 (U.S.)	liters	28.316
Gallons (U.S.)	ft^3	0.13368
Gallons (U.S.)	cm^3	3785
Gallons (U.S.)	m^3	0.0037854
Gallons (U.S.)	gallons (Imperial)	0.83268
Gallons (U.S.)	liters	3.78533
Gallons (U.S.)/min	ft^3/hour	8.0208
Gallons (U.S.)/min	liters/sec.	0.06308
Gallons/min/ft^2	gallons/min/ft^3	1/bed depth in ft.
Gallons/min/ft^2	ml/min/cm^2	4.074
Gallons/min/ft^3	bed volumes/hr	8.02
Gallons/min/ft^3	liters/hr/L	8.02
Gallons/min/ft^3	bed volumes/min	0.1336
Gallons/min/ft^3	liters/min/L	0.1336
Grains	grams	0.0648
Grains	pounds (avoirdupois)	1/7000
Grains ft^3 as $CaCO_2$	equivalents/L	4.573 x 10-5
Grains/gallon (U.S.)	parts per million (ppm)	17.118
Grains/gallon as $CaCO_3$	normality	3.42 x 10-4
Grams	grains	15.4324
Grams	pounds (avoirdupois)	0.0022
Grams CaO/L	kilograins $CaCO_2$/ft^3	0.78
Grams CaO/L	Kilograins $CaCO_3$/ft^3	0.78
Grams/c.c.	pounds/ft^3	62.43
Grams/c.c.	pounds/gallon (U.S.)	8.3454
Grams/L	grains/gallon (U.S.)	58.417

To convert from	to	multiply by
Grams/L	parts per million	1000
Grams/L	pounds per ft^3	0.06243
Inches (U.S.)	centimeters	2.54
in^2	ft^2	0.006944
in^2 (U.S.)	cm^2	6.4516
Kilograins/ft^3 as $CaCO_3$	equivalents/L	0.0458
Kilograins/ft^3 as $CaCO_3$	gms CaO/L	1.28
Kilograms	grains	15432.4
Kilograms	pounds (avoirdupois)	2.2046
Kilograms/m^3	pounds/ft^3	0.06243
Kiloliters	ft^3	35.317
Kiloliters	gallons (U.S., liquid)	264.18
Liters	ft^3	0.0353
Liters	gallons (U.S.)	0.2642
Liters/hr/L	gallons/min/ft^3	0.1247
Liters/min/L	gallons/min/ft^3	7.481
m^3	ft^3 (U.S.)	35.3144
m^3	gallons (U.S.)	264.173
Meters	feet (U.S.)	3.281
Meters	inches (U.S.)	39.37
Meters/hr	gpm/ft^2	0.409
Milliequivalents/ml	grains/ft^3	21.85
Milliequivalents/ml	kilograins/ft^3	21.85
Milligrams	grains	0.01543
Milligrams	pounds (avoirdupois)	2.2046 x 10-6
Milligrams/L	ppm	1.0
Milligrams/L as $CaCo_3$	equivalents/L	2 x 10-5
ml/hr/ml	gallons/min/ft^3	0.1247
ml/min/ml	gallons/min/ft^3	7.481
Normality	grains/gal. (U.S.) as $CaCO_3$	2923.2
Parts per million (ppm)	grains/gallon (U.S.)	0.0584
Parts per million (ppm)	ppm as $CaCO_3$	50/equiv.wt.
Pounds (avoirdupois)	grains	7000
Pounds (avoirdupois)	grams	453.592
Pounds (avoirdupois)	kilograms	0.4536
Pounds/ft^3	grams/L	16.02
Pounds/ft^3	grams/ml	0.01602
Pounds/gallon (U.S.)	grams/c.c.	0.1198
Pounds/in^2	atmospheres	0.06804
Pounds/in^2	kg/m^2	703.1

CONVERSION MESH SIZE OF SIEVE OPENINGS

US mesh no.	10	12	14	16	18	20	25	30	35	40	45	50	60	70	80
mm	2.000	1.700	1.400	1.180	1.000	0.850	0.710	0.600	0.500	0.425	0.355	0.300	0.250	0.212	0.180
µm	2000	1700	1400	1180	1000	850	71	600	500	425	355	300	250	212	180

US mesh no.	100	120	140	170	200	230	270	325	400
mm	0.150	0.125	0.106	0.090	0.075	0.063	0.053	0.045	0.038
µm	150	125	106	90	75	63	53	45	38

[1)] The information and data presented are believed to be accurate. However all information is without guarantee of correctness and completeness.

EQUIVALENTS

Cations

Cation	Symbol	Atomic weight	Equivalent weight	To convert ppm as ion to ppm as $CaCO_3$, multiply by	To convert mg/L to meq/L divide by
Hydrogen	H^+	1.0	1.0		
Ammonium	NH_4^+	18.0	18.0	2.78	18
Sodium	Na^+	23.0	23.0	2.18	23
Potassium	K^+	39.1	39.1	1.28	39
Magnesium	Mg^{++}	24.3	12.15	4.10	12
Calcium	Ca^{++}	40.1	20.04	2.49	20
Ferrous	Fe^{++}	55.85	27.9	1.79	28
Cupric	Cu^{++}	63.54	31.77	1.57	32
Zinc	Zn^{++}	65.4	32.7	1.53	32.7
Aluminum	Al^{+++}	27.0	9.0	5.55	9
Chromic	Cr^{+++}	52.0	17.3	2.89	17.3
Ferric	Fe^{+++}	55.85	18.6	2.69	18.6

Anions

Anion	Symbol	Atomic weight	Equivalent weight	To convert ppm as ion to ppm as $CaCO_3$, multiply by	To convert mg/L to meq/L divide by
Hydroxide	OH^-	17.0	17.0		
Chloride	Cl^-	35.5	35.5	1.41	35.5
Bicarbonate	HCO_3^-	61.0	61.0	0.82	6
Nitrate	NO_3^-	62.0	62.0	0.81	62
Silicate	$HSiO_3^-$	77.1	77.1	0.65	77
Bisulfate	HSO_4^-	97.1	97.1	0.52	97
Carbonate	CO_3^{--}	60.0	30.0	1.67	30
Silicate	SiO_3^{--}	76.1	38.0	1.31	38
Sulfate	SO_4^{--}	96.1	48.0	1.04	48
	CO_2	44.0	22.0	1.14	
	SiO_2	60.1	60.1	0.83	

CONCENTRATION CONVERSION FACTORS

	U.S./Brit. ppm as $CaCO_3$	U.S. grains/gal. as $CaCO_3$	Brit. grains/gal. as $CaCO_3$ 1)
U.S./Brit., ppm as $CaCO_3$	1	0.0584	0.070
U.S., grains/gal., as $CaCO_3$	17.118	1	0.201
Brit., grains/gal., as $CaCO_3$ 1)	14.28	0.833	1
French degrees	10	0.584	0.700
German degrees	17.85	1.042	1.25
International, meq/l	50	2.923	3.5

	French degrees	German degrees	International meq/litre
U.S./Brit., ppm as $CaCO_3$	0.1	0.056	0.02
U.S., grains/gal., as $CaCO_3$	1.712	0.959	0.342
Brit., grains/gal., as $CaCO_3$ 1)	1.428	0.800	0.286
French degrees	1	0.56	0.2
German degrees	1.785	1	0.357
International, meq/l	5	2.8	1

1 French degree = 10 ppm, as $CaCO_3$
1 German degree = 10 ppm, as CaO

SPECIFIC CONDUCTIVITY AND RESISTIVITY OF APPROXIMATE DISSOLVED SOLIDS CONTENT IN WATER

Conductivity (µS/cm @ 25°C (77°F))	10 Resistivity (ohm-cm @ 25°C (77°F))	Dissolved solids (ppm)
0.055	18 300 000	0
0.056	18 000 000	0.00042
0.063	16 000 000	0.00363
0.071	14 000 000	0.00776
0.083	12 000 000	0.0133
0.100	10 000 000	0.0210
0.125	8 000 000	0.0325
0.167	6 000 000	0.052
0.2	5 000 000	0.067
0.25	4 000 000	0.090
0.5	2 000 000	0.206
1	1 000 000	0.44
2	500 000	0.90
4	250 000	1.8
6	166 667	2.7
8	125 000	3.7
10	100 000	4.6
12	83 333	5.5
14	71 428	6.4
16	62 500	7.4
18	55 555	8.3
20	50 000	9.2
22	45 454	10.1
24	41 666	11
26	38 461	12
28	35 714	13
30	33 333	14
40	25 000	19
50	20 000	23
60	16 667	28
70	14 286	32
80	12 500	37
100	10 000	47
120	8 333	57
140	7 143	66
160	6 250	75
180	5 555	85
200	5 000	91
250	4 000	117
300	3 333	140
400	2 500	190
500	2 000	237
600	1 667	288
700	1 429	341
800	1 250	391
900	1 111	445
1 000	1 000	495
1 500	667	747
2 000	500	1 000
3 000	333	1 520
4 000	250	2 065
5 000	200	2 650
6 000	167	3 150
7 000	143	3 756
8 000	125	4 270
9 000	111	4 850
10 000	100	5 400
20 000	50	10 800

ppm of dissolved solids are expressed as ppm or mg/L of sodium chloride.
To convert into ppm or mg/L as $CaCO_3$ multiply NaCl value by 0.856.

SPECIFIC CONDUCTIVITY VS CONCENTRATION OF DIFFERENT ELECTROLYTES IN DEIONISED WATER

Conductivity is expressed in µS/cm at 25°C (77°F)

Weight %	ppm mg/L	Sodium Chloride NaCl	Sodium Hydroxide NaOH	Hydrochlorid Acid HCl	Sulfuric Acid H_2SO_4	Nitric Acid HNO_3	Hydrofluoric Acid HF
0.0001	1	2.2	6.2	11.7	8.8	6.8	10
0.0003	3	6.5	18.4	35.0	26.1	20	30
0.001	10	21.4	61.1	116	85.6	67	98
0.003	30	64	182	340	251	199	290
0.01	100	210	603	1 140	805	657	630
0.03	300	617	1 780	3 390	2 180	1 950	1 490
0.1	1 000	1 990	5 820	11 100	6 350	6 380	2 420
0.3	3 000	5 690	16 200	32 200	15 800	18 900	5 100
1.0	10 000	17 600	53 200	103 000	48 500	60 000	11 700
3.0	rarely used	48 600	144 000	283 000	141 000	172 000	34 700
5.0	rarely used	78 300	223 000	432 000	237 000	275 000	62 000
10.0	rarely used	140 000	258 000	709 000	427 000	498 000	118 000
20.0	rarely used	226 000	414 000	850 000	709 000	763 000	232 300
30.0	rarely used	saturated	292 000	732 000	828 000	861 000	390 000
40.0	rarely used	saturated	191 000	saturated	770 000	820 000	N/A
50.0	rarely used	saturated	150 000	saturated	620 000	717 000	N/A
75.0	rarely used	saturated	saturated	saturated	182 000	340 000	7.8 (0°C)
100.0	rarely used	saturated	saturated	saturated	10 000	50 000	4 (0°C)
Point of max. solubility	–	26%	about 50%	37%	–	–	–
Point(s) of max. conductivity	–	26%	16%	18.5%	31% 92.5%	31%	about 35%
Max. conductivity (@) HAc data at 18°C	–	244 000	412 000	852 000	830 000 139 000	862 000	N/A

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For the address of your nearest local sales office please visit our website.

Governmental regulations vary from country to country. Please seek advice from your local representative in order to determine the best resin choice and operating conditions. Food grade resins often require specific and extended certifications.

Operating conditions refer to the use of the product under normal operating conditions. They are based on experience in industrial applications. However, additional data are needed to calculate the resin volumes for larger plants. For more questions please contact our technical experts.

Ion exchange polymers and adsorbents are generally of industrial grade and impure except otherwise stated by CHEMRA™. Chemicals and gases must be handled with care and by trained personal, regulatory requirements and safety standards must be met. Oxidative chemicals like nitric acid or peroxides can be explosive in combination with ion exchange polymers and adsorbents, others can be corrosive. Rewetted dry polymers develop heat and expand significantly. CHEMRA makes no warranties either expressed or implied as to the accuracy or appropriateness of this information and technical advice – whether given verbal, in writing or by way of trials – is given in good faith and expressively excludes any liability upon CHEMRA arising out of its use. Our recommendations cannot be seen as recommending the use of the product in violation of any patent or license. We recommend that the prospective users determine for themselves the suitability of CHEMRA materials and suggestions for any use prior to their adoption. Specifications might be subject to change without further notice. Materials safety data sheets and handling methods are available on request.

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