

# VALOMAG

2<sup>nd</sup> Seminar – Delft, the 6<sup>th</sup> December 2022

## Leaching and selective recovery of rare earth elements found in NdFeB magnets using organic acids

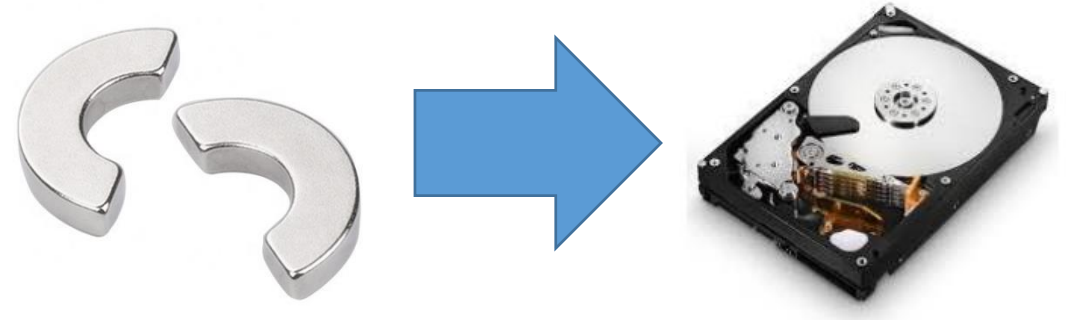
MENAD Nourredine - SERON Alain - BELFQUEH Sahar



Co-funded by the  
European Union



# Objectives

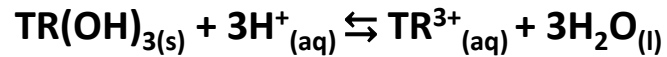
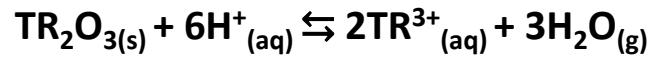
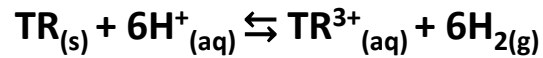


- To propose an outlet allowing rare earth elements (REEs) that can be recovered from ultimate permanent magnet material extracted under forms (fine powders, specific composition,) that cannot be reused in the direct recycling route
- To optimize leaching procedure (residence time, concentration of the solvent, reagents, temperature, ...);
- To improve kinetics of leaching and conversion efficiency

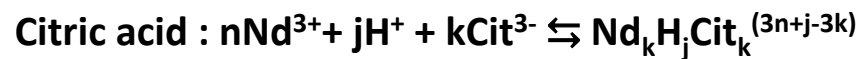
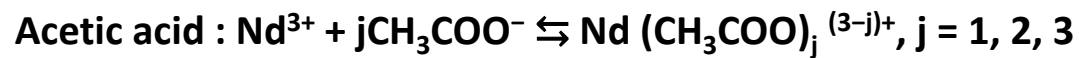
# Organic acids as leaching agents

*In a hydrometallurgical process, leaching is the process of dissolving certain metals from the ore or waste.*

Mineral acid, such as:  $\text{H}_2\text{SO}_4$ ,  $\text{HCl}$ ,  $\text{HNO}_3$

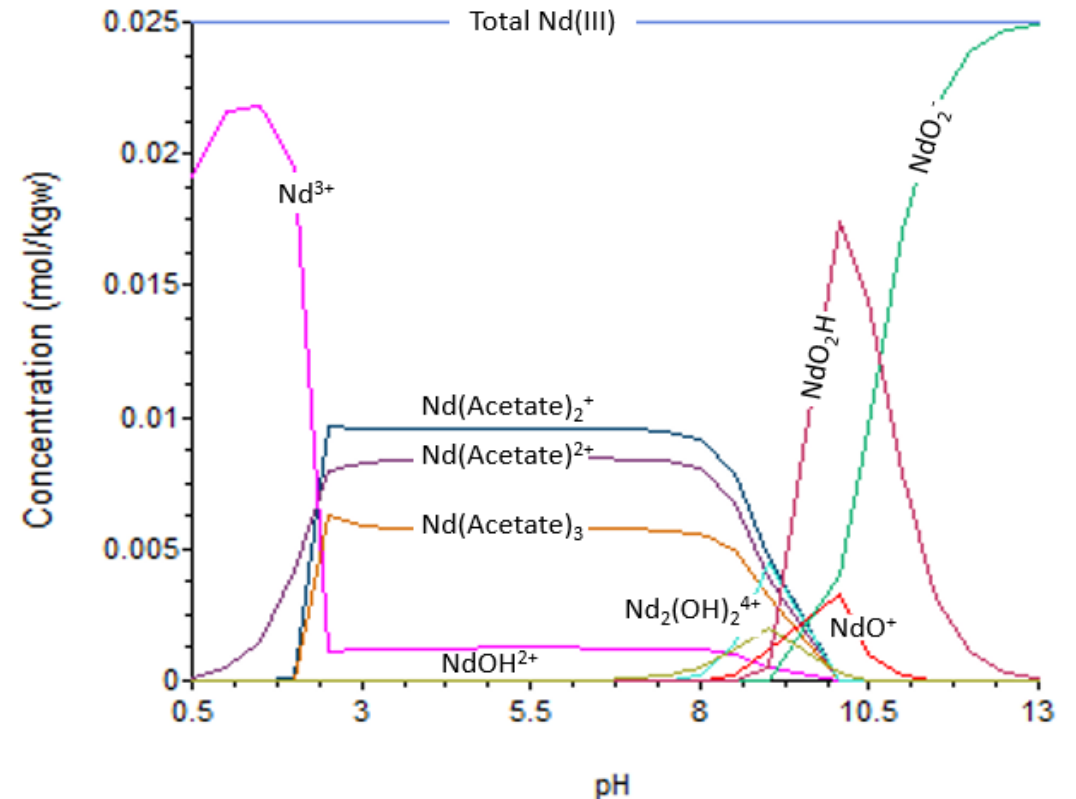


**Eco-friendly alternatives: organic weak acids**



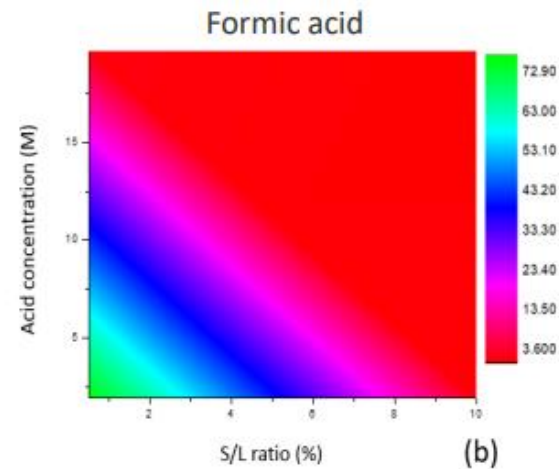
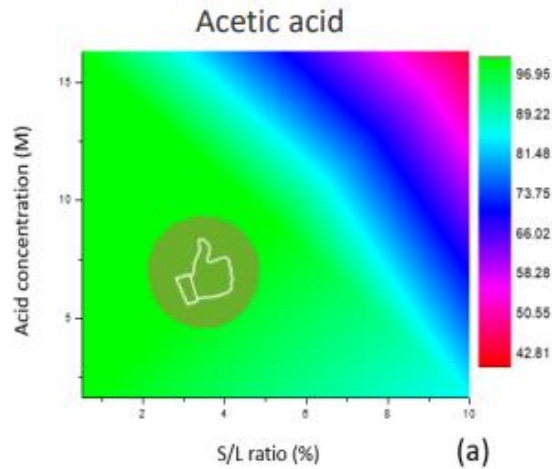
*Presence of  $\text{NdCit}$ ,  $\text{NdHCit}$ ,  $\text{NdHCit}_2$ ,  $\text{NdCit}_2$  in a pH range of [2-5].*

**Easier to handle, form less toxic gases, easier biodegradability, possible production from agro-industrial waste...**



*Aqueous speciation of Nd(III) as a function of pH in diluted acetic acid using pHreeqC (Database: LLNL).*

# Leaching performances of organic acids



Nd, Pr and Dy have the same leaching behavior in all tested acids

**Acetic acid:** Best candidate for leaching REEs under industrially favorable conditions; high S/L ratios and low acid concentrations

> 90% of REEs leached:

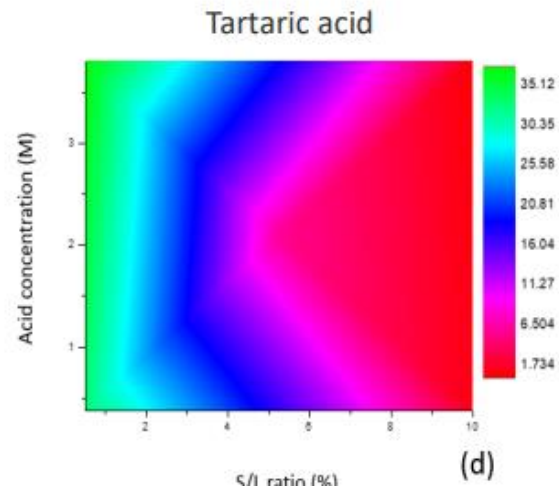
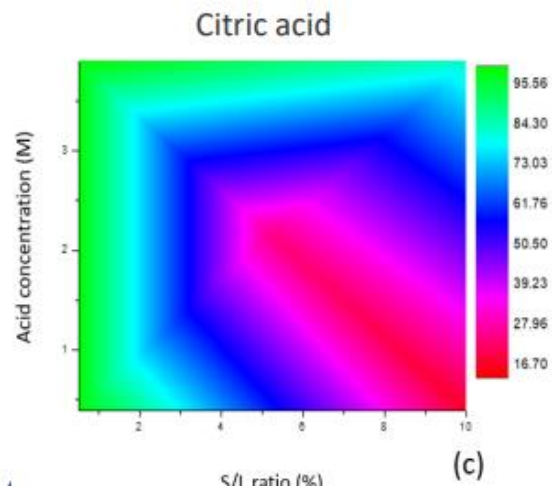
S/L ratio (%) [0.5 - 5]

Acetic acid concentration (M) [1.6-10]

**Partial/ total co-leaching of Fe, Co and B**

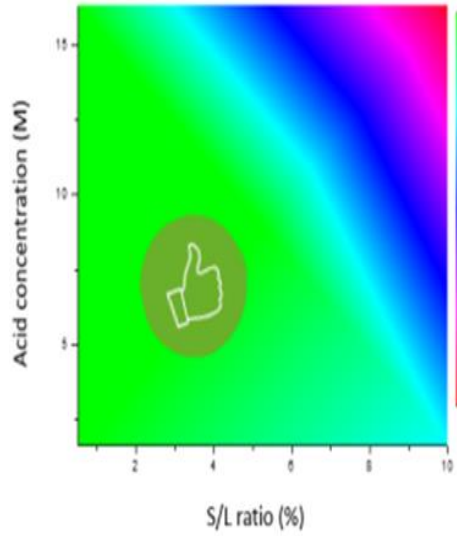
**Formic acid:** Precipitation of REEs in formates

**Tartaric acid:** Precipitation of REEs in hydroxides

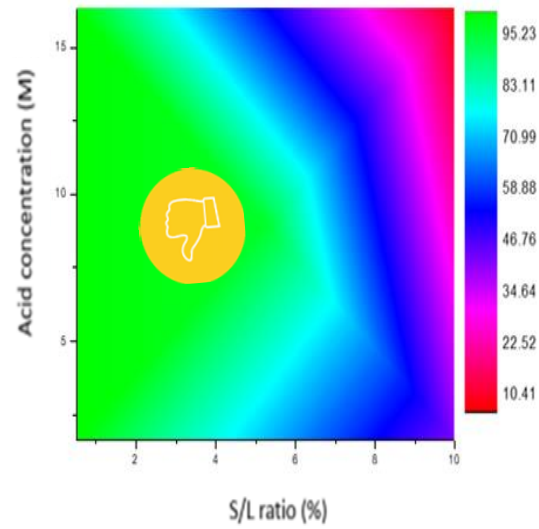


# Leaching performances of organic acids

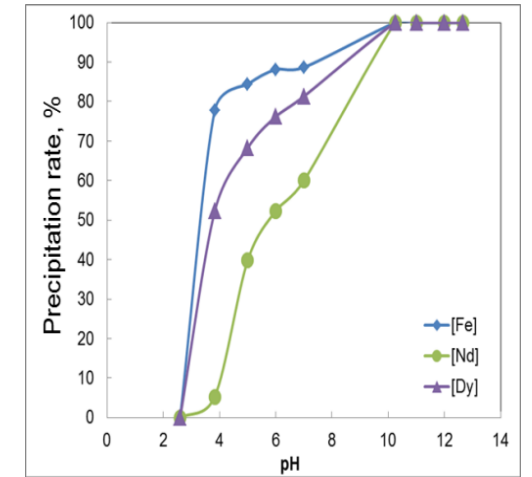
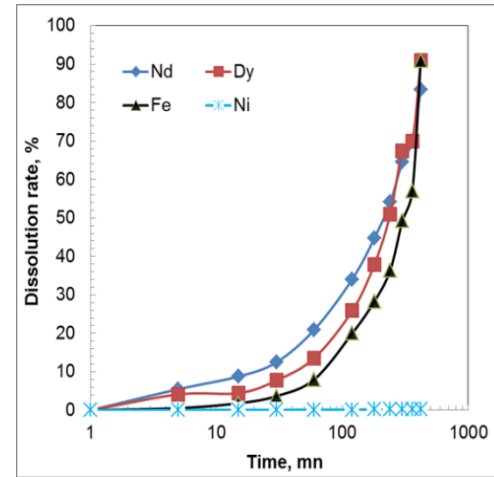
Nd



Fe



➔ No leaching selectivity between Rees and Fe

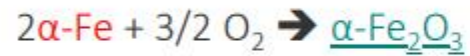
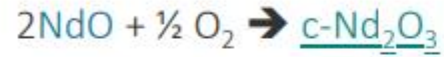


➔ Co-leaching and coprecipitation of Rees and Fe

# Roasting for selective leaching

Patented results

Oxidative roasting of NdFeB powder



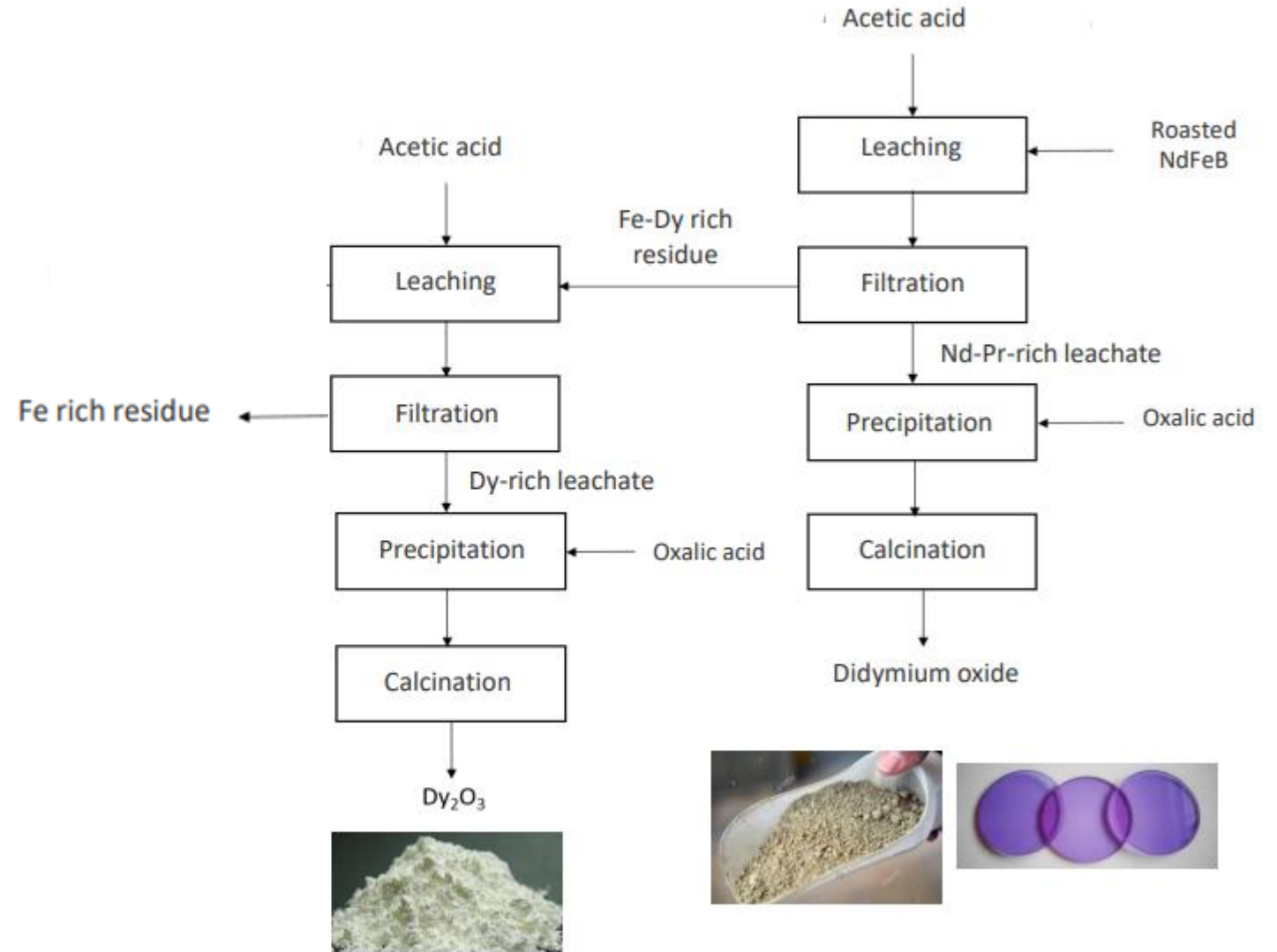
From 500°C:



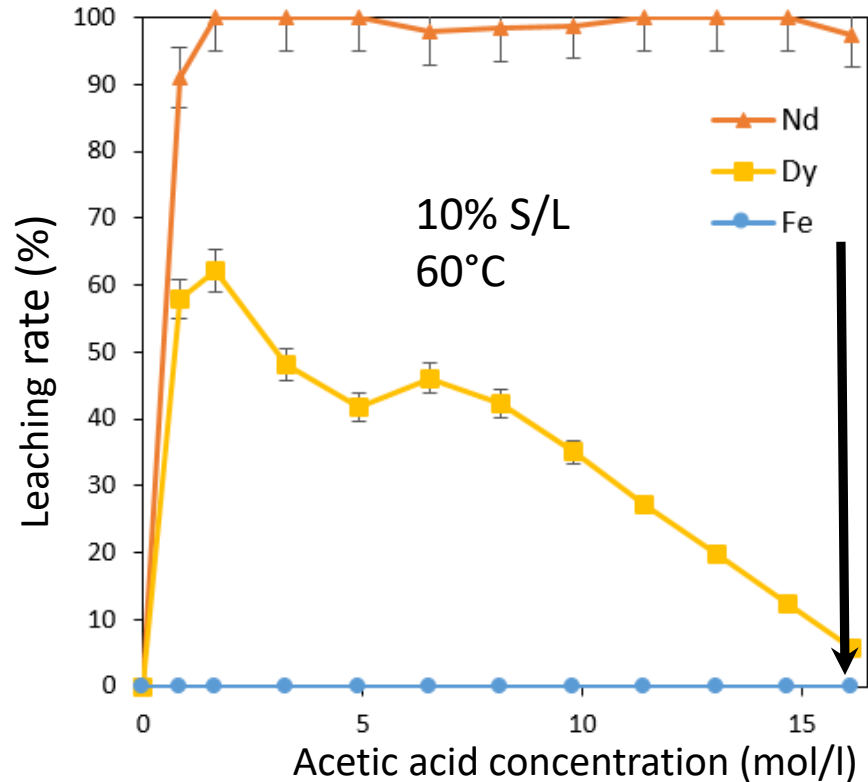
Nd, Pr, Dy > 95%

Pureté > 99.9%

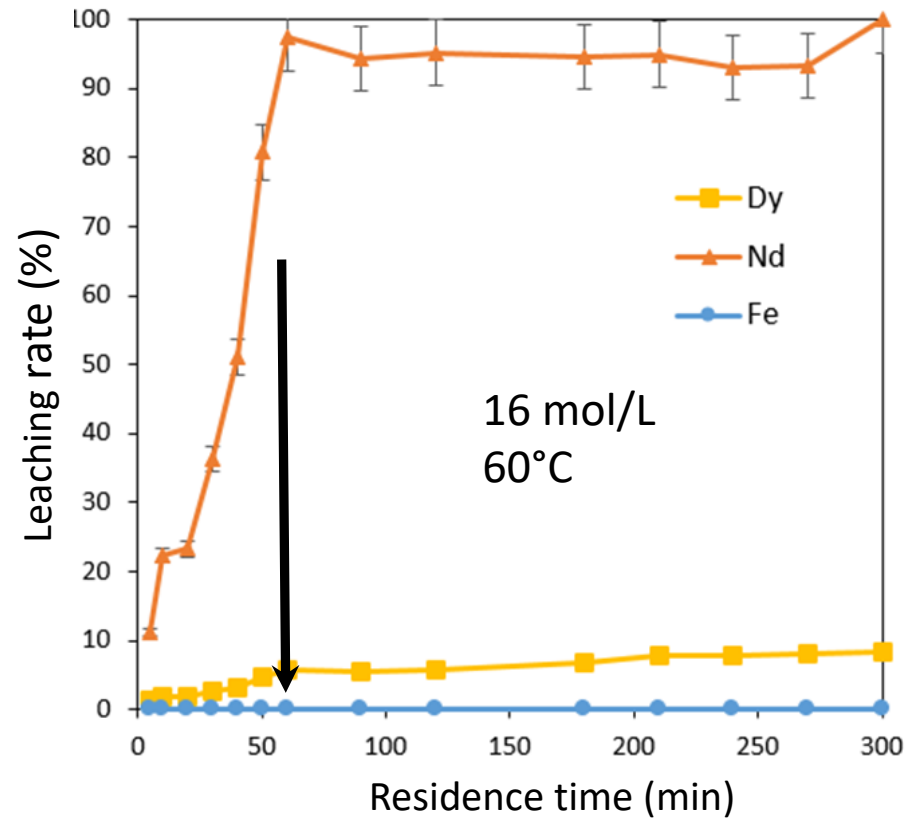
Patent N° FR2103621



# Roasting for selective leaching

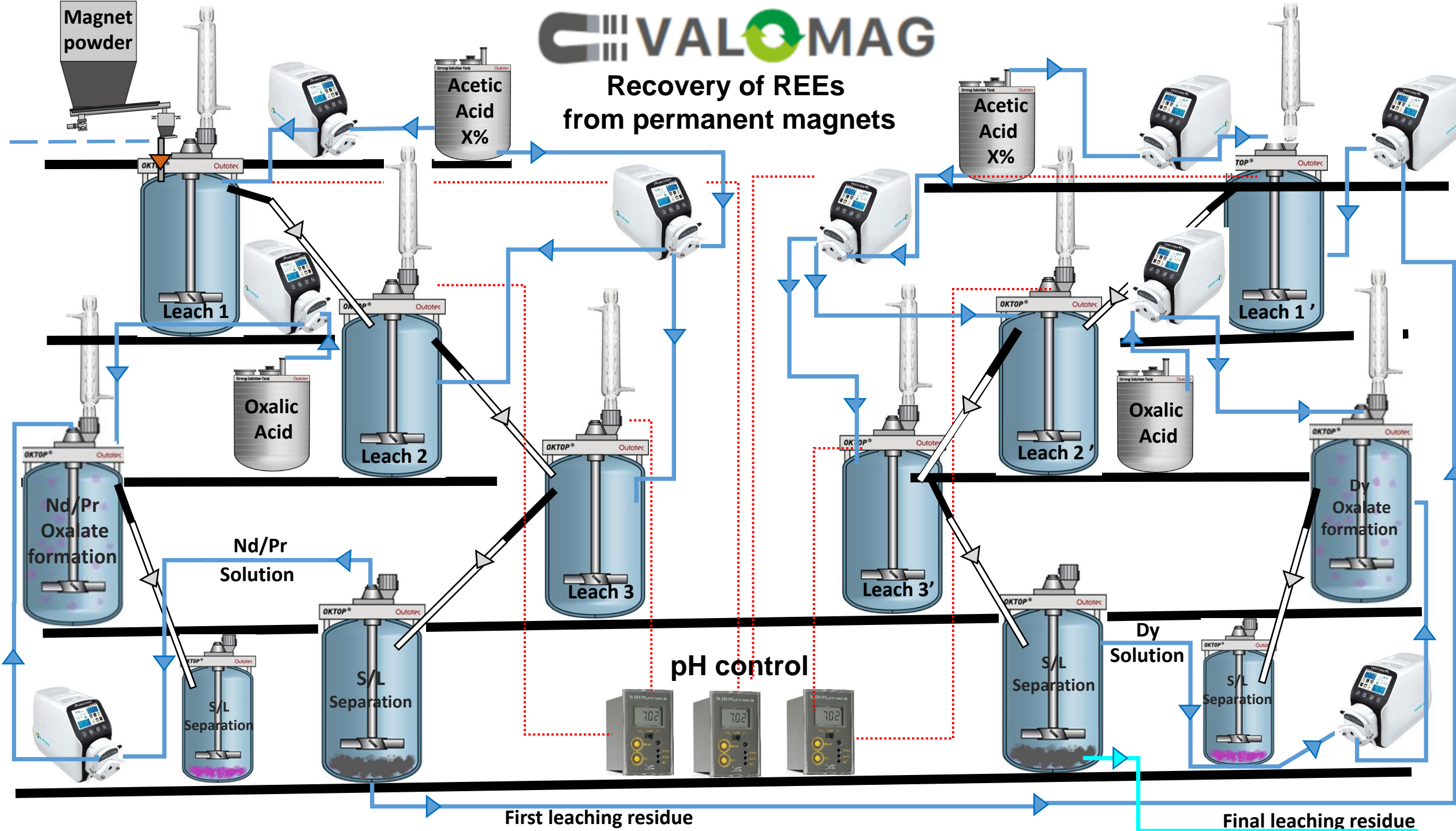


- Full leaching of Nd oxide from 2 to 16 mol/L acid
- No leaching of iron oxide
- Selective leaching of light REEs using 16 mol/l acetic acid



- Leaching selectivity between Nd, Dy and Fe oxides
- No leaching of iron oxide
- Full leaching of Nd after 60 min
- Only 5% of Dy are leached after 60 min

## Recovery of REEs from permanent magnets





# CONCLUSIONS

## **Leaching**

- Acetic acid more efficient weak acid to leach REE in favourable conditions,
- Feasible intra-selective leaching on oxidised magnet powder.

## **Solvent extraction**

- The extraction is rapid and exothermic
- Good recyclability of the organic phase
- Rapid stripping of REES using EDTA
- McCabe Thiele: Two stages of counter-current solvent extraction for total extraction and stripping

**Thank you for your  
attention**

**Questions?**