Application of the SisClever process in a pilot-scale mixer-settler battery to separation and purification in valuable-metals recycling

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Motivation

challenge: ores, waste, fermentation broth: complex mixtures of valuable components

conventional solution: complex multi-step hydrometallurgical separations

efficient recycling of critical metals (Co, Li, REEs) and other components: circular economy and urban mining

Goals

simple, high purity, and high concentration separation process

Theoretical basis

net flow rate:

$$\dot{G}Y_i - \dot{L}X_i = \dot{L}X_i\left(\frac{\dot{G}Y_i}{\dot{L}X_i} - 1\right) = \dot{L}X_i\left(\frac{\dot{G}K_i}{\dot{L}} - 1\right) = \dot{L}X_i(\lambda_i - 1)$$

with $\frac{Y_i}{X_i} = K_i$ and $\frac{\dot{G}K_i}{\dot{L}} = \lambda_i$

Process Idea: SisClever Process

SImultaneous **S**eparation of multi-**C**omponent systems to high **LEVE**l of **R**ecovery

- accumulation zones, $\lambda_i = 1$, for each component individually along the process
- example reactive extraction: impose corresponding pH-profile

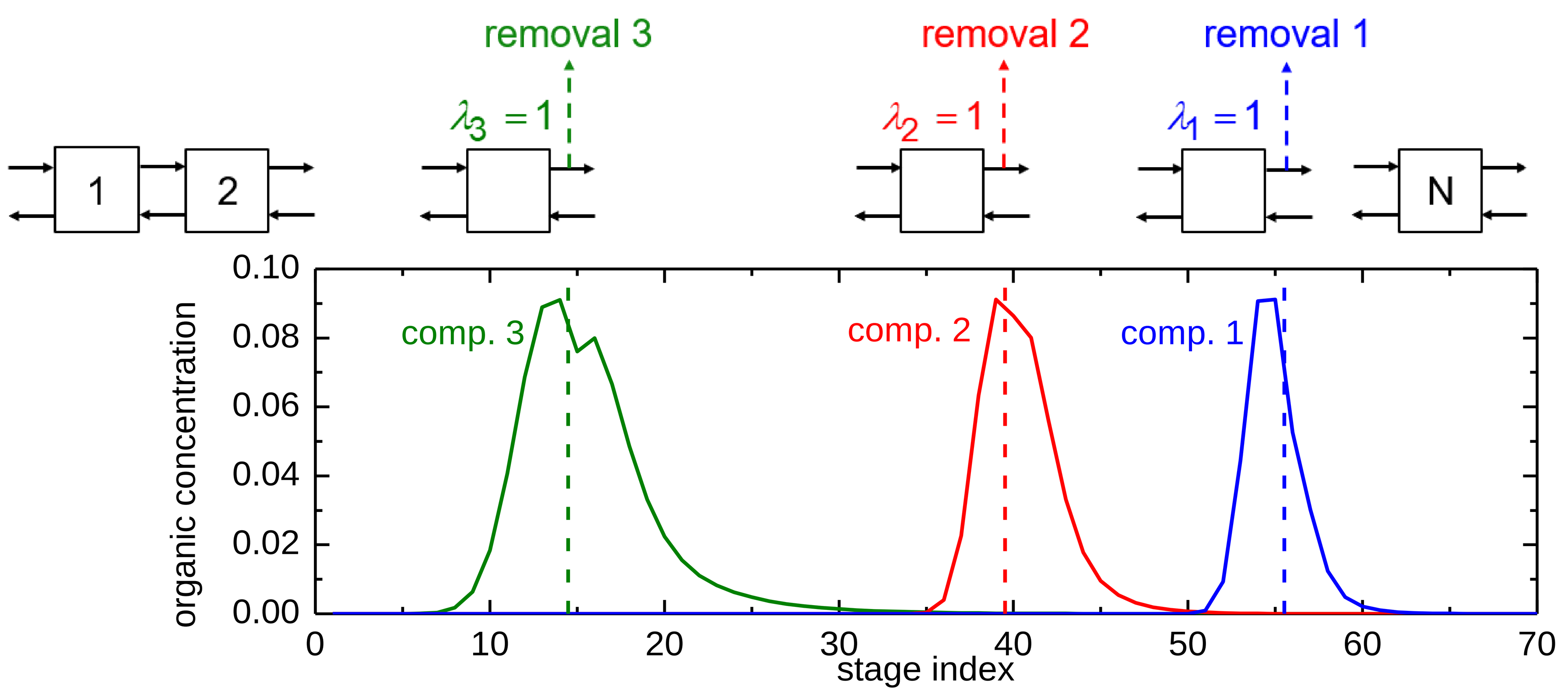

Figure 1. schematic representation of the process idea with three transfer components

Validation

Zn^{2+} and Co^{2+}, extractant D2EHPA

initial state: simulated steady state

constant *p*H-profile: HCl and NaOH injections

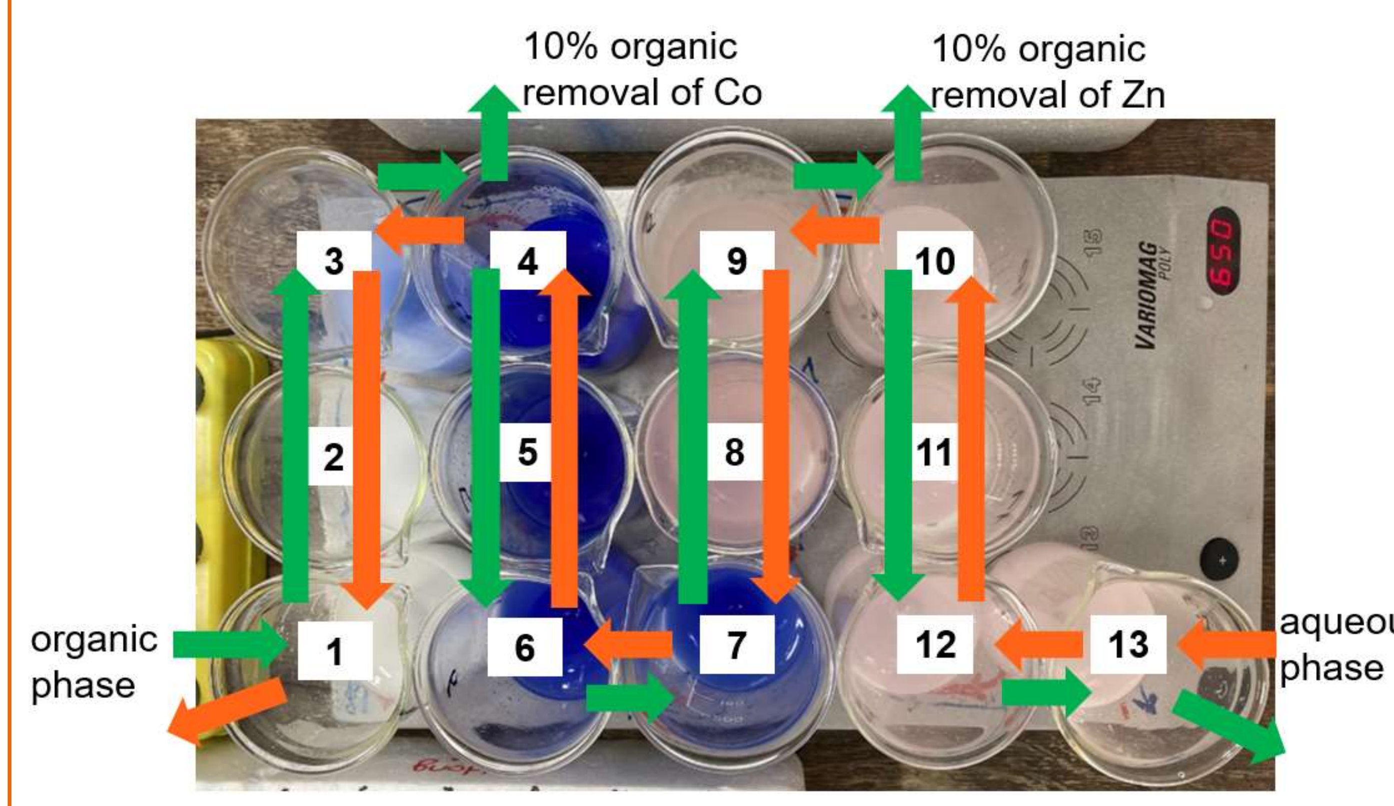

Figure 2. Extraction of Co and Zn with D2EHPA: 13 equilibrium stages

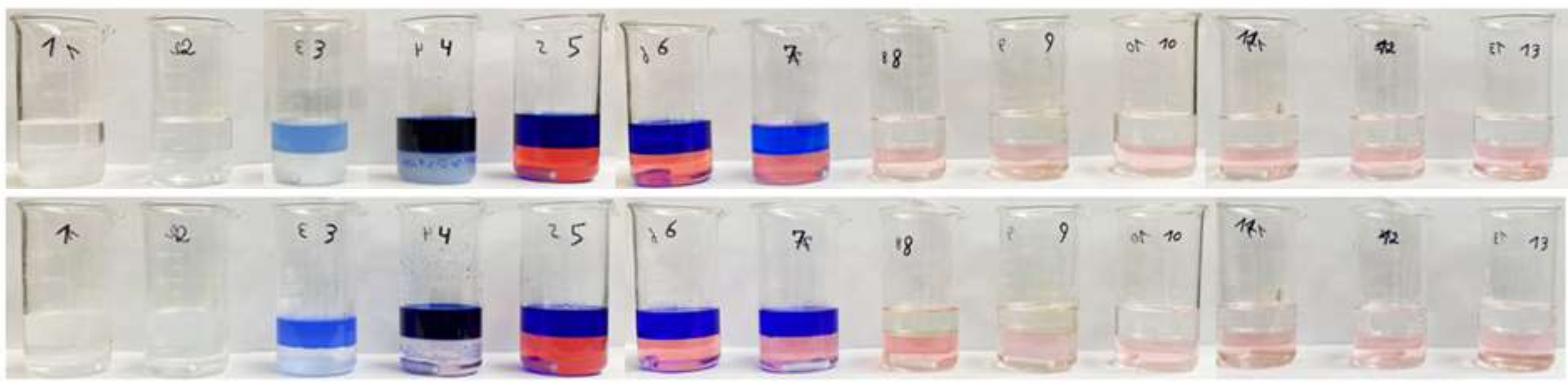

Figure 3. beakers at start of experiment, and after 5 residence time

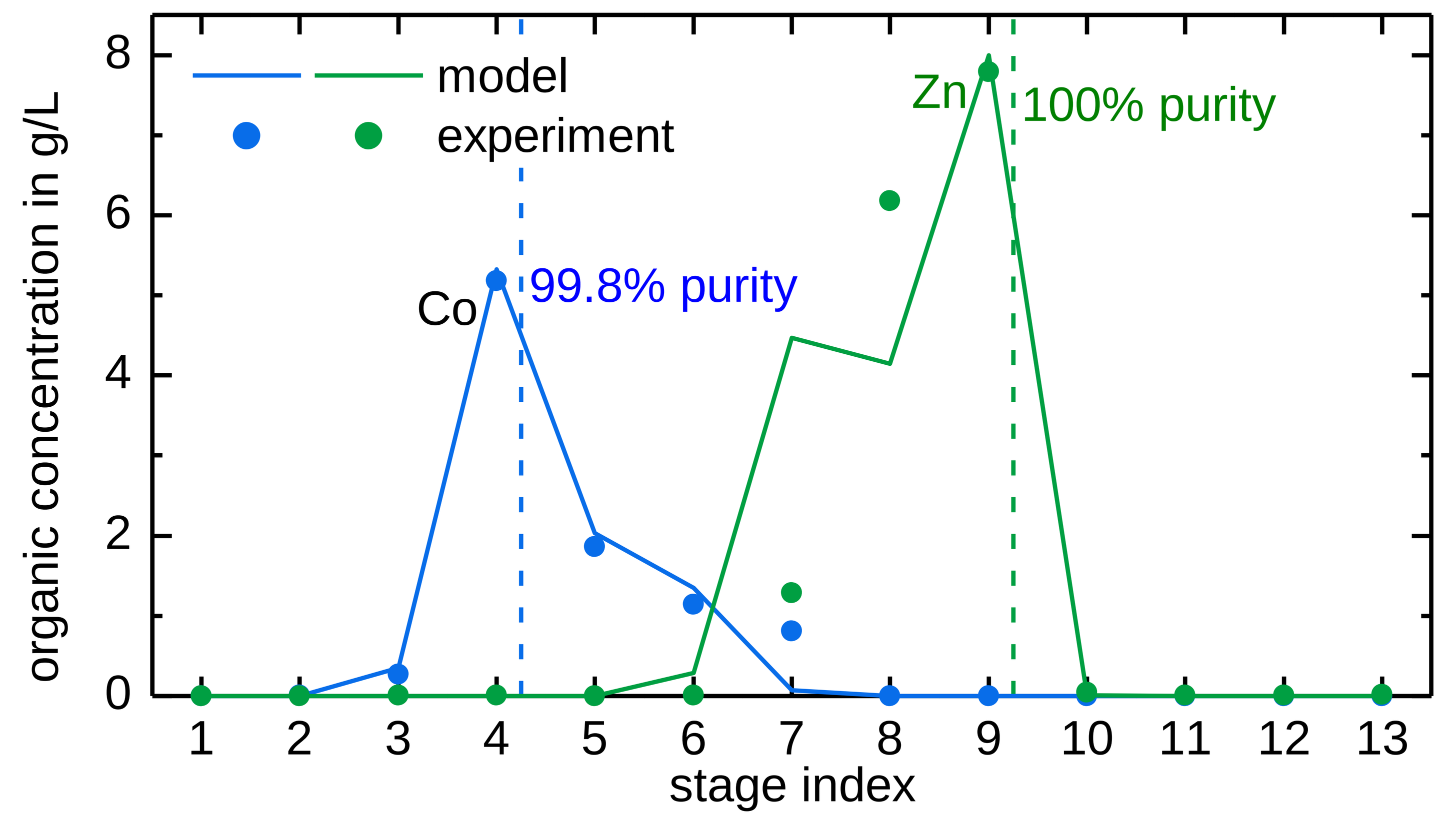

Figure 4. experimental result compared to simulated steady state. Inlet concentrations: Co^{2+}: 0.53 g/L, Zn^{2+}: 0.80 g/L

Conclusions

- steady state = initial c-profile, i.e. simulated steady state: simulation exact, steady state reached
- c-profile as predicted: process validated in quasi-steady state
- high enrichment as predicted: 10-fold enrichment easily possible
- high purities at removal

Advantages

- high purity by adjusting theoretical stages
- high enrichment by small product removal flowrates
- recovery of minor components from disparate feed
- flexible product concentration via controlled removal points
- main flowrate ratio around 1: easy operation and control

Limitations

- single extractant: challenge for future extractant development
- components with too similar equilibrium: single product

Next step

- 18 stages continuous MSU 0.5 mixer-settlers battery with pH and flow control
- process monitoring and control via LabVIEW
- test for up to four-metal separation

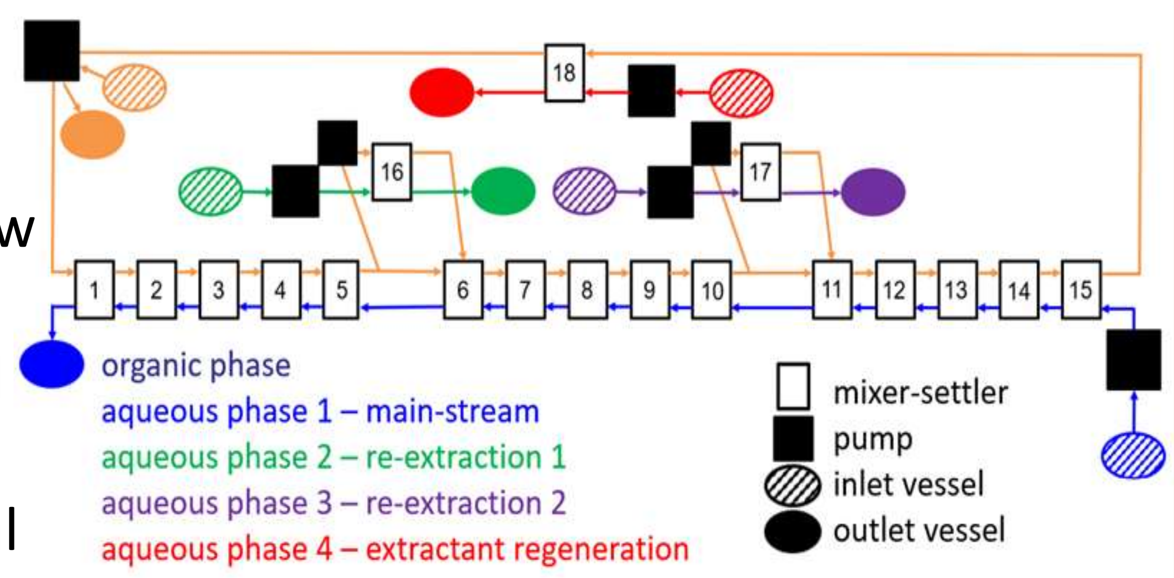

Figure 5. 18 stages mixer-settler configuration

Take-home messages

- efficient hydrometallurgy and recycling: high purity and concentration with minimal processing steps
- easy extraction and purification of valuable metals from primary and secondary resources: fosters urban mining and circular economy
- potential applications: cation-exchange extraction and metal separation, anion-exchange separation like organic or amino acids, others

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