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Voltea's Technical Bulletin

CapDI Ion removal comparison

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Introduction

Voltea's Capacitive Deionization (CapDI) technology is tunable water deionization technology designed to remove dissolved salts from a variety of water sources ranging from tap water and brackish groundwater to industrial process water. CapDI can be tailored to the flow capacity required for the application while maintaining high water recovery percentages (up to 95%). This is an electrochemical process that works by removing ions from water and storing them in capacitive electrodes. The removal mechanism is achieved by applying a potential across the electrodes, attracting any charged species in the water to their respective oppositely charged electrode where they are temporarily stored. Regeneration of these electrodes upon reaching maximum storage capacity is simply accomplished by reversing the polarity over the electrodes, which avoids the need for chemical or salt regeneration commonly required in traditional water treatment systems (e.g. Softeners).

In the CapDI cell, ions move according to the applied electric field based on their specific physical properties. These include ionic size, valence, charge density and solvation enthalpy, which determine how easily these ions can be attracted to the electrodes within the cell. The below table outlines the relative ease that ions are removed when compared to 'Average Conductivity Reduction' (ACR), which is defined as the average reduction in feed conductivity or TDS that is achieved by CapDI technology and determined by the system settings. The system settings are application-specific and predetermined based on the feed water quality, recovery and removal targets.   For example, divalent ions such as Calcium and Magnesium are removed at a higher rate inside the CapDI cell than monovalent ions like Sodium and Chlorides over the same period of time. As all ions contribute to conductivity, this parameter can be used as a measure for the average change in ion concentration at any point in time. The information gathered here is representative of Voltea's own field and laboratory experience in operating CapDI systems and collecting data over the years at various project sites.

Due to the complexity of various water types and chemistry compositions, the table below is a representation of expected CapDI performance. Percentages can vary depending on the water composition.

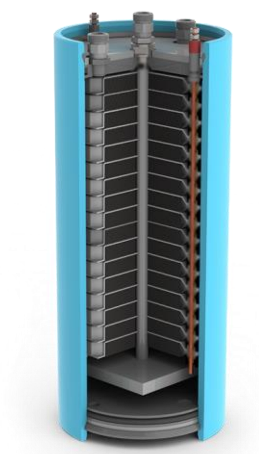
Some of the rare species mentioned on the table, which may not have been encountered in field applications or pilot trials by Voltea, have been assessed according to the widely available knowledge of these ions regarding the characteristics mentioned above (size, valence, charge density and solvation enthalpy).

Symbol	*Ion*	*Summary*	*Found in*	*Typical CapDI performance vs. ACR [%] **		*CapDI Fouling potential*	*Optimum pH window*
				50% ACR	*85% ACR*		
Al	Aluminium	A highly reactive metal that is the most common metal in the earth's crust	Most waters	45 - 55	80 - 85	Low	Below pH 5
As	Arsenic	Used in many industrial applications such as semi-conductor doping	Ground water	30 - 40 Operation with a low dosing of chlorine is advised.	60 - 65	Low risk	Above pH 9
B	Boron	Important use in glass manufacture. Agriculture, fire retardants, and detergents rely on boron compounds.	Sea water at 4-5 ppm level and typical river water contains ca. 10ppb of boron.	20 – 25	30 - 40	Low risk. Operation is advised at pH 8-9 due to higher removal of boron	6-9
Ca	Calcium	5th most abundant element in the earth's crust. Calcium carbonate scaling can be detrimental to many industrial processes	Most waters, particularly near gypsum, limestone and/or dolomite rock formations	55 - 60	85 - 90	Scale formation should be considered and controlled	2 - 12
Cl	Chloride	Most salts are highly soluble in water and NaCl is the main constituent of seawater. Can cause corrosion of metals	Most waters	45 - 55	80 - 90	None	2 - 12
CO_3	Carbonate	Most well-known salt $CaCO_3$ (main constituent of limestone). Used in many industrial applications such as cement	Most waters	40 - 50	70 - 80	Can form scale with calcium (or magnesium)	Below pH 7
Co	Cobalt	Primarily used in magnetic, high-strength alloys. Cobalt compounds give a distinctive blue color to ceramics and paints	Ground water through dissolution of natural ores Industrial pollution may contain high concentrations	30 - 40 Operation is advised at low pH to prevent plating	80 - 85	Risk of electroplating	Below pH 8
Cr	Chromium	A highly corrosion resistant and hard metal. Used in the manufacture of stainless steel and electroplating	Industrial waste water. Ground water through dissolution of natural ores	45 - 55	80 - 85	Low risk	Below pH 4

Cu	Copper	A malleable and conductive metal typically not found in high quantities in water	High levels due to corrosion of piping by acidic water or waste water leaching (e.g. mining, agriculture). Also found in seawater	35 - 45 Operation is advised at low pH to prevent plating	70 - 80	Risk of fouling	Below pH 6
F	Fluoride	Fluorides are relatively low in abundance and pure fluorine is very expensive to refine	Most waters. In some countries fluoride is added to municipal water. Some ground water concentrations can be high	30 - 40	70 - 80	None	2 - 12
Fe	Iron	Accounts for approximately 5% of the earth's crust, making it the 4th most abundant element	Possible presence in most water types, particularly wells	40 - 65	80 - 90	Particulate fouling and electroplating risk; may also encourage biogrowth	Below pH 6
Mg	Magnesium	8th most abundant element in the earth's crust and is essential for most life	Most waters, particularly near areas with gypsum, limestone and/or dolomite rock formations	50 - 60	85 - 90	Scale formation risk is low due to slow crystal formation rate,	2 - 12
Mn	Manganese	Not found as a pure element in nature, often combining with iron. It is used in metal alloys	Particularly common in well water	55 - 65	85 - 95	If oxygen is present, particulate fouling may occur	Below pH 7
Na	Sodium	Not found as a pure metal in nature. Most commonly found as NaCl making up the main constituent of sea water	Most waters	40 - 50	80 - 85	None	2 - 12
Ni	Nickel	A hard and ductile metal that is typically resistant to oxidation, it is frequently used in metal plating	Municipal waters through corrosion of fittings. Also found in ground water through dissolution of mineral ore	30 - 40 Operation is advised at low pH to prevent plating	80 - 85	Risk of electroplating	Below pH 8
NO_3	Nitrate	Predominately used in fertilizers, but common throughout nature and are essential for most life	Most waters	45 - 55	80 - 90	None	2 - 12

Pb	Lead	As abundant in the earth's crust as copper and also a malleable metal. It is a neurotoxin	Corrosive water can take up lead from pipes and fixtures	30 - 40 Operation is advised at low pH to reduce precipitation risk	55 - 65	Most lead compounds are not water-soluble and can cause particulate fouling	Below pH 5
SiO_x	Silica	2nd most abundant element in the earth's crust and is present in many lifeforms	Most waters	Very low removal at high pH level only		pH 10 to 11	Typically does not foul
Sn	Tin	Tin has been used in bronze and pewter since 3000 BC and 600 BC, respectively. Its most notable use now is soft solder and tin cans	Though typically in low quantities, tin can be found in sea, surface and ground water. Most compounds are insoluble in water	Very low		Particulate and electroplating risk	pH 2 (Below pH 2 is not advised for prolonged periods of operation)
SO_4	Sulfate	In many common compounds, such as magnesium sulfate (bath salts) and gypsum (plaster). Contributes to acid rain	Most waters. Ground water can contain high levels due to the dissolution of sulfide ores	40 - 60	80 - 90	Low (Scale possible when combined with calcium or magnesium)	2 - 12
Zn	Zinc	Many similar properties to magnesium. It is used predominately for corrosion resistant zinc plating	Usually low concentrations in most ground and surface waters. In municipal waters it can be higher due to leaching	55 - 65	85 - 95	Risk of electroplating	Below pH 9

*estimated from a theoretical 2000 µS/cm well source at 20 ºC with a system water recovery of 70%.



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