Ion exchange resin regenerated with alternative bicarbonate counter ion for the removal of natural organic matter

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Researcher

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#missionwater

Ion exchange at Andijk WTW

Suspended Ion eXchange SIX®

- Direct treatment of Ijssel lake
- DOC removal prior to
  - Microfiltration (ceramic)
  - Advanced oxidation - UV / hydrogen peroxide
  - Activated carbon filter
- 120 Mld or 1,5 m^3/s
- Strong basis Lewatit S-5128 resin initially loaded with chloride
- Commissioned in May 2014

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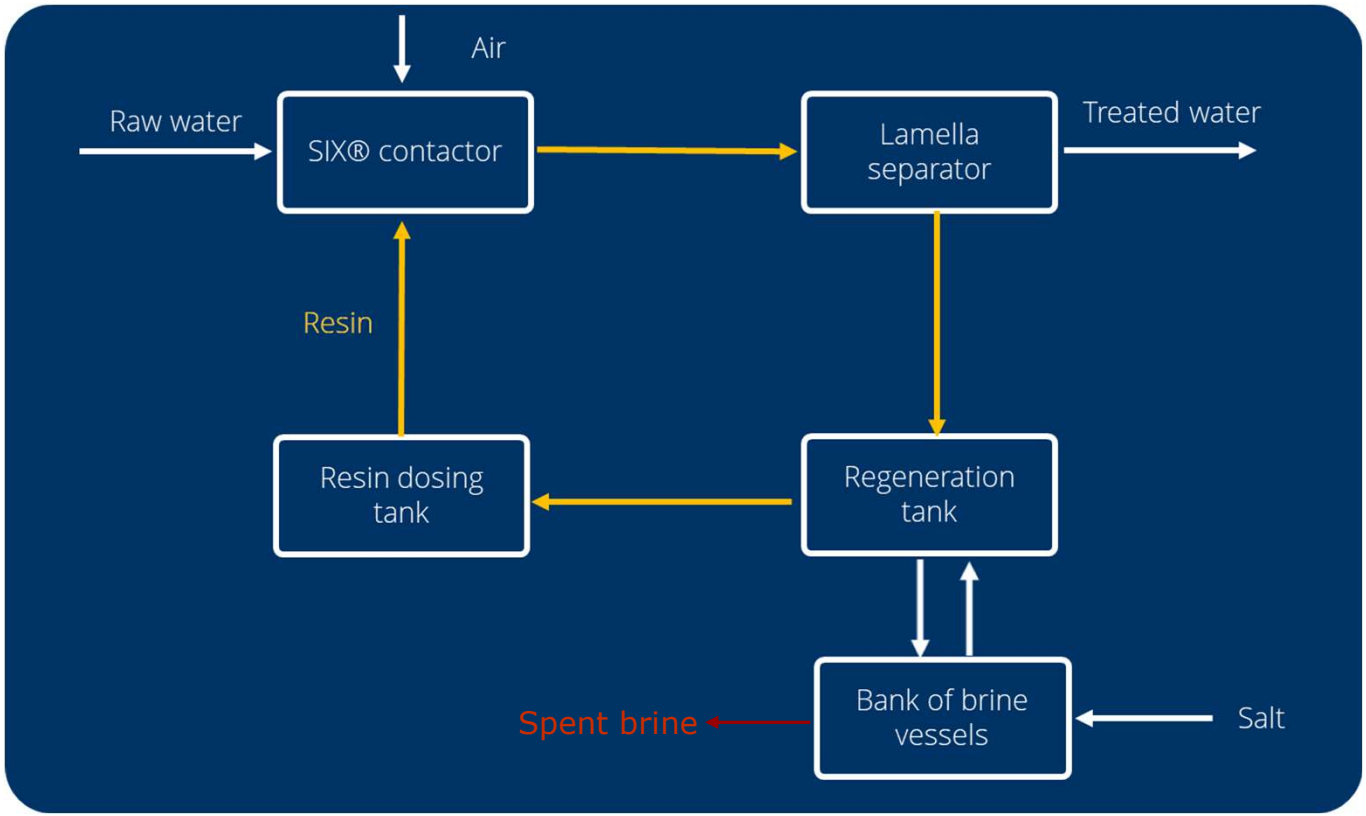
SIX® description



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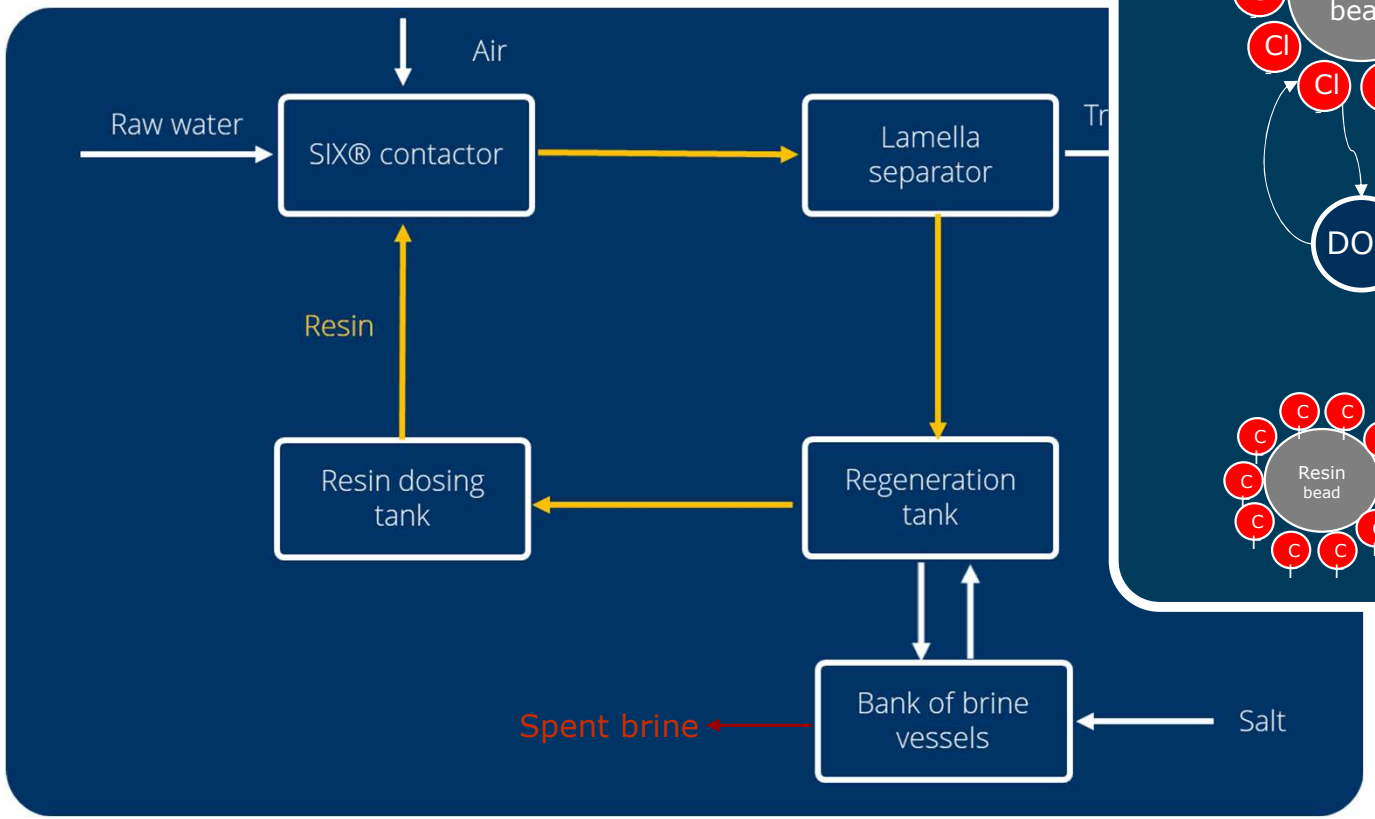
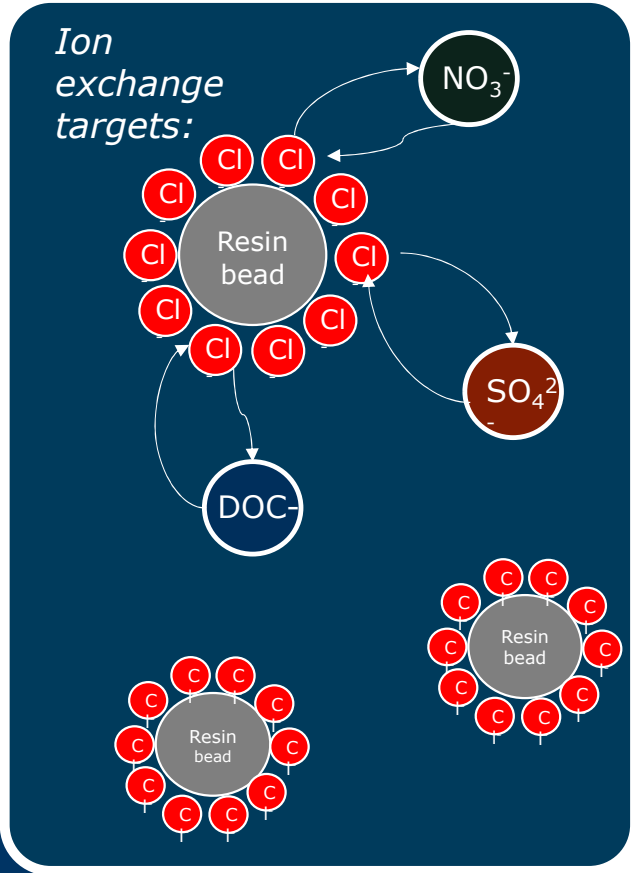
SIX® description





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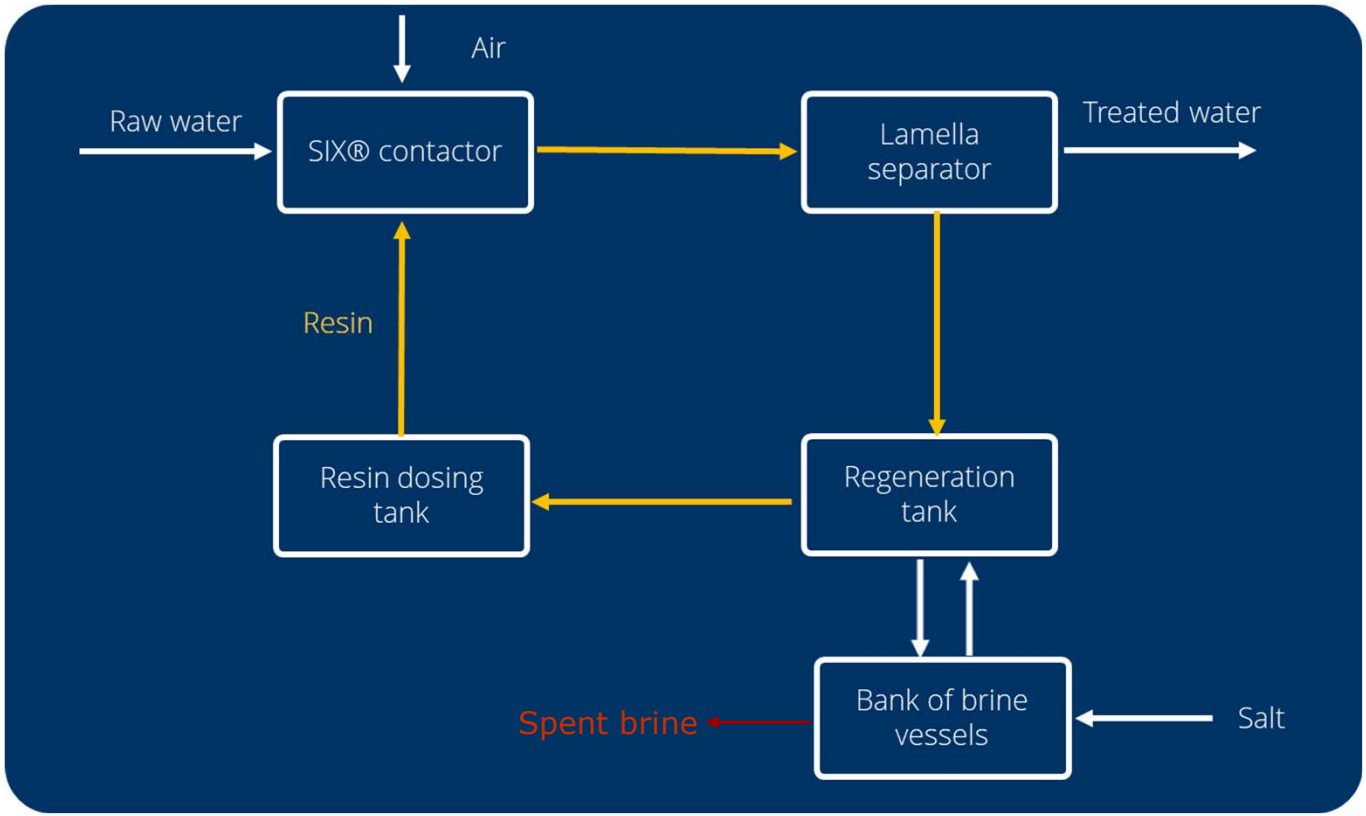

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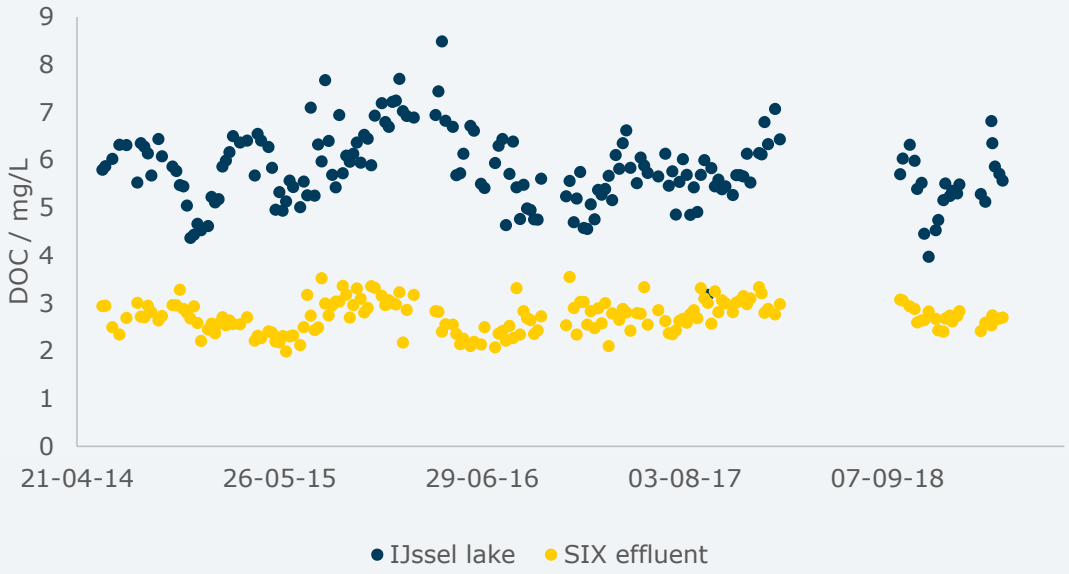
SIX® - DOC targeted adsorption



DOC adsorption

- Average removal 52%
- Average influent 5.8 mg C / L
- Average effluent 2.7 mg C/ L

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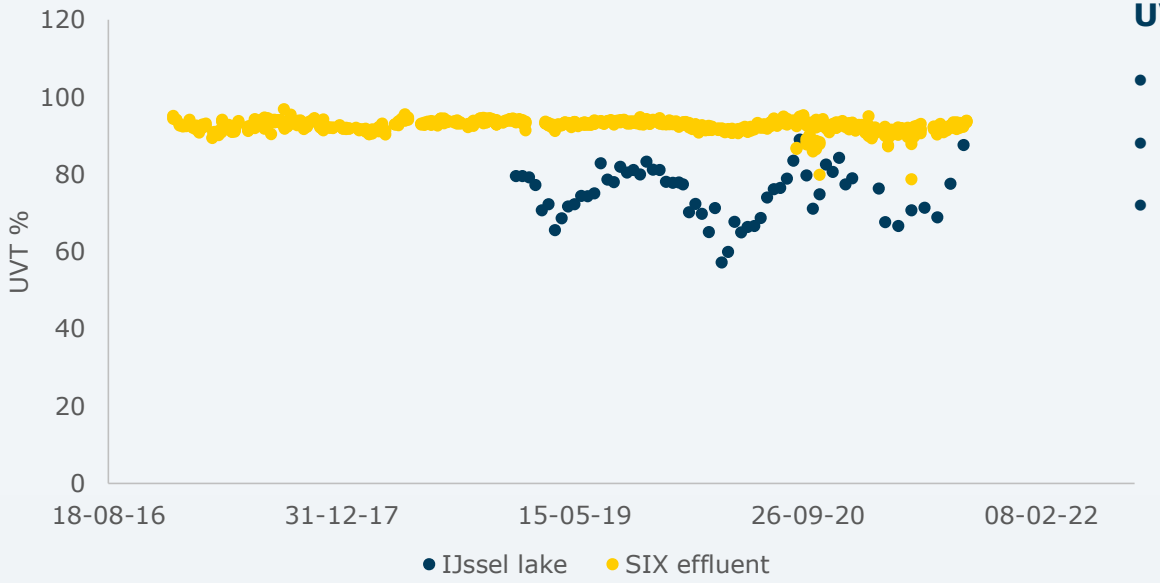
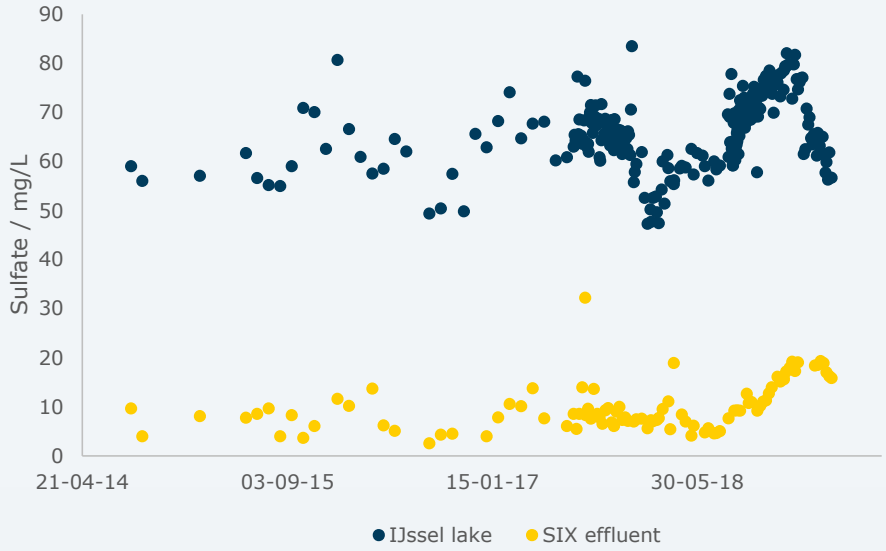
SIX® - UVT increase



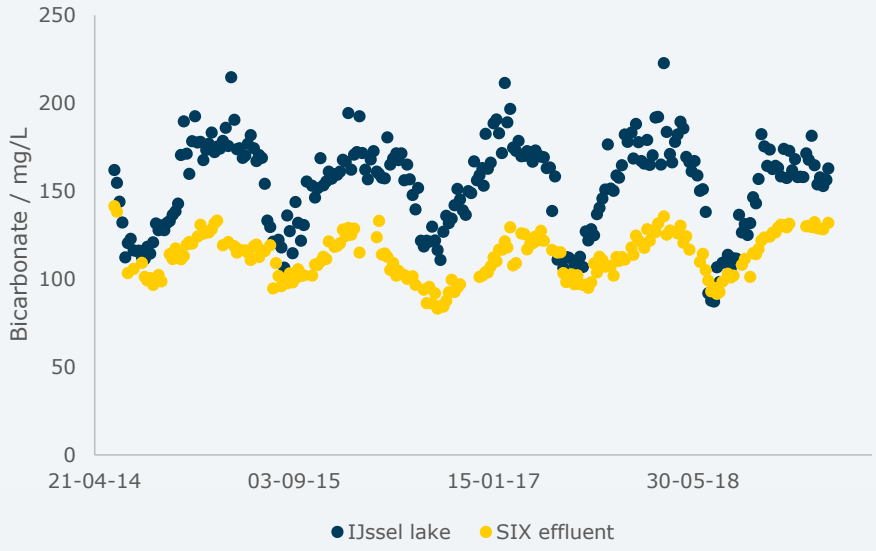
UVT increase

- Average increase 18 %
- Average influent 75%
- Average effluent 93%

SIX® - SO_4 / HCO_3 untargeted adsorption



87% av SO_4 removal



25% av HCO_3 removal

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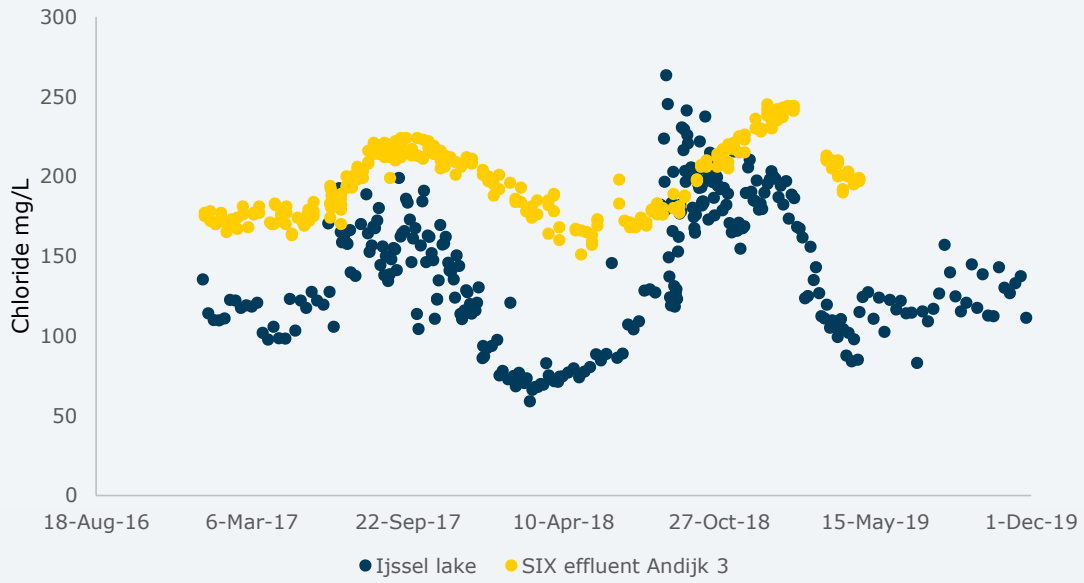
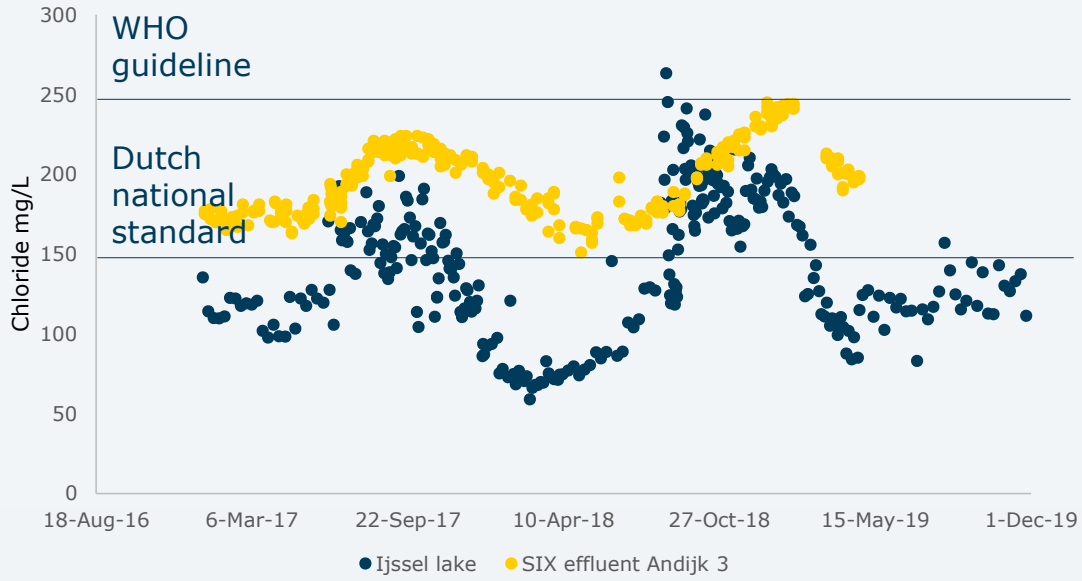
SIX® - Chloride counter ion release



Chloride release

- Average increase 36%
- Average influent 145 mg Cl / L
- Average effluent 198 mg Cl/ L

SIX® - Chloride counter ion release

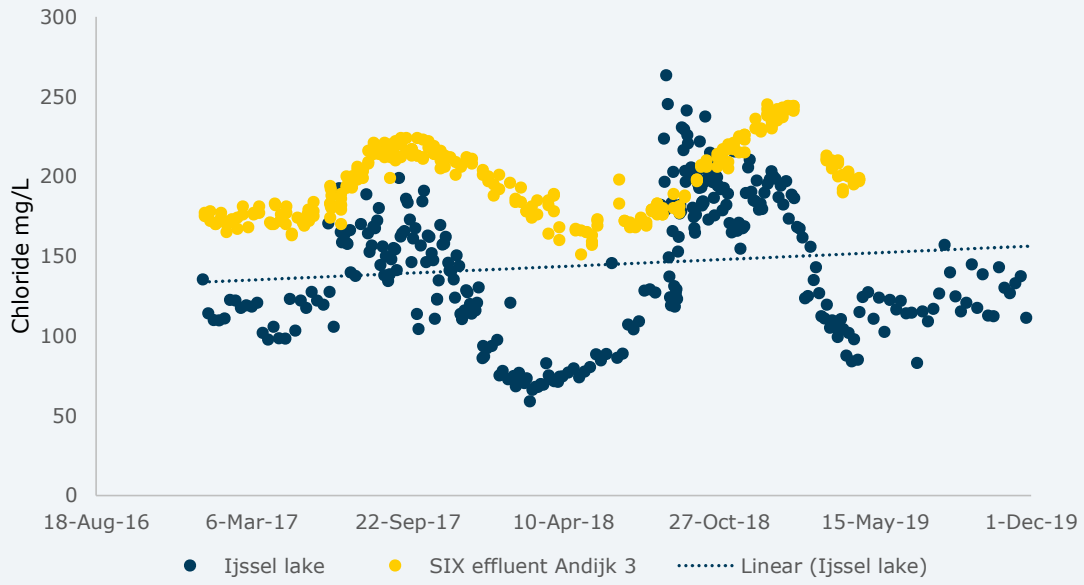


Chloride release

- Average increase 36%
- Average influent 145 mg Cl / L
- Average effluent 198 mg C/ L

Effluent quality above standards

SIX® - Chloride counter ion release



Chloride release

- Average increase 36%
- Average influent 145 mg Cl / L
- Average effluent 198 mg C/ L

Aggravated by seasonality and overall salinization of the source

Research goal: alternative counter ion

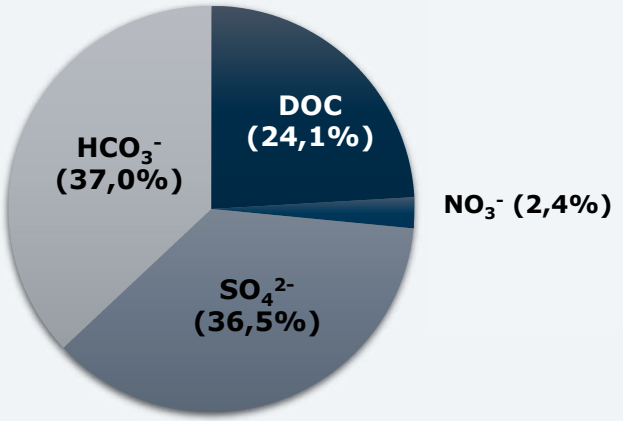
SIX® largely contributes to the chloride increase in treated water (+36%)

- 25 % to 30 % used for targeted compounds
- 70% to 75% used for untargeted compounds

Resin selectivity range: SO_4>DOC>NO_3>Cl ≈ HCO_3

Properties of bicarbonates

- Low resin selectivity
- No impact on human health – not regulated
- Increased alkalinity - Reduced corrosivity in distribution system

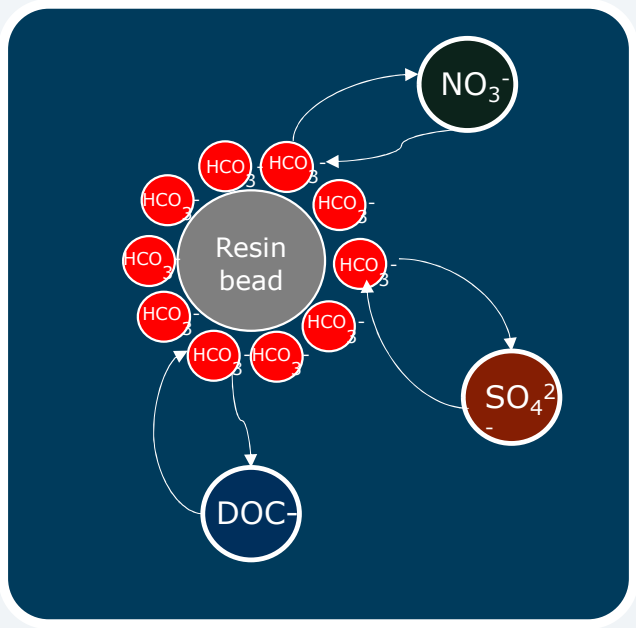


Research goal: alternative counter ion

Explore the feasible to substitute NaCl regeneration for $NaHCO_3$ regeneration to reduce chloride levels in the SIX® effluent while preserving DOC adsorption?

Research goals

- Assess the impact on DOC removal efficiency and ion exchange kinetics
  - Quality of effluent water
- Evaluate the feasibility of regeneration with $NaHCO_3$
  - Impact on continuous operation
  - Quality of spent brine
- Determine practical implications of counter ion switch



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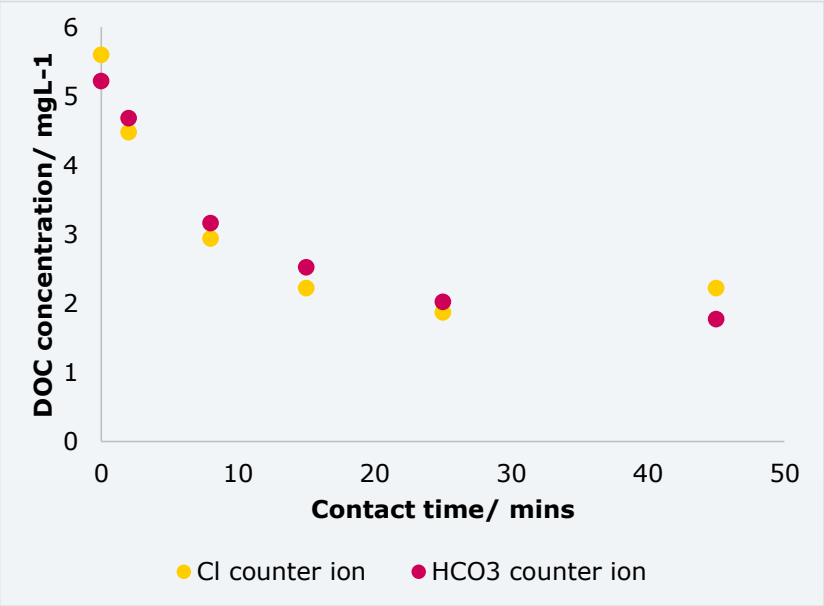
1- Bench scale comparative adsorption studies

- 60 L water from Ijssel lake
- 900 mL or 15 mL/L resin (dosage at Andijk III WTP)
  - with Cl counter ion
  - or HCO_3 counter ion
- 45 minutes contact time

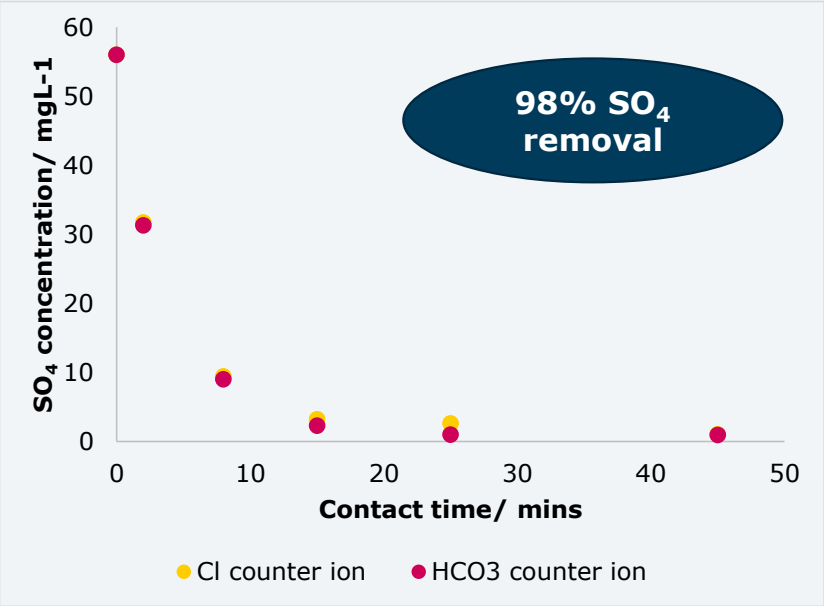
1 – Jar test DOC adsorption

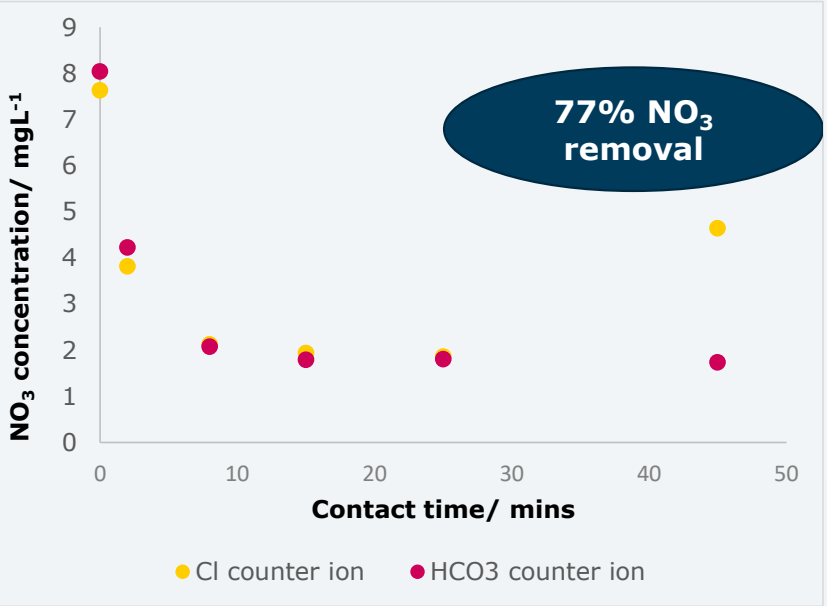


DOC adsorption

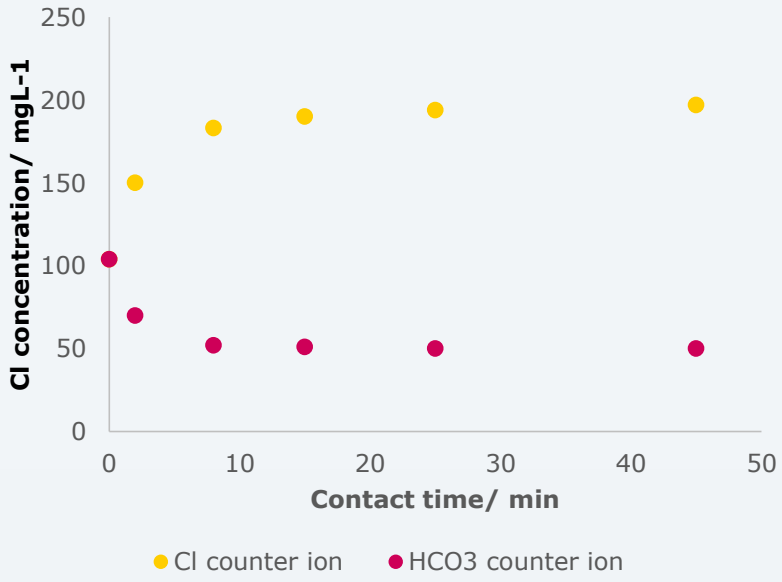
- Removal percentage
  - 60 % with chloride counter ion
  - 66% with bicarbonate counter ion
- Equilibrium Value
  - 2.2 mg/L with chloride counter ion
  - 1.7 mg/L with bicarbonate counter ion
- Kinetic constant
  - k= 0.124 with chloride counter ion
  - k= 0.116 with bicarbonate counter ion

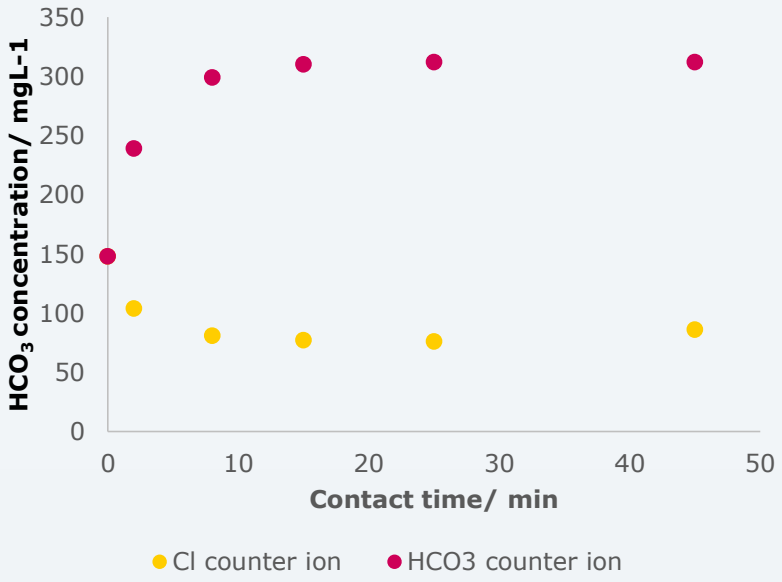
1 – Jar test SO_4 and NO_3 adsorption





1 – Jar test Cl - HCO_3 adsorption /release





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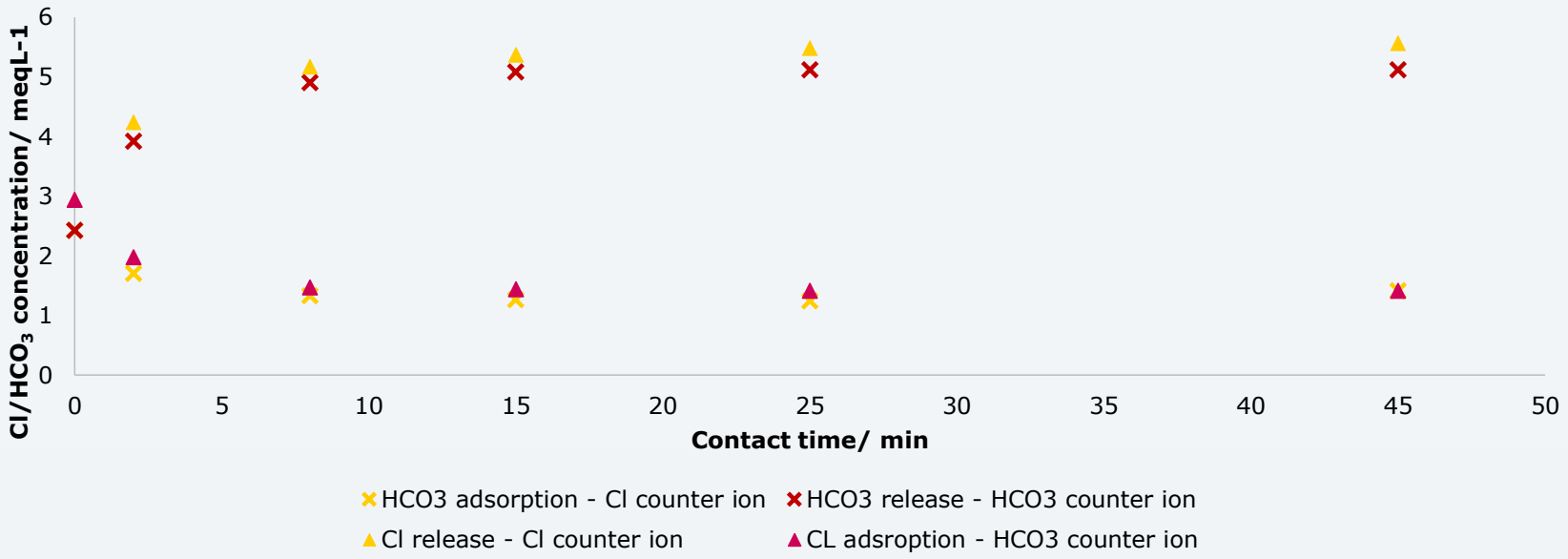

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Organic matter removal with bicarbonate-form ion exchange: water quality, kinetics and mass transfer mechanisms

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[b] Innovation Discovery, Anglian Water, Thorpe Wood House, 36 Thorpe Wood, Peterborough, PE3 6SR, UK

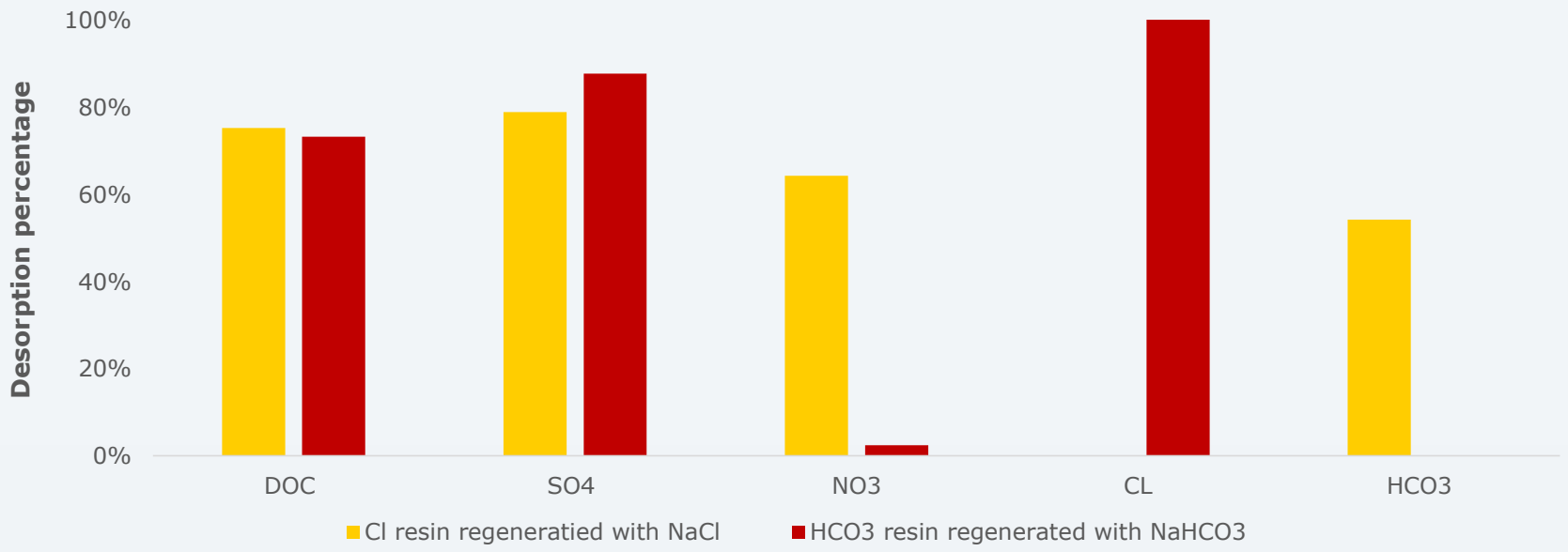
Resins in Cl and HCO_3 forms displayed :

- Marginal differences with regards to organic fractions (LC-OCD) removed
- Similar reduction of disinfection by product formation potential of -71% THM-FP and -72% HAA-FP attributed to unchanged selectivity towards DBP precursors.
- Corrosion indexes estimated with Larson index and chloride to sulphate mass ratio (CSMR) reduced by factors 5 – 10 using HCO_3 counter ion rather than Cl.

2- Bench scale comparative regeneration studies

- 250 mL resin previously used
  - With either CL and HCO_3 counter ion
- 500 mL of regenerant solution
  - 63 g/L NaCl
  - 90 g/L $NaHCO_3$
- 30 minutes contact time

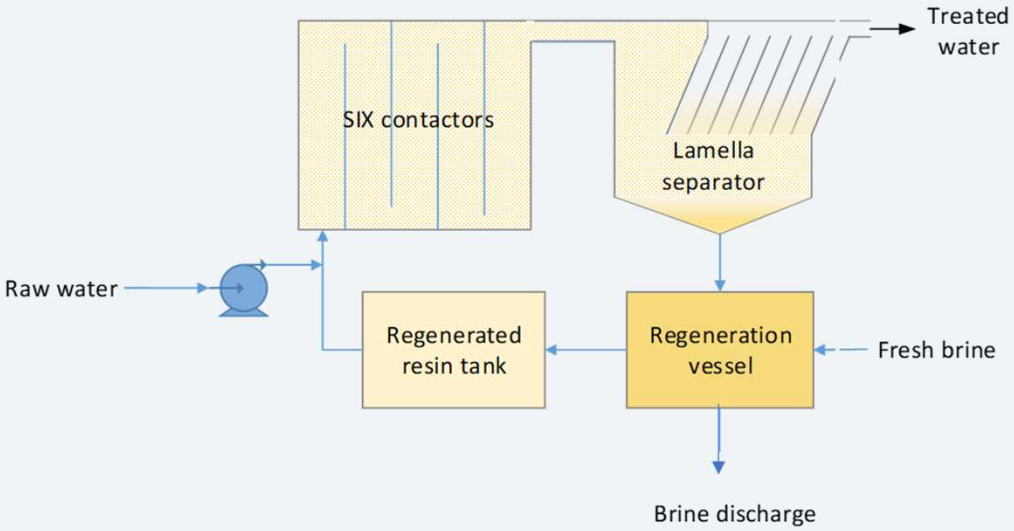
2 – regeneration results

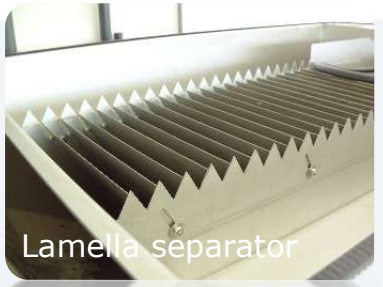


3- Continuous operation pilot scale

7m^3/h capacity
3.5 weeks continuous operation

3- Pilot plant operations





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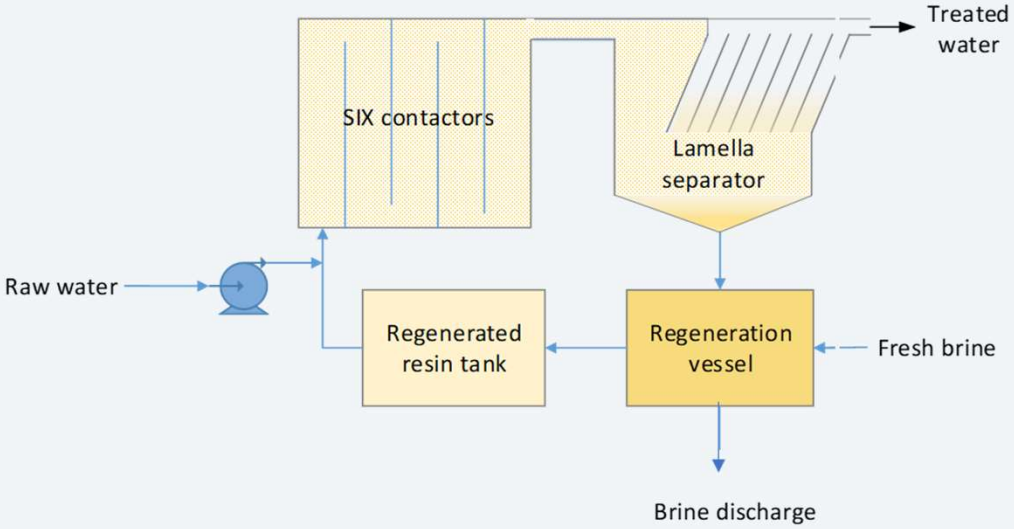
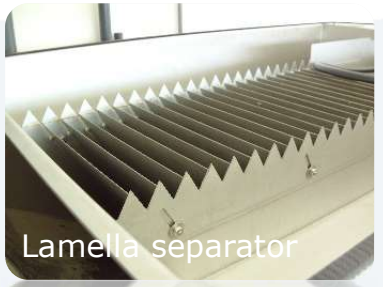
3- Pilot plant operations

contact time 30 minutes

15mL/L Lewatit S 5128 (initially in cl form)





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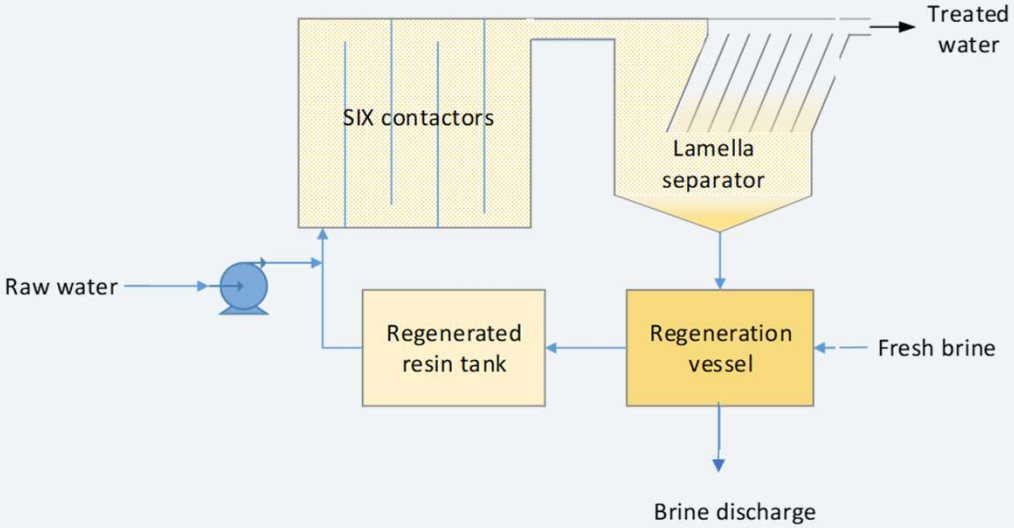
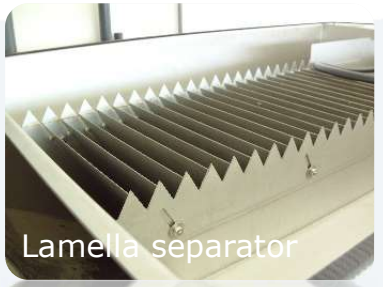


Regeneration with: - 50 g NaCl/L (initial conditions)
- 84 g $NaHCO_3$/L (2.5 weeks)
- 65 g $NaHCO_3$/L (1 week)



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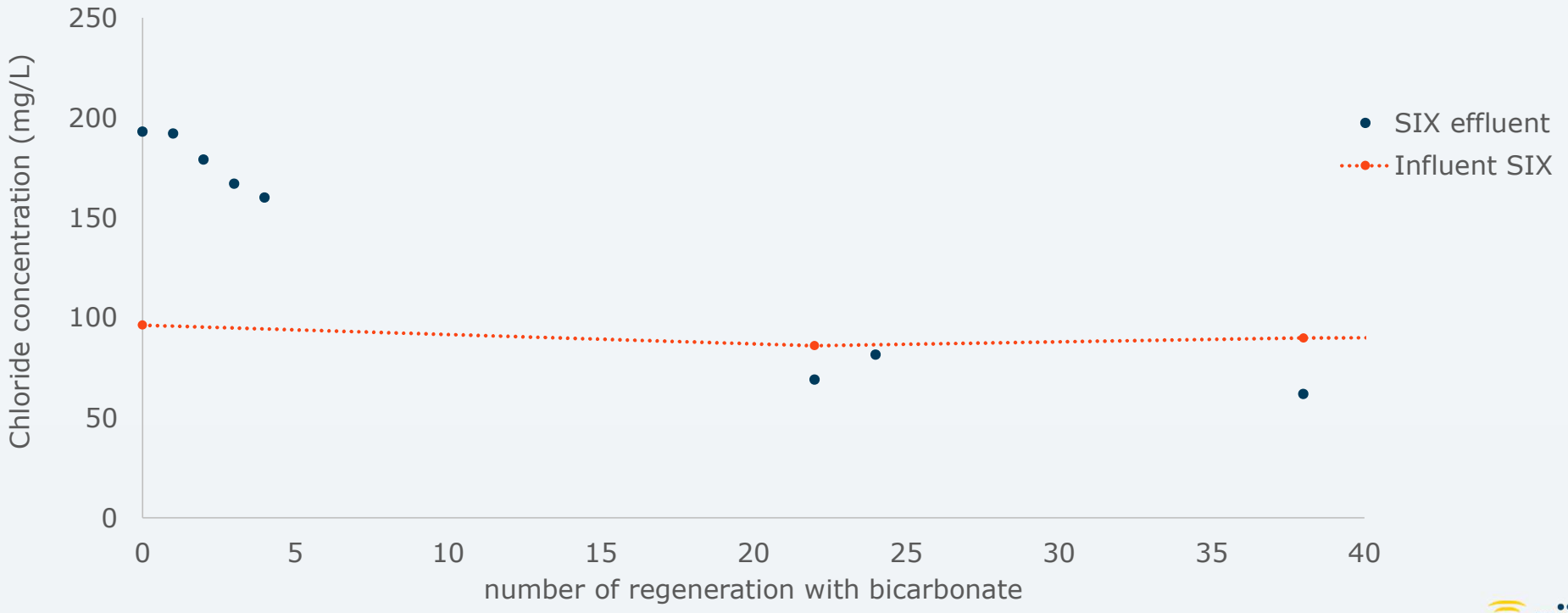
3- Transition to HCO_3 regeneration



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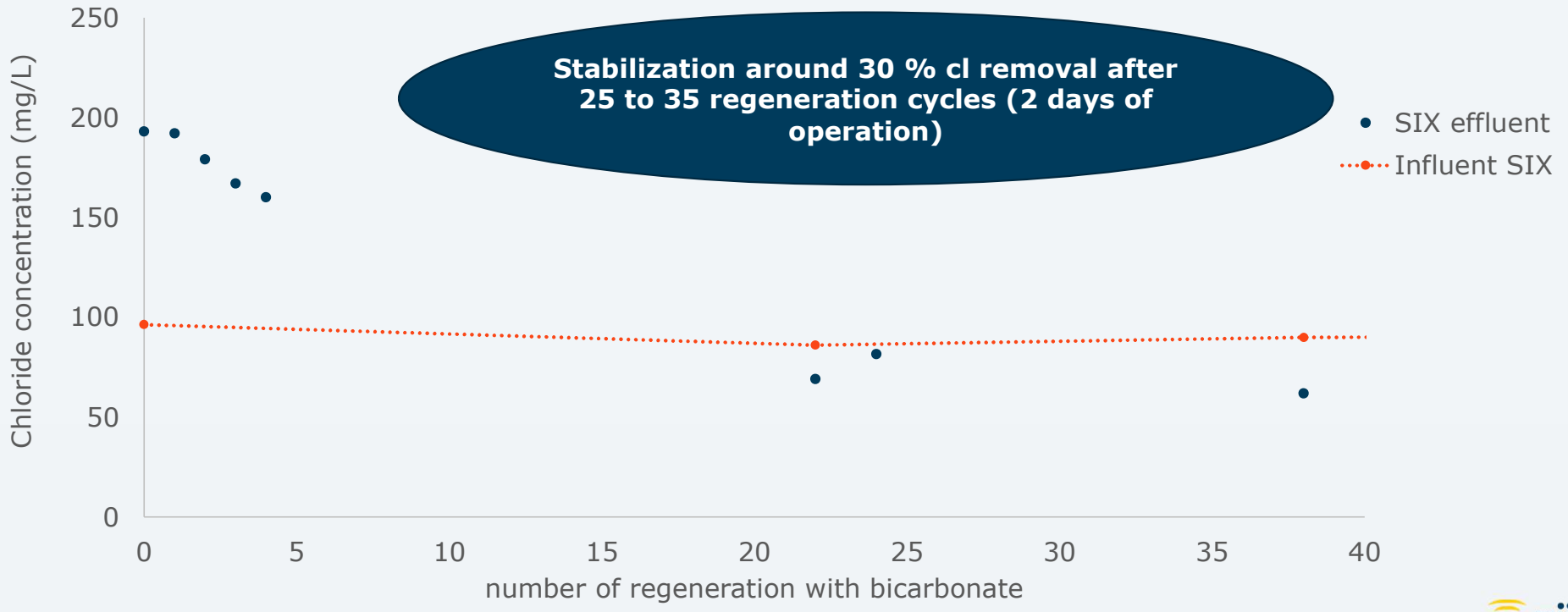

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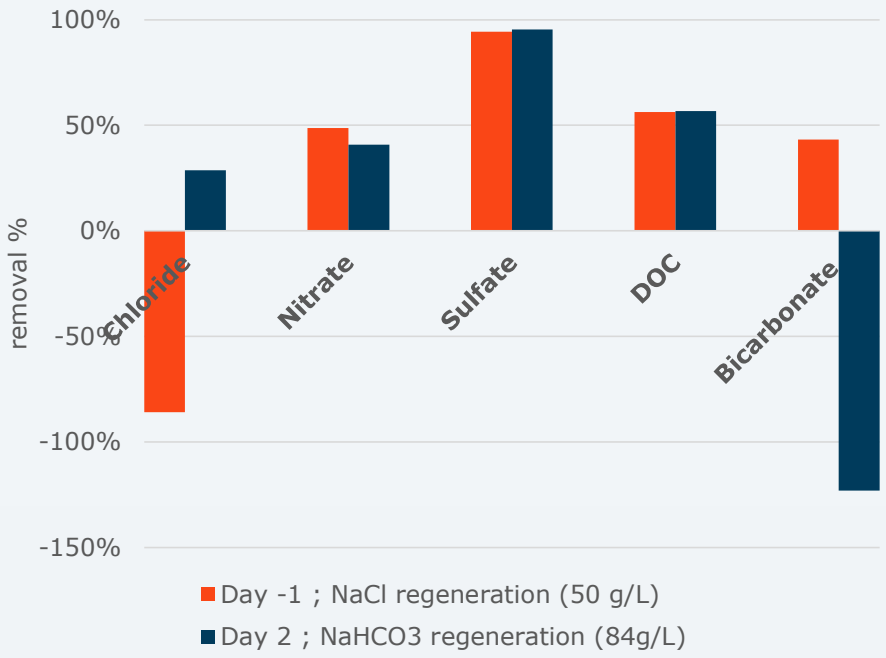

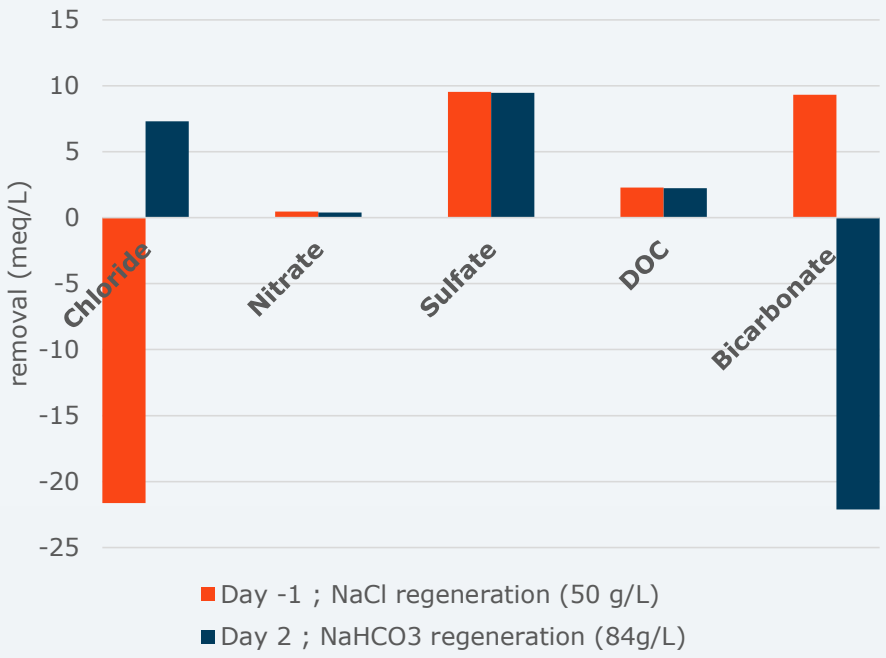

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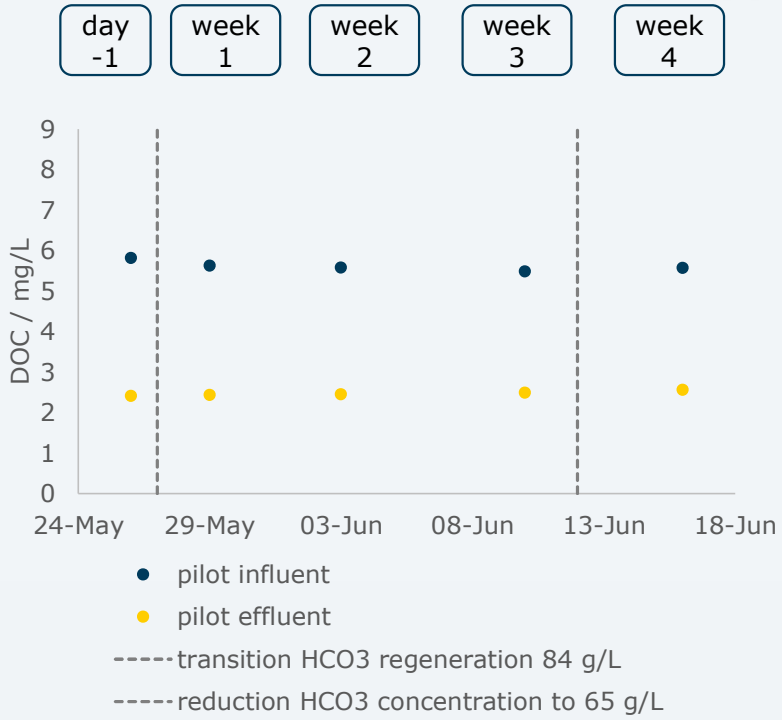
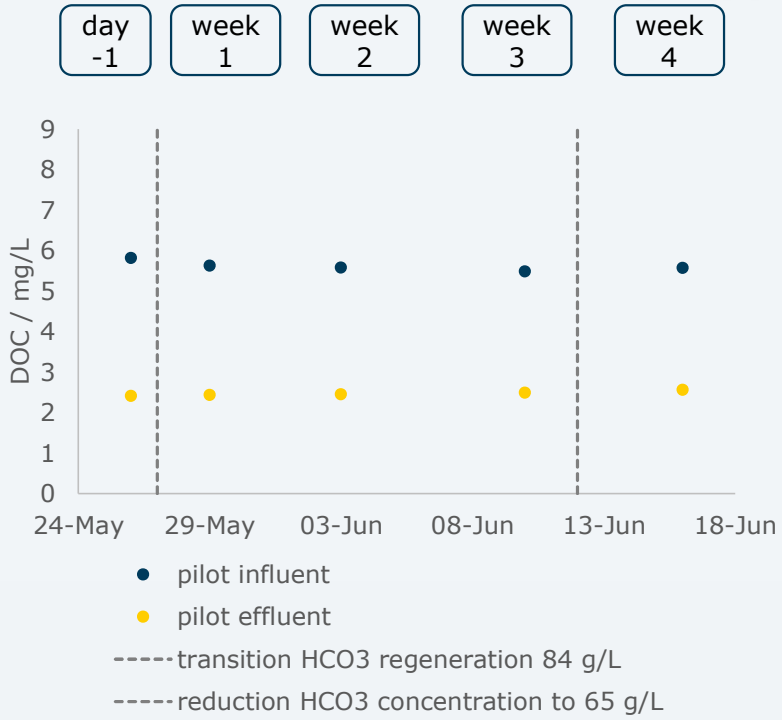
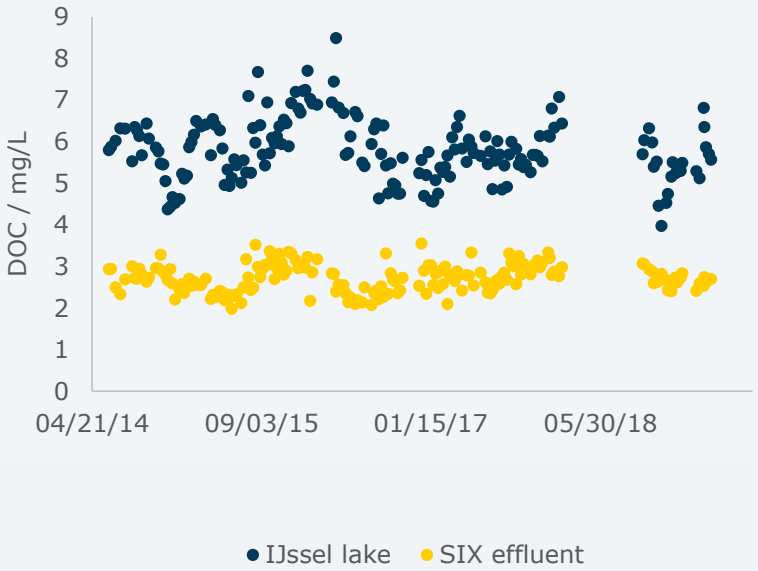
3- Continuous DOC removal with HCO_3 resin



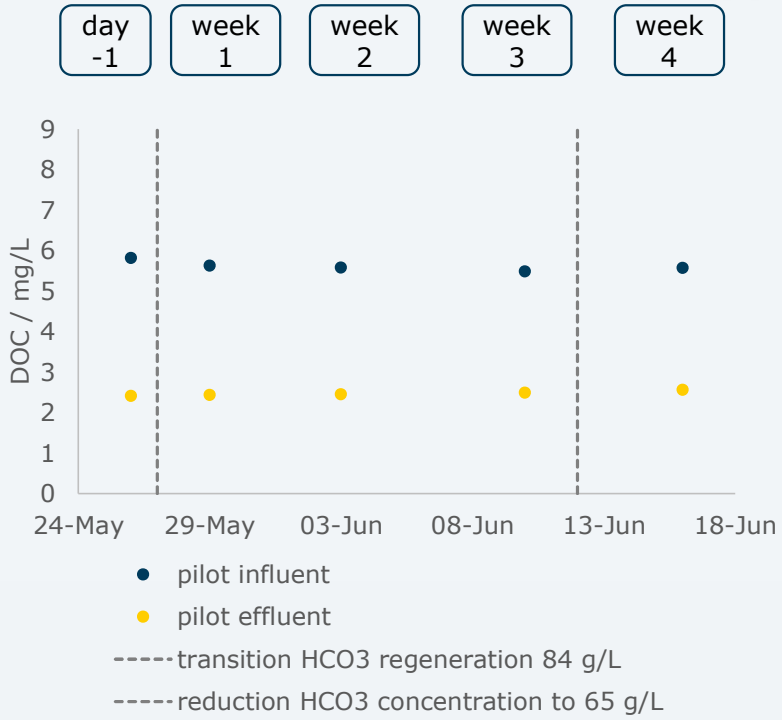
- Average 55 % reduction DOC
- Stable in time

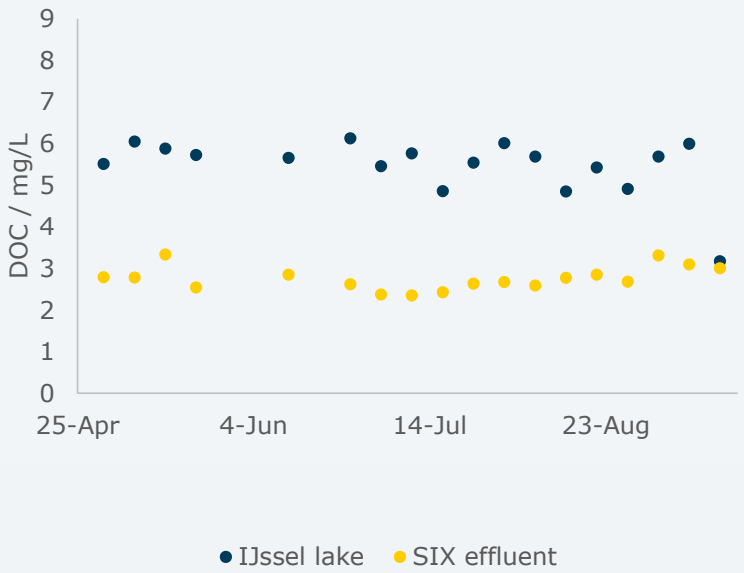
3- Continuous DOC removal with HCO_3 resin



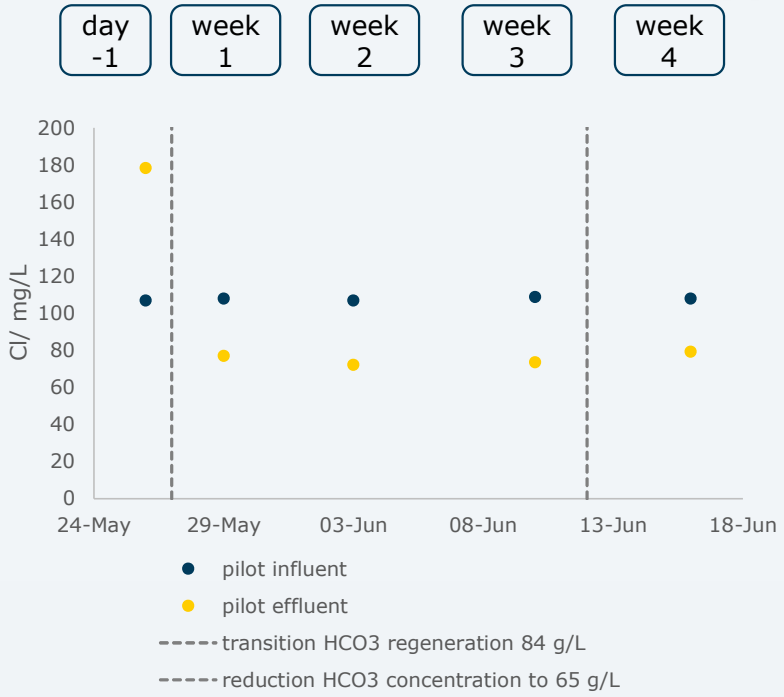


3- Continuous DOC removal with HCO_3 resin



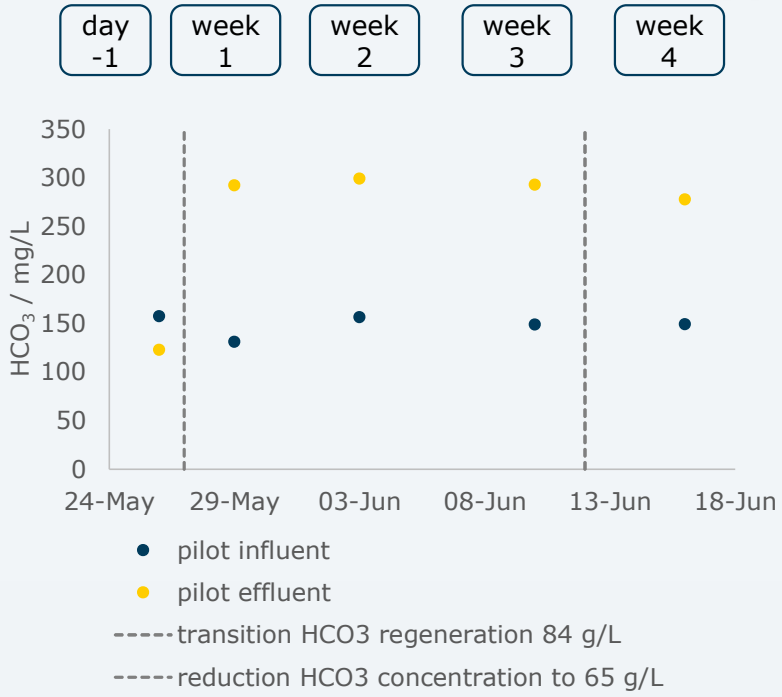


3- Continuous chloride removal with HCO_3 resin



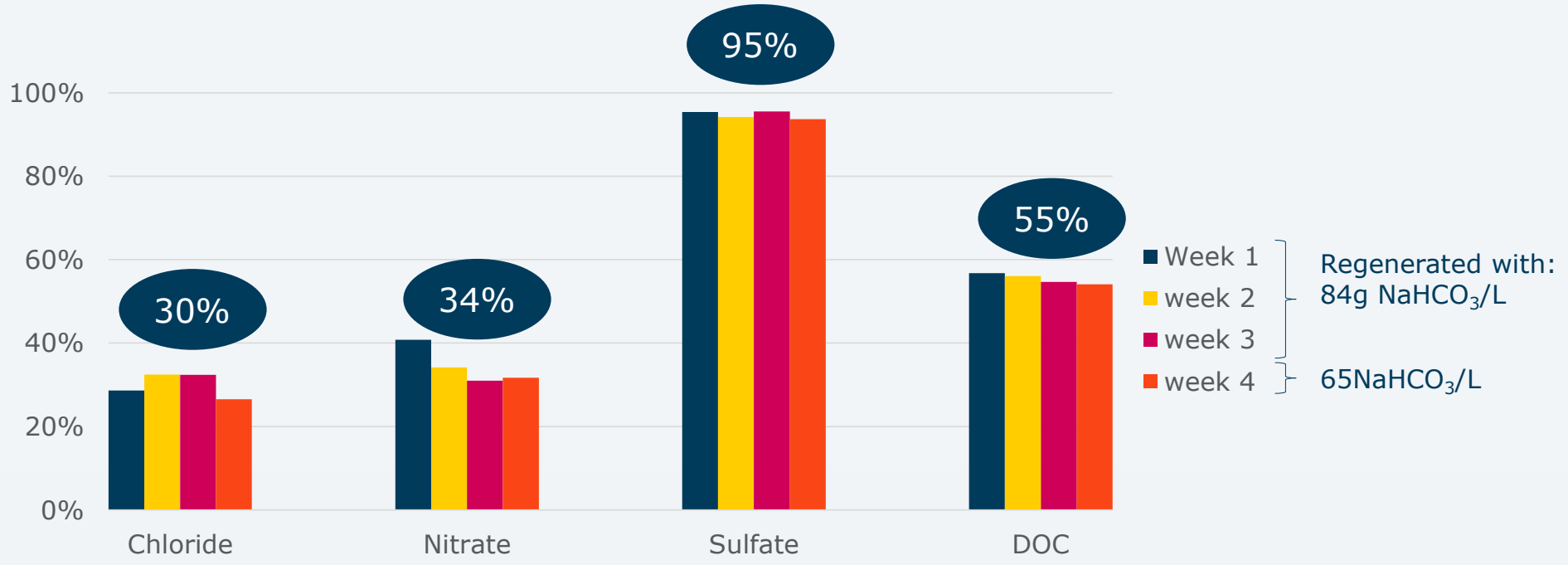
- Average reduction chloride in effluent:
  - 30 % compared to influent water
  - 60 % compared to full scale/ chloride exchange situation
- Below Dutch quality standards

3- Continuous HCO_3 exchange



- Average HCO_3 increase :
  - 87% with 84g/L HCO_3 regeneration
  - 75% with 65 g /L HCO_3 regeneration
- No impact on pH
  - Influent water pH: 8.1
  - Pilot effluent pH: 7.9
  - Full scale effluent (cl form): 8.2

3- Anions removal with HCO_3 resin



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3- Spent brine composition

Regeneration conditions	84 g $NaHCO_3$/L (61 g HCO_3/L)	+/-	65 g $NaHCO_3$/L (47 g HCO_3/L)	
Bicarbonate	26 (43% in excess)	1.6	18 (38% in excess)	g/l HCO_3
Sulfate	6.1	0.2	6.0	g/l SO4
Chloride	4.4	0.1	3.9	g/l Cl
DOC	350	30	400	mg/l C
Nitrate	280	80	240	mg/l NO_3
pH	9	0.1	9.1	

conclusions

Proof of principle on alternative regeneration with HCO_3

- Adsorption:
  - Similar removal (kinetic and equilibrium) of DOC / UV_{254}-absorbing substances /nitrate and sulphate
  - Continuous operations maintains DOC removal at 55%
  - While reducing the chloride in treated water
    by 28 % compared to influent water
    and 60 % compared to current situation

- Resin regeneration
  - Regeneration with 65 g/L $NaHCO_3$ maintained stable continious operation
  - Further optimization may be possible

Feasibility regeneration with HCO_3

- Water quality improvement
  - Reduced chloride
  - Increased alkalinity
  - Reduced corrosion index
- Spent brine management
  - Reduced environmental impact of disposal
  - Reduced corrosion index
  - Compatible with WWTP disposal (positive impact on nitrification)
  - Reduced costs of disposal than NaCl
- Plant operations
  - $NaHCO_3$ manufactured as powder compared to rock salts for NaCl
  - Low solubility: 90 g $NaHCO_3$ /L at 20^{o}C compared to 360 g NaCl /L
  - Decrease in solubility with temperature
  - Additional dissolution time
  - Potential formation of carbonate precipitate
  - Carbon source for biological growth
- Salt usage and cost
  - Increased mass usage of HCO_3 compared to Cl
  - Increased cost of HCO_3 per mass compared to Cl
  - Overall estimated 6 times increase

Thank you !

Question?

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