ZERO BRINE

WP5 Update

ZERO BRINE Project Meeting, Barcelona, Sept. 19th 2019

DLR, UNIPA, NTUA, EURECAT, TU Delft, SEALEAU

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The ZERO BRINE project (www.zerobrine.eu) has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730390.

5.1 - Refurbishment and minor design modifications (upgrade) of pilot brine treatment systems

Refurbishment of the MED-NTUA Evaporator

- Installation of the **evaporator and crystallizer** in 20 feet high cube container for the safe and easy transportation, its protection against corrosion due to exposure to outside environment, and avoidance of intended or unintended damage.
- **Replacement of 2 steam traps and relevant auxiliaries** (INOX valves, filter, non-return check valves);
- Installation of **4 polypropylene tanks** (capacity: 300 liters each) (2 feed brine containers, 1 distillate water container and 1 concentrated brine container).
- Installation, mounting and connection of the (i) **brine circuit** (container, dosing pumps); (ii) **concentrated brine circuit**; (iii) **distillate water circuit.**
- Installation of 1 **new pump for the recirculation of the brine** exiting the 1st effect (type: centrifugal, nominal flow: 0.3 m^3/h).
- Installation of **2 new feed pumps** (type: dosing, nominal flow: 0.05 m^3/h).
- Level electrodes mounted on 4 polypropylene containers.
- Installation of 1 new pump at the exit of the 2nd effect of the evaporator for the recirculation of the brine (type: centrifugal, power: 0.55 kW, nominal flow: 1.8 m^3/h).
- Installation of one **heat exchanger for the condensate vapor**.

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Installation of the MED-NTUA Evaporator & of the Crystallizer (March 2019)

Transportation of the container from Greece to the Netherlands (August 2019)

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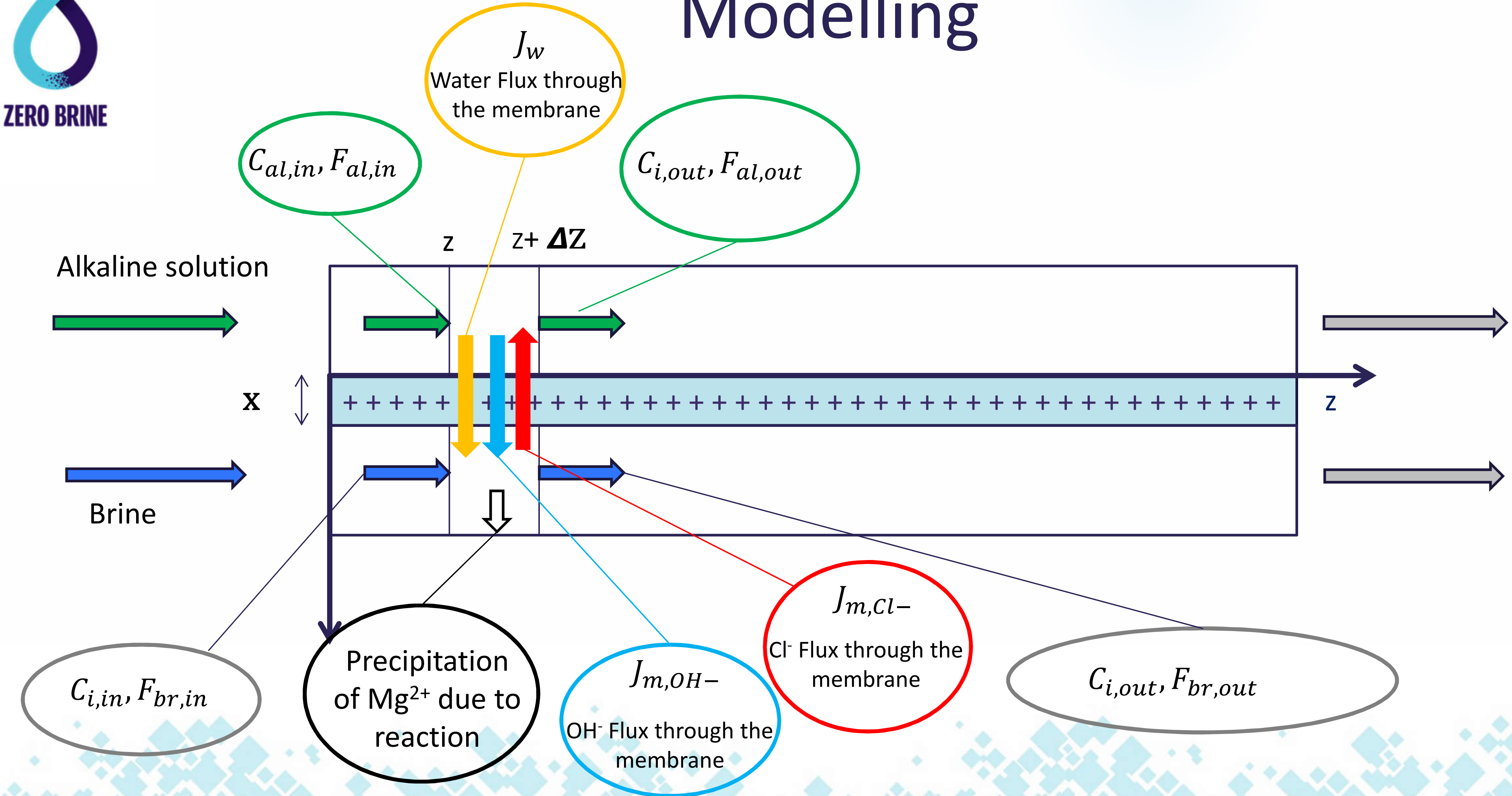
Modelling



J_w
Water Flux through the membrane
$C_{al,in}, F_{al,in}$
$C_{i,out}, F_{al,out}$
z
z+ ΔZ
Alkaline solution
x
z
Brine
$C_{i,in}, F_{br,in}$
Precipitation of Mg^{2+} due to reaction
$J_{m,OH-}$
OH^- Flux through the membrane
$J_{m,Cl-}$
Cl^- Flux through the membrane
$C_{i,out}, F_{br,out}$

Mass Balance Equations

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$$J_{m,OH^-} = -D_{OH^-} * \frac{\Delta C_{OH^-}}{x} - \frac{D_{OH^-} * z_{OH^-} * C_{OH^-} * F * \Delta\psi}{RTx} + J_w * C_{OH^-}$$

Alkaline Channel

$$C^{OUT}_{OH^-} * F^{OUT}_{al} = -(J_{m,OH^-}) * w\Delta z + (C^{IN}_{OH^-} + 2x) * F^{IN}_{al}$$

$$C^{OUT}_{Cl^-} * F^{OUT}_{al} = -(J_{m,Cl^-}) * w\Delta z + C^{IN}_{Cl^-} * F^{IN}_{al}$$

$$C^{OUT}_{Ca^{2+}} * F^{OUT}_{al} = (C^{IN}_{Ca^{2+}} + x) * F^{IN}_{al}$$

$$F^{OUT}_{al} = (J_w) * w\Delta z + F^{IN}_{al}$$

Brine Channel

$$C^{OUT}_{Cl^-} * F^{OUT}_{br} = -(J_{m,Cl^-}) * w\Delta z + C^{IN}_{Cl^-} * F^{IN}_{br}$$

$$C^{OUT}_{Ca^{2+}} * F^{OUT}_{br} = C^{IN}_{Ca^{2+}} * F^{IN}_{br}$$

$$C^{OUT}_{Na^+} * F^{OUT}_{br} = C^{IN}_{Na^+} * F^{IN}_{br}$$

$$F^{OUT}_{br} = (J_w) * w\Delta z + F^{IN}_{br}$$

$$F^{REAC}_{OH^-} = (J_{m,OH^-}) * w\Delta z$$

$$F^{OUT}_{Mg^{2+}} = -\frac{F^{REAC}_{OH^-}}{2} + F^{IN}_{Mg^{2+}}$$

$$J_w = P_{os}\Delta\pi + \sum\beta_i * J_i$$

$$J_{m,Cl^-} = -D_{Cl^-} * \frac{\Delta C_{Cl^-}}{x} - \frac{D_{OH^-} * z_{Cl^-} * C_{Cl^-} * F * \Delta\psi}{RTx} + J_w * C_{Cl^-}$$

Nomenclature:

X is the molar concentration alkaline
β_i is the hydration number
$\Delta\psi$ is potential of the membrane
$\Delta\pi$ is the osmotic pressure
P_{os} is the permeability of membrane
z_i is the valence number of ith ion
F is the Faraday constant
x is membrane thickness
ΔC_i is the concentration gradient of the ith ion between the surfaces of the membrane

Mass Balance Equation at two Storage tanks (alkaline and brine solution)

$$\frac{d\boldsymbol{\rho}_{brine}V_{brine}}{dt} = \boldsymbol{\rho}_{brine,in,dyn} * F_{brine,in,dyn} - \boldsymbol{\rho}_{brine,out,dyn} * F_{brine,out,dyn}$$

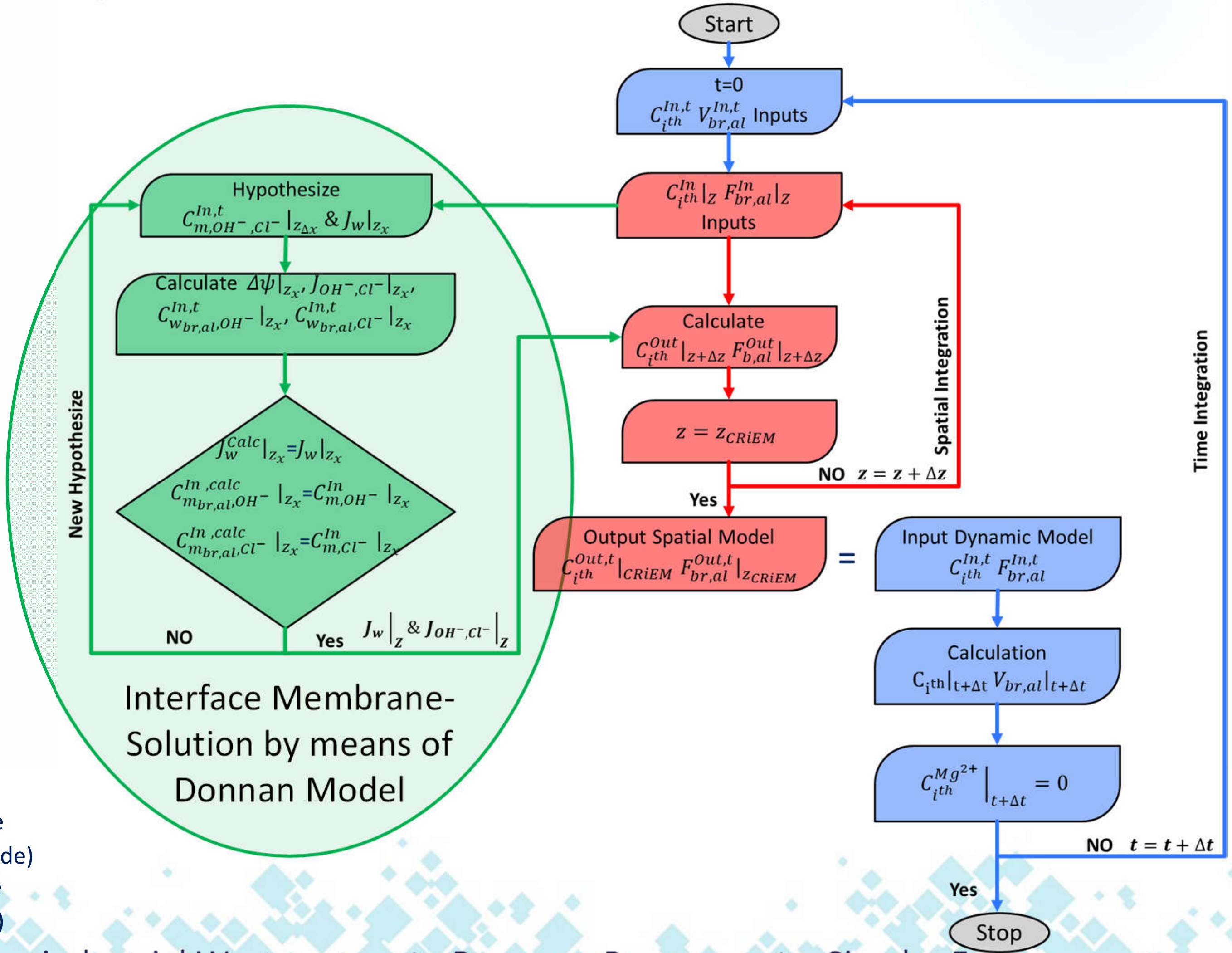
$$\frac{d\boldsymbol{\rho}_{alk}V_{alk}}{dt} = \boldsymbol{\rho}_{alk,in,dyn} * F_{alk,in,dyn} - \boldsymbol{\rho}_{alk,out,dyn} * F_{alk,out,dyn}$$

Conditions:

$F_{brine,in,dyn} = F_{2,out}$ $F_{brine,out\ dyn} = F_{2,in}$

$F_{alk,in,dyn} = F_{1,out}$ $F_{alk,out,dyn} = F_{1,in}$

Algorithm for the numerical implementation



Nomenclature:

$C_{m^{br,al}, i^{th}}$ is the concentration in the surface of membrane (membrane side)

$C_{w^{br,al}, i^{th}}$ is the concentration in the surface of membrane (solution side)

Model vs Experimental data

Operative Initial Condition:

- Brine Side:
- Mg^{2+} = 0.32 g/l
- Ca^{2+} = 0.42g/l
- Na^{+} = 10.6 g/l
- Cl^{-} = 16.95 g/l
- OH^{-} = 0 g/l

- Alkaline side:
- Ca^{2+} = 0.92 g/l
- OH^{-} = 0.78 g/l

Model Results	Volume Flow-rate [ml/min]	Time Conv [min]	Final Volume Brine [l]
Test 1	22	175	2.034
	40	146	2.020
Test 2	80	123	2.010
	100	118	2.008
Test 3	160	111	2.005

Experimental Data	Volume Flow-rate [ml/min]	Time Conv [min]	Final Volume Brine [lt]
Test 1	22	160	2.04
Test 2	80	120	2.01
Test 3	160	100	2.005

EFC Experiments (EURECAT)

- the experiment test bench (EFC)running
- correlations will be obtained within next weeks
- planned integration of results for model validation
- ED: EURECAT is updating the model

5.2 - Plans for shared use of BEC equipment

- New updated report delivered by June 2019
  - List of available technologies
  - Updated schedule plan for shared use of BEC equipment

5.3 - Development of technology libraries (software tool) and integration into a common platform

- Task concluded 11/2018
- All selected technolgies have been modeled
- Modules from DLR and EURECAT could be integrated in the common simulation platform (RCE)
- Issues regarding RCE server connectivity have been solved
- … more in the workshop this afternoon ☺