Supporting Information

Layer-by-layer membrane modification allows scandium recovery by nanofiltration

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Elemental analysis

The concentrations of Fe and Mg were analyzed in triplicate using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) (Spectroblue SOP, Spectro Analytical Instruments, Kleve, Germany) using standard conditions (power of 1,400 W, coolant flow: 13 L/min, auxiliary flow: 1 L/min, nebulizer flow: 0.75 L/min). All other elements were measured using triple quadrupole Inductively Coupled Plasma Mass Spectrometry (qqq-ICP-MS) on an Agilent 8800 series machine (Agilent, Basel, Switzerland) using general-purpose operational settings. Quantification was performed via multi-element standards (Sigma- Aldrich). Rh was used as internal standard to account for matrix effects. Chloride concentrations were analyzed using ion chromatography (IC). The IC consisted of a Dionex 2100 system, equipped with an online eluent generator, a self-regenerating suppressor, a guard and analytical column (AG17-C and AS17-C, 2 mm) (all Dionex, Olten, Switzerland). Chloride was separated from other ions using a hydroxide gradient and quantified by conductivity detection.

Tab 1. Elemental concentration in the acid waste solution

Element	Concentration [mg/L]	Removal at pH 1.5 precipitation [%]
Sc	76 - 90	~20
Ni	22 - 84	0
U	20 - 23	~40
Th	102 - 133	~75
Ti	3 906 - 4 228	100
Na	447 - 1 182	-
Al	6 124 - 7 722	0
Ca	667 - 839	-
Fe	39 374 - 45 160	0
K	401 - 631	-
Cl	153 150 - 180 000	-

Tab 2. Elemental concentration in the retentate after pH adjustment, dilution and filtration (60% permeate recovery)

Element	Concentration [mg/L]
Sc	23
U	5
Th	93
Fe	8 070

Filtration set-up

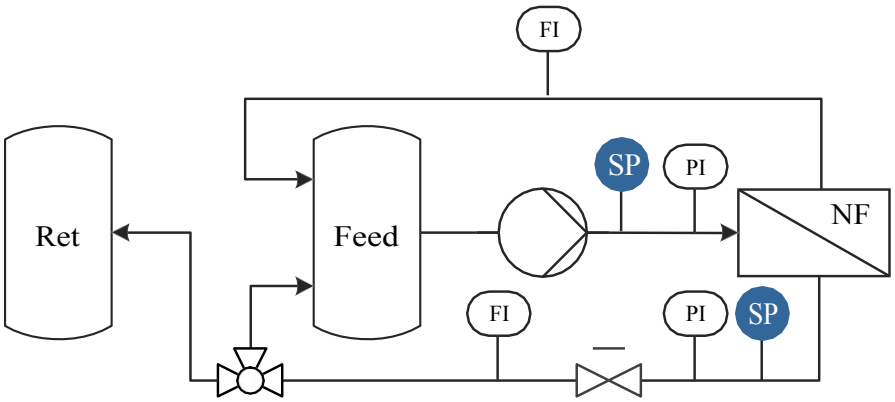

Figure 1: Flow chart of the custom made filtration unit used for the experiments with flowmeters (Fl), pressure meters (Pl) and nanofiltration membrane (NF)

Stability towards higher HCl concentrations

Magnesium retention was used as an indicator of membrane acid stability. For this, 0.5 mM Mg was dissolved in deionized water. Mg retention was determined in cross-flow mode (5 bars of transmembrane pressure, TMP) using 0.5 mM Mg solution. The flow was 160 mL/min, resulting in a cross-flow velocity of 2.65 m/s and a Reynolds number > 2,300 (thus a turbulent flow). HCl (32 wt%; Roth, Switzerland) was diluted in deionized water to 1 M, 2 M and 3 M, respectively, and Mg (as Mg_2SO_4 heptahydrate, ≥ 99%, Sigma-Aldrich) added to a final concentration of 0.5 mM.

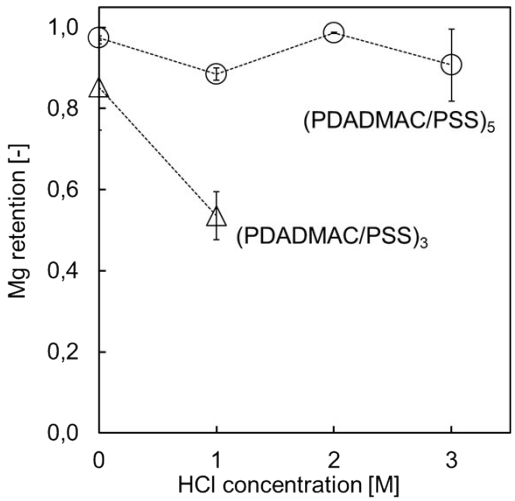

Figure 2: Acid stability in terms of Mg retention as a function of HCl concentration using 3 or 5 bi-layers systems. Coating was done at a higher (1 M NaCl) ionic strength .