Membrane Capacitive Deionization (MCDI) For Water & Wastewater Minimization

The webinar will start at the top of the hour

If you need assistance, type in the Questions box

Websites: dhptraining.com
voltea.com

MCDI for W & WW Minimization

Instructors

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Today's Webinar

- 40 minute presentation
  - David gives Intro
  - Bryan provide details
- 15-20 minutes of Q & A
- Type your questions into the Questions box

Today's Webinar

- This presentation is recorded
- Will be available at:

  http://www.dhptraining.com/webinars-and-videos.html
- You'll be sent a Thank You email with a PDF of this presentation and link to this recorded webinar

Today's Webinar

- David H. Paul, Inc. and Voltea do not have a financial relationship
- This webinar is presented to give the water treatment industry information on a topic of interest and potential value

David Paul

- Working with high-tech water treatment systems since 1977
- Training and consulting at hundreds of plants since 1988
- Master of Science Degree in Microbiology
- ROS IV certified through David H. Paul, Inc.

Bryan Brister

- CEO of Voltea since 2014
- Founding member of Aqua Ventures (ticker WAAS)
- Former Program Manager at GE Water- Caribbean BOO Portfolio
- Ph.D Polymer Science - University of Southern Mississippi (USM)

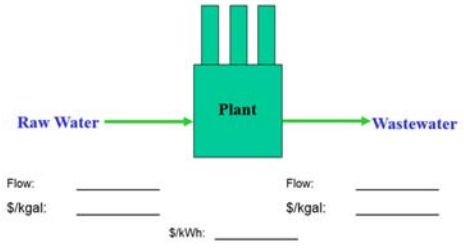
Questions?

- Input your question(s) at any time during the presentation
- We'll cover as many questions as we can during the Q & A session at the end
- Any questions not covered in the Q & A session will be answered by email

Water & Wastewater Minimization

Using Current and Emerging Membrane Technologies

Water & Wastewater Costs



Water & Wastewater Costs

- Largest cost savings usually:
  - Reduced water in
  - Reduced wastewater out
  - Reduced power consumption

Water & Wastewater Costs

- Reduced water & wastewater flow rates typically mean higher overall recovery rates
- Reduced power
  - Efficient operation
  - Technology

Membrane Technologies

- **Pressure Driven**
  - Microfiltration (MF)
  - Ultrafiltration (UF)

Polymeric

Ceramic

Membrane Technologies

- **Pressure Driven**
  - Nanofiltration (NF)
  - Reverse Osmosis (RO)

Membrane Technologies

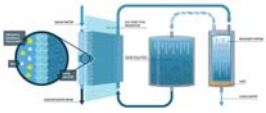
- **Electrical Potential Driven**
  - Electrodialysis Reversal (EDR)

  - Electrodeionization (EDI)

  - Membrane Capacitive Deionization (MCDI)

Membrane Technologies

- **Other**
  - Forward Osmosis (FO)



  - Membrane Distillation (MD)

Current and Emerging

Current/Proven Technologies

- Reverse Osmosis (NF & RO)
- Membrane Filtration (MF & UF)
- Electrodialysis Reversal (EDR)

Emerging Technologies

- Closed Circuit Desalination (CCD™)
- Forward Osmosis (FO)
- Membrane Distillation (MD)
- Membrane Capacitive Deionization (MCDI)

W & WW Treatment Limitations

Limitations

- Capital cost
- Operating cost
- Scaling
- Fouling

Scaling

- Scaling is based on the saturation limit of dissolved compounds, which varies with temperature, pH, ionic strength and other parameters
- At the same conditions, it doesn't matter which technology you use, scaling will occur at essentially the same point

Scaling Potential Example

	Feed	Concentrate
LSI	-1.41	0.22
S&DSI	0.0	-0.8
$CaSO_4$, % Saturation	102	520
$BaSO_4$, % Saturation	2,038	9,501
$SrSO_4$, % Saturation	46	245
CaF_2, % Saturation	90	5,746
SiO_2, % Saturation	14.5	54.3
$Mg(OH)_2$, % Saturation	0.0	0.0

Fouling

- Suspended solids
  - Non-living
    - Clay, silt, sand
    - Precipitates
    - Organics
    - Polymers
  - Living: Bacteria
- Organics
  - Natural Organic Material
  - Oil
  - Polymers

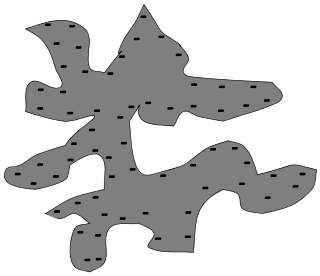
Emerging Technologies

- When evaluating emerging technologies, we need to see real-world:
  - Applications (pilot to full-scale)
  - Operations (scaling, fouling, power usage, etc.)
  - Costs
    - Capital
    - O & M

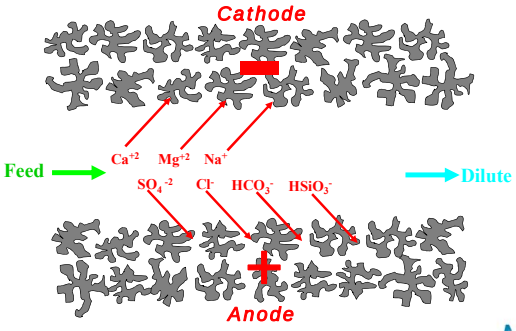
Membrane Capacitive Deionization (MCDI)

Capacitive Deionization (CapDI)

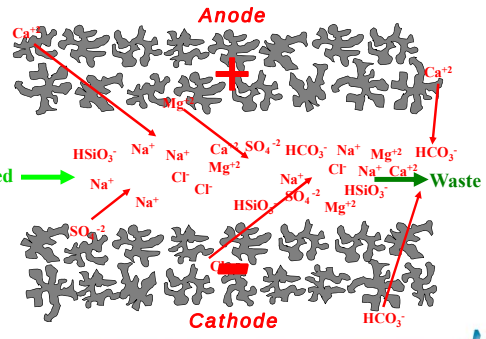
Activated Carbon Cathode Particle



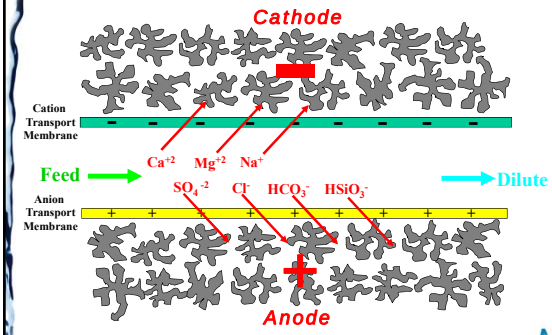
Capacitive Deionization (CapDI)



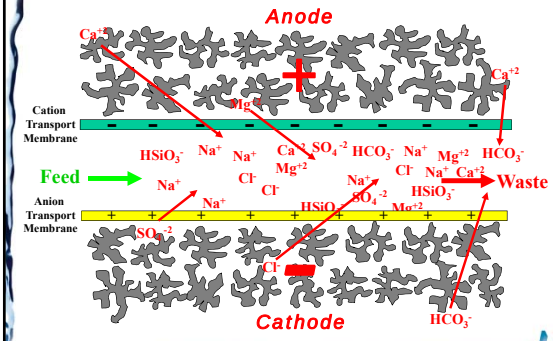
CapDI Regeneration



Membrane CDI (MCDI)



MCDI Regeneration



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Bryan Brister – CEO

DAVID H. PAUL

5 APR 2017

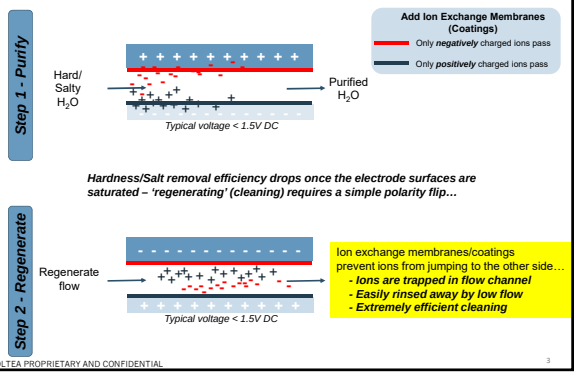
WHY VOLTEA IS DRIVEN TO INNOVATE

We fundamentally believe there is a lower cost, better way to desalinate

Voltea is driving a revolutionary, cost-effective and environmentally responsible water treatment and reuse technology into every business and household on the planet!

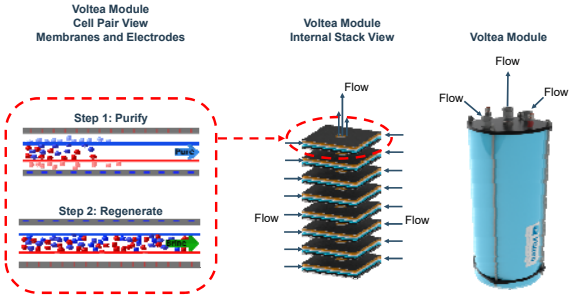
VOLTEA'S MEMBRANE CAPDI©

Voltea patents ion exchange membranes/coatings for CapDI



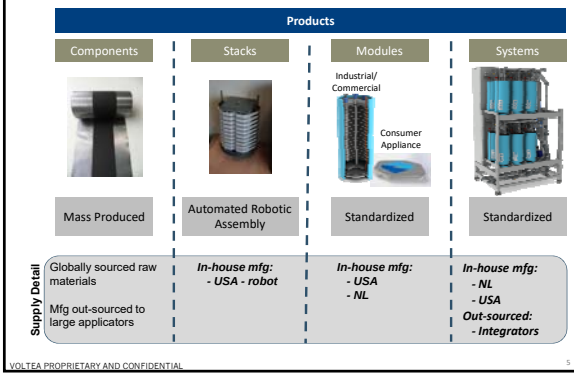
ADVANCED MATERIALS SCIENCE FOR DESAL

Electrostatic water softening and desalination via CapDI



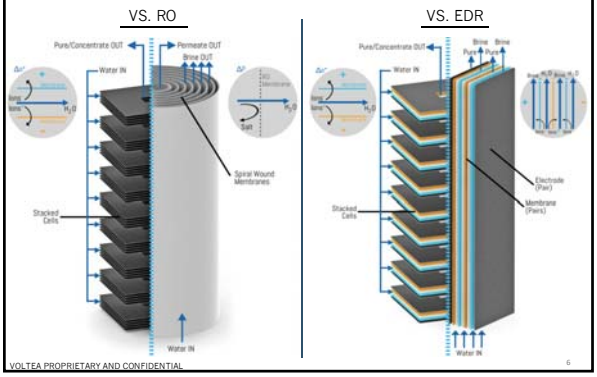
MASS PRODUCED STANDARD PRODUCTS

Technology advances and mass, robotic production have driven out cost



COMPARISON TO TRADITIONAL DESAL

CapDI represents a significant departure from traditional desal technologies



WHY CAPDI?

An elegant electrical method, saving cost and enabling a wider range of uses

ALL OF THIS

Voltea's CapDI

"Electrostatic salt removal using electric fields"

- ✓ Capital efficient
- ✓ Energy efficient
- ✓ Low water wastage
- ✓ Non-polluting
- ✓ Miniaturized for appliances
- ✓ Broad operating temps
- ✓ Hot water desal (60ºC)

Reverse Osmosis - *"Force water through membranes at extreme pressures"*

- Energy intensive
- Huge wastage of water
- High maintenance
- Hard to scale down
- Limited operating temps

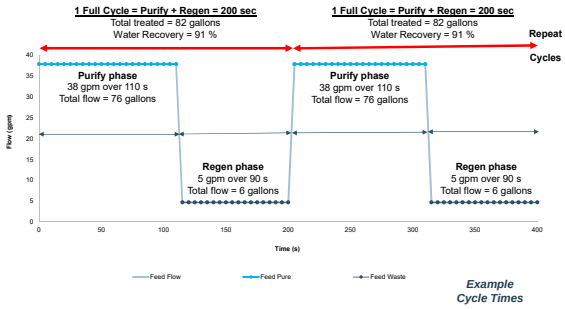
Traditional Softeners – *"Replace bad salt with less-bad salt"*

- Polluting
- Regulated against
- High consumable cost

NONE OF THIS

SEMI-BATCH MODE OF OPERATION

Voltea's CapDI operates in a semi-batch process



Example Cycle Times

SEMI-BATCH MODE OF OPERATION – CONT'D

Voltea's CapDI operates in a semi-batch process

1 Full Cycle = Purify + Regen = 200 sec
Total treated = 82 gallons
Water Recovery = 91 %

Purify phase
38 gpm over 110 s
Total flow = 76 gallons

+

Regen phase
5 gpm over 90 s
Total flow = 6 gallons

Total elapsed cycle time = 200 sec

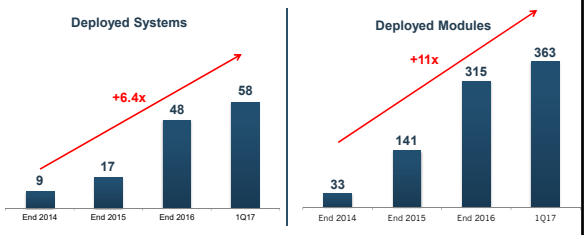
Total water treated = 76 gal pure + 6 gal regen = 82 gallons

Average ***pure*** flow rate = 76 gallons/200 sec = 22.8 gal per min (gpm)

Cycles repeat over and over…

ADOPTION IS ACCELERATING

Commercialization gaining speed across 5 continents



- Global foot print
- Multi-industry deployments
- Multi-application deployments

DEPLOYMENT EXAMPLES

Voltea's CapDI is winning in multiple industries and multiple applications

Example 1	Automotive paint line rinse water re-use
Example 2	Cooling Tower (CT) make-up water
Example 3	CT blow-down for re-use
Example 4	Salinity removal from membrane bioreactor (MBR) effluent
Example 5	Horticulture irrigation water for yield increase
Example 6	Commercial Laundry – TDS removal allowing re-use
Example 7	Commercial Laundry – no salt/no chemical softening of municipal feed

CASE STUDY – AUTOMOTIVE PAINT LINE

CapDI enables automotive paint line rinse water re-use

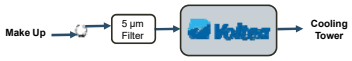
Feed (µS/cm)	Pure (µS/cm)	Recovery Actual	Salt Removal	Energy (kWh/m³)	Source
1212	169	85%	86%	0.96	Automotive Rinse Line

Sample	Feed	Purified
pH	5.5	5.8
Fluoride	75.9	40.8
Nitrite	381	43.5
Nitrate	355	39.2
Tot. Hardness (as $CaCO_3$)	2.6	0.34
Iron	0.5	0.013
Sodium	84.7	16.4
Zinc	185	16.7

***NOTE**: Energy used/m³ includes feed pumps, CapDI treatment, product forwarding pumps and **ALL** treatment equipment!*

CASE STUDY – COOLING TOWER (CT) MAKE-UP

CapDI softens cooling tower feed water to increase CoC without chemicals

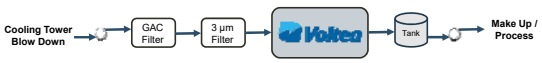


Feed (µS/cm)	Pure (µS/cm)	Recovery Actual	Salt Removal	Energy (kWh/m³)	Source
1722	516	90%	70%	0.56	Canal Water
1270	254	65%	80%	0.33	Canal Water

***NOTE**: Energy used/m³ includes feed pumps, CapDI treatment, product forwarding pumps and **ALL** treatment equipment!*

CASE STUDY – CT BLOW DOWN FOR REUSE

CapDI desalinates CT blow down water allowing re-use

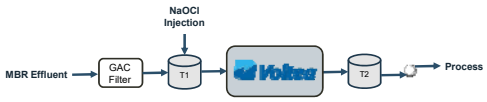


Feed (µS/cm)	Pure (µS/cm)	Salt Removal	Water Recovery	Energy (kWh/m³)	Source
6364	3881	39%	71%	0.94	Cooling Tower Blow Down
4684	2106	55%	70%	0.97	Cooling Tower Blow Down

***NOTE**: Energy used/m³ includes feed pumps, CapDI treatment, product forwarding pumps and **ALL** treatment equipment!*

CASE STUDY – MBR EFFLUENT TREATMENT

CapDI enables TDS removal from MBR waste water effluent



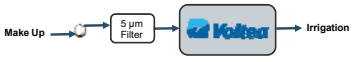
	Feed (µS/cm)	Salt Removal Target	Salt Removal Actual	Recovery Target	Recovery Actual	Energy (kWh/m³)	Source
RO	3100	65%	97%	85%	60% ✗	>1* ✗	MBR Effluent
CapDI	3000	65%	72%	75%	73%	0.45	MBR Effluent

** Target energy consumption < 1kWh/m³; RO failed to achieve this target*

** **NOTE**: Energy used/m³ includes feed pumps, CapDI treatment, product forwarding pumps and **ALL** treatment equipment!*

CASE STUDY – HORTICULTURE

CapDI enables tunable sodium removal for optimized irrigation water

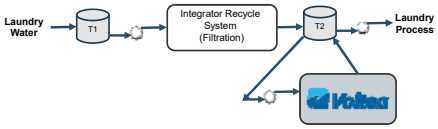


Feed (µS/cm)	Pure (µS/cm)	Feed Na⁺ (ppm)	Pure Na⁺ (ppm)	Water Recovery	Energy (kWh/m³)	Source
486	196	57	29	84%	0.34	Ground Water
482	116	47	19	80%	0.53	Ground Water
487	94	54	14	80%	0.54	Ground Water
477	11	58	0	78%	0.60	Ground Water

***NOTE**: Energy used/m³ includes feed pumps, CapDI treatment, product forwarding pumps and **ALL** treatment equipment!*

CASE STUDY – COMMERCIAL LAUNDRY

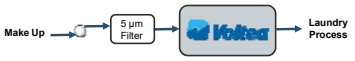
CapDI removes TDS from spent laundry water allowing re-use



Feed (µS/cm)	Pure (µS/cm)	Salt Removal	Water Recovery	Temperature (°C)	Source
1331	679	50%	86%	50	Laundry Recycle Water

CASE STUDY – COMMERCIAL LAUNDRY

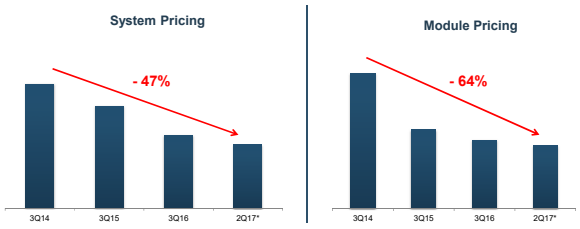
CapDI delivers no-salt, no-chemical softened feed water



Feed (µS/cm)	Pure (µS/cm)	Salt Removal	Water Recovery	Temperature (°C)	Source
1,000	<250	75%	86%	18	Municipal Water

MASSIVE COST STRUCTURE IMPROVEMENTS

Cost improvements underpin global commercial momentum



- Technology advances yielded tremendous cost out & improved reliability
- Robotic stacking reduces costs & increases quality
- ***Improved cost structure driving commercial revolution***

THANK YOU!

QUESTIONS?

Q & A

For More Info

- DHP has:
  - A 3-day seminar:
    - *Current & Emerging Membrane Technologies for Water & Wastewater Minimization*
    - April 18-20
    - Albuquerque, NM
  - Whatever your high-tech water treatment training needs, DHP can support you

www.dhptraining.com

Thank You for Attending!

Please answer the 3 Polling Questions before leaving (will take only 10-30 seconds)

Voltea & David H. Paul Webinar – Q&A
April 5, 2017

What actually fouls in the CapDI? When you have to clean with citric acid, what's fouling? The membranes? *Typically the spacer channel and membrane surface is what needs to be cleaned with citric.*

How many stacks in a module? *Depends completely on module size and ranges from 1 to 17, or more.*

Can you comment on individual ion removal differences observed when applying MCapDI? E.g. are divalent ions removed better compared to monovalent ions? *The greater the ion density, the higher the removal. So divalent and multi-valent ions are removed faster.*

How does CapDI Opex compare to RO Opex costs? *This depends on the application, but it is not uncommon to see CapDI Opex at half to one-third or less compared to RO. View this document for more answers to this question: https://online.flippingbook.com/view/145820/.*

What Specific Cooling Tower Biocides that GAC doesn't take out of the game might impact the CapDI System membrane(s)? *GAC is effective at removing organic biocides. Fouling will depend on the amount removed, and Voltea will work with you individually on the specific list.*

What do you think is the biggest barrier preventing MCDI to be widely accepted? TDS range, Capex, or the pre-taken market of RO*? I think the biggest barriers so far have been capital cost, robustness of the technology and simply educating the market. Voltea has solved the challenges for cost and reliability, and the market is adopting the technology fast.*

The system uses low voltage but high capacitance, doesn't it? *Vanishingly low voltage, and depending on the application, the amperage could be low as well. Its application specific.*

How sensitive is the system to dissolved or to dispersed hydrocarbon such as crude oil? *Voltea advises total organic content in the feed water to be less than 50ppm, although our systems are tolerant to intermittent spikes to 700ppm.*

How much monitoring and manual operation do the systems require? *Voltea's systems are built from the ground up to be FULLY automated. Other than ensuring CIP tanks are topped off, the systems can be fully, remotely operated.*

Do you have a case study on nutrient removal from municipal wastewater or anaerobic digestate water? *We will reach out to you directly to understand this question a bit better. Thank you*

Is there a lot of maintenance required (e.g. monthly)? Can it be done by the end-user or only by Voltea technicians? *Maintenance is incredibly easy and systems are designed for FULL remote operation and automated CIP.*

Voltea & David H. Paul Webinar – Q&A
April 5, 2017

Is it possible to use this technology for the treatment of sulfates from tailings of copper mines? *We have experience removing sulfates from other water sources, so in principal, yes.*

For your full-scale installations, how is the reject disposed of? Have you encountered disposal challenges when municipal sewer discharge is not possible? *Because we do not require chemicals for treatment, we have had no issues with municipal disposal and require no special permitting.*

In laundry waste water reuse, what causes TDS of waste water to increase? And what type of pre-treatment required before voltea? *TDS rises in laundry water from a variety of sources including what's washed out of the linens as well as detergents. Pre-treatment depends on what is laundered. We are happy to discuss live with you and will reach out.*

Can you also use ozone to prevent fouling? *We have systems operating where ozone is used for disinfection prior to water entering the CapDI.*

Why COC has to be 4 for cooling towers for CapDI to be effective for make-up water? *CapDI is profoundly effective in treating CT make-up water, regardless of CoC. However, if the goal is to make a business case in terms of ROI, the water usage profile for a CT is difficult.*

You said that CapDI uses less energy than RO, but what about the investment? How does this compare to RO? *Capital costs for Voltea's CapDI have gained parity with RO in many applications, and are actually cheaper than RO for a lot of applications.*

Does CapDI have any effect on pharmaceutical removal? *We have not looked specifically at this, but if the species is charged, there is a likelihood that CapDI will effectively remove it.*

Do we have any data of power saving, as compared with RO system? What is the life cycle, we assume for these electrodes, considering favourable conditions? *We have a tremendous amount of data on power savings, and it is often half to one-third of RO. Module lifetime is typically between 2 and 7.5 years.*

Can this system be integrated with Solar Panels where there is no electricity? *Owing to the low energy requirements, this is possible and has been done by one of our partners in Australia.*

Given that MCDI has potential to replace BWRO membranes, from the standpoint of drinking water industry, does MCDI get any log removal credits? *I am not aware of 'Log Removal Credits' - we will reach out to you directly to discuss this. Thank you*

Please, indicate pre-treatment needed. I would also appreciate if you could give us a number about specific desalination rate per surface electrode? *Required pre-treatment depends wholly on the water being treated. We provide on our website a guide for water quality coming into our system and I will share that with you.*

Voltea & David H. Paul Webinar – Q&A
April 5, 2017

Have you containerized systems that can be portable for camp use or to be able to be moved from site to site? *Yes, we have containerized systems and this is easily accomplished.*

What happens when the flow stops during service? *Voltea has developed a proprietary operating program named Dynamic CapDI, and if the flow stops, Dynamic CapDI automatically stops applying electricity to the modules.*

CAPEX comparison between CapCDI and RO, EDR or other conventional softeners? Return of investment (ROI)? *CapDI has achieved parity with RO and EDR, and in many cases CapDI is significantly less expensive. CapDI also requires less pre-treatment, which reduces overall capex.*

We are working for a Caribbean Client with high Silica (Colloidal: 30 ppm) raw water. Can this technology be used if Ultrafiltration is used as pre-treatment to bring down Silica levels? *30 ppm silica would pass right through CapDI without causing any problems. If silica must be removed for other reasons, this would be an effective pre-treatment.*

Can CapDI remove silica? *CapDI does not remove silica- see above Q&A.*

What is the differences comparing with RO membranes talking about price? *Depending on the type of RO membrane used, CapDI will be slightly more expensive. However, other cost factors must be considered which tip the costs in favor of CapDI.*

Is this CapDI technique suitable to produce (ultra) pure water? *Yes, we have done this.*

What limits CapDI recovery*? A variety of factors come into play, such as salinity of the feed water and what specific salts/salt composition is in the feed, and targeted purified water quality.*

Do you provide system performance projections based on the water analysis and desired product quality? *Absolutely - with a minimum of data regarding feed water quality and target purified, we provide excellent projections.*

What is the life of CapDI membrane? *In real-world applications, we see anywhere from 2 to 7.5 years.*

Can CapDI be applied on dairy effluent treated by MBR? *It can. We provide guidance on what the feed water quality to the CapDI must be, and it is relatively easy to deliver.*

Are CAPDI modules ozone tolerant or does the ozone have to be removed up front? *There is some resistance to ozone, but you wouldn't want the residual ozone levels to be too high or oxidation will occur.*

Voltea & David H. Paul Webinar – Q&A
April 5, 2017

Can MCDI handle brominated cooling tower blow-down? Can it deal with anionic scale inhibitor, and certain film forming corrosion inhibitor? *Depending on the specific molecules, yes. Voltea's technical team will work with you through these details.*

What is the flow rate of each module, and how long do they last? *Flow depends on 3 factors: feed salinity, composition of the salts in the feed and targeted purified water quality. Lifetime is 2 to 7.5 years.*

Traditionally, EDR systems expect 50-60% removal per pass, but are your MCDI systems able to achieve up to 85% removal in a single pass? *Yes, they are and in some cases as high as 90% +.*

What are the physical differences between ambient and hot water modules? *The biggest difference is the type of membrane used. We use a different membrane type for hot water tolerance.*

What is the method by which membranes are attached to the electrodes? Coating or mechanical adhesion? *Membranes are coated onto the electrodes in a mass production environment.*

HOW MANY FLUORIDES CAN BE REMOVED FROM GROUND WATER? *In principal, ultra pure water can be produced.*

How to deal with varying feed quality in terms of TDS? E.g. if it shows fluctuation between 200 and 1000 ppm? How can a module/system handle? Is additional/advanced control needed? *Voltea developed a proprietary control program named Dynamic CapDI that adjusts performance based on feed fluctuations.*

In general you use it for brackish water. Do you also have first-hand experiences in treating sea water? (36mg/l)? *Voltea has successfully treated seawater but it is not our commercial focus.*

Do those membranes block bigger molecules as in normal membrane filtration, even if they are charged? Or do those bigger charged organic molecules go through those membranes as well and are adsorbed by the electrodes too? *It is likely they remain on or within the membrane.*

Like RO, is MCDI able to remove TOC? *CapDI will remove TOC but it is not ideal as residual organics can foul the spacer channels and membrane surfaces.*

In the presentation, we say the OPEX. What will be the comparison with other conventional system in CAPEX? *Voltea's CapDI has achieved parity with RO, and is less than EDR. In many cases, Voltea's CapDI is even less than RO.*

Service time of electrodes/membranes, depending on the source water? *2 to 7.5 years.*

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What are the major differences between CapDI and EDR other than configuration and applied voltage? *EDR typically requires significantly greater amounts of chemicals to ensure smooth operation, and delivers only 40-60% 1st pass recovery.*

Have you a study case for metals removal? I mean Fe, Mn or As? *We do for Mn- please view this brochure here: https://online.flippingbook.com/view/907876/.*

What is the life of CapDI membrane? *2 to 7.5 years.*

What about water recovered from fracking operations? Too ugly? *CapDI can handle it so long as the water quality entering the CapDI meets guidelines. Voltea focuses on brackish salinity levels.*

is it possible to selectively remove divalent ions mostly? *This is under development.*

WHAT IS CAPEX & OPEX PER LITER OF PURE WATER PRODUCED? *This depends fully on salinity of the feed, composition of the salts in the feed and target purified water quality.*

Can you tell me about the material of the Exchange Membranes? How are they built up? *The chemistry we use for our membranes/coatings is proprietary, but I can tell you they are coated onto the electrode surfaces.*

What is the max capacity installation you have for MCDI*? Currently 150,000 gpd.*

How is the spacer look like? Is it just a gap or is it woven material? *Cheap, woven fiber.*

Typically, EDI is not used to replace Ion exchange resins beyond 1-1.5 MGD. Is this valid for MCDI as well? *Voltea's CapDI is suitable for larger flows. We are bidding a 4.8 MGD opportunity now.*

The membranes are stacked in your modules. The inlet is as well as the outlet on top of the module. How do you assure that the fluid flow does not go only through the upper spacers? *We have performed extensive studies on flow characteristics. Soon, we are launching our next generation modules which will be horizontal.*

Is there pure flow rate variability due to constant switchback between normal and regen operations? *The system is always either flowing in 'Pure' or 'Regenerate'.*

Does it use any pumping pressure? *Pumping is only used to move water through the modules.*

How do you anticipate the life time operating costs of mcdi to compare to RO? *Significantly lower total cost of ownership.*

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Do you use both inlets simultaneously? Or only one? *Both inlets simultaneously during pure, but only one during regeneration.*

How much MLD per day can we produce from sea water*? Voltea does not focus on sea water. We only focus on brackish water where the TDS is less than 3,000ppm.*

Are you using industrial waste energy at power plant cooling tower blow down recovery process? *Not currently.*