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RECOVERY OF SCANDIUM AND OTHER RARE EARTHS FROM GREEK BAUXITE RESIDUE

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KU Leuven, Belgium

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KU LEUVEN SIM2
Sustainable Inorganic Materials Management

Who we are?

SIM² KU Leuven is a leading, interdisciplinary research cluster at KU Leuven uniting the research groups working on **Sustainable Inorganic Materials Management**.

https://kuleuven.sim2.be

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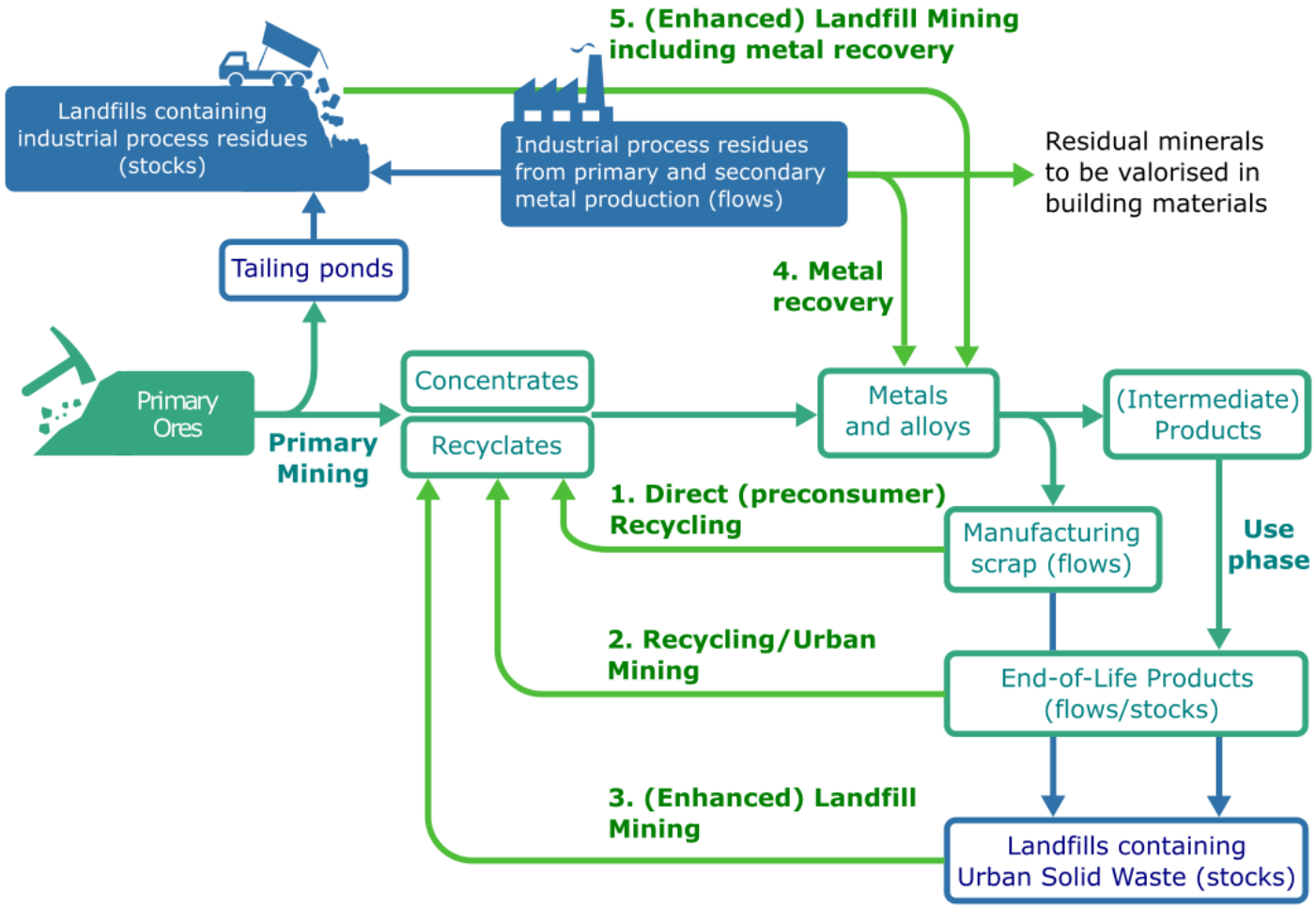
1. **About the SIM² KU Leuven**
2. Bauxite residue
3. Solvent extraction by ionic liquids (IL)
4. Sorption by supported ionic liquids (SILPs) and biopolymers



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RESEARCH LINE 1

Geological exploration and advanced resource characterisation

RESEARCH LINE 2

Pyro- and electrometallurgical processes

RESEARCH LINE 3

Hydro- and solvometallurgical processes

RESEARCH LINE 4

Upcycling processes for primary and secondary resources

RESEARCH LINE 5

Sustainability Assessment and Policy Research

RESEARCH LINE 6

Process intensification and digitalisation

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SOLVOMET is KU Leuven's Centre set up to industrially valorise the expertise in solvometallurgy (incl. hydrometallurgy) that has been and is being developed in Prof. Koen Binnemans' research group (Department of Chemistry, KU Leuven, Belgium).

KU LEUVEN SOLVOMET Industrial Service Centre

https://solvomet.eu/

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SYNTHESIS

Synthesis of new mining chemicals (extractants, diluents, adsorbents, collectors, flotation agents) for base and critical metal recovery and purification

CONCENTRATION & SEPARATION

- Solvometallurgical leaching
- Solvent extraction for separation and purification of base and critical metals
- Metal recovery from dilute aqueous waste streams by adsorption and ion flotation

SPECIATION

Development of more selective processes through a deeper understanding of the mechanism of solvent extraction processes

PROCESSES

Chemical engineering and mini-pilot-scale testing (upscaling) of developed processes and mining chemicals

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Bauxite residue = waste from the production of alumina by the Bayer process

- ✓Estimated global production 150 millions of tonnes/year
- ✓Bauxite residue is only rarely used in bulk quantities
- ✓Presence of **Sc(III)** comprises more than 90% of its economic value of rare earth elements (REEs)

Greek bauxite residue = 120 g/tonne of Sc

Compound	wt. %
Fe_2O_3	44.6
Al_2O_3	23.6
CaO	11.2
SiO_2	10.2
TiO_2	5.7
Na_2O	2.5

- ✓ The recovery of REEs with or without other metals from bauxite residue, and utilization of the left-over residue in other applications like building materials = contribution to a solution of the management problem of the bauxite residue.

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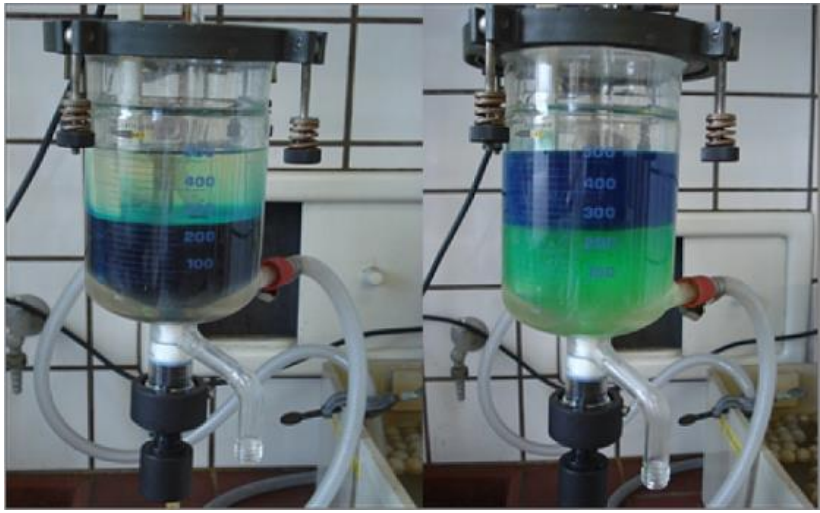
K. Evans, J. Sustain. Metall., 2016, **2**, 316–331.
C. R. Borra, Y. Pontikes, K. Binnemans, T. Van Gerven, Min. Eng., 2015, **76**, 20- 27.

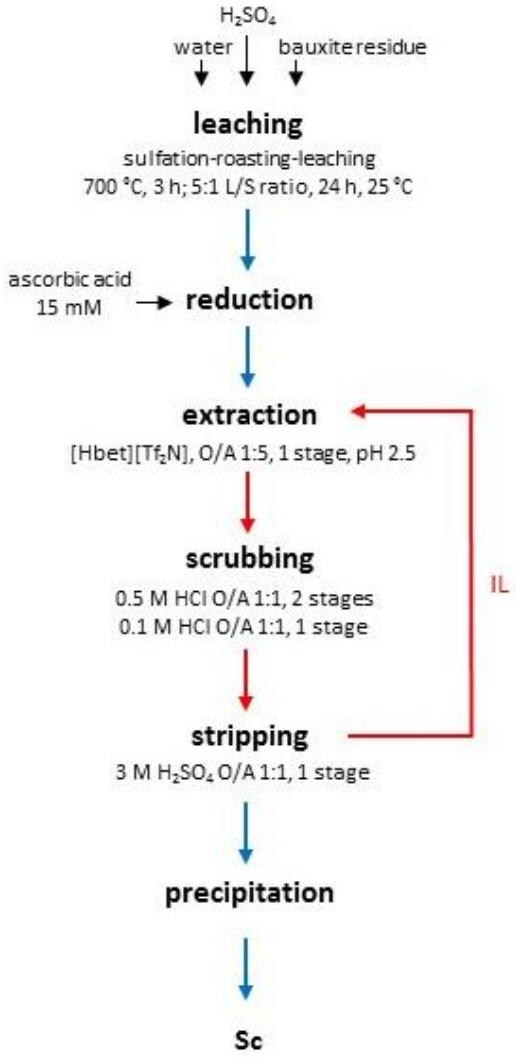
Compounds consisted exclusively of ions.
They can be organic or inorganic salts, with low melting temperature.

The most important properties:
- ✓ negligible vapor pressure,
- ✓ broad electrochemical window,
- ✓ low flammability,
- ✓ broad liquidus range,
- ✓ tunable structures (acidic groups for leaching)

- Designer solvents.

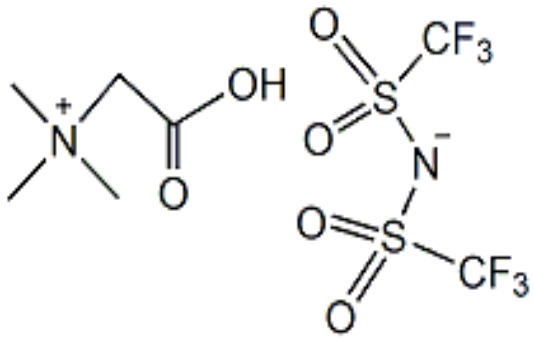


Ionic liquid process for Co/Ni separation (SOLVOMET)

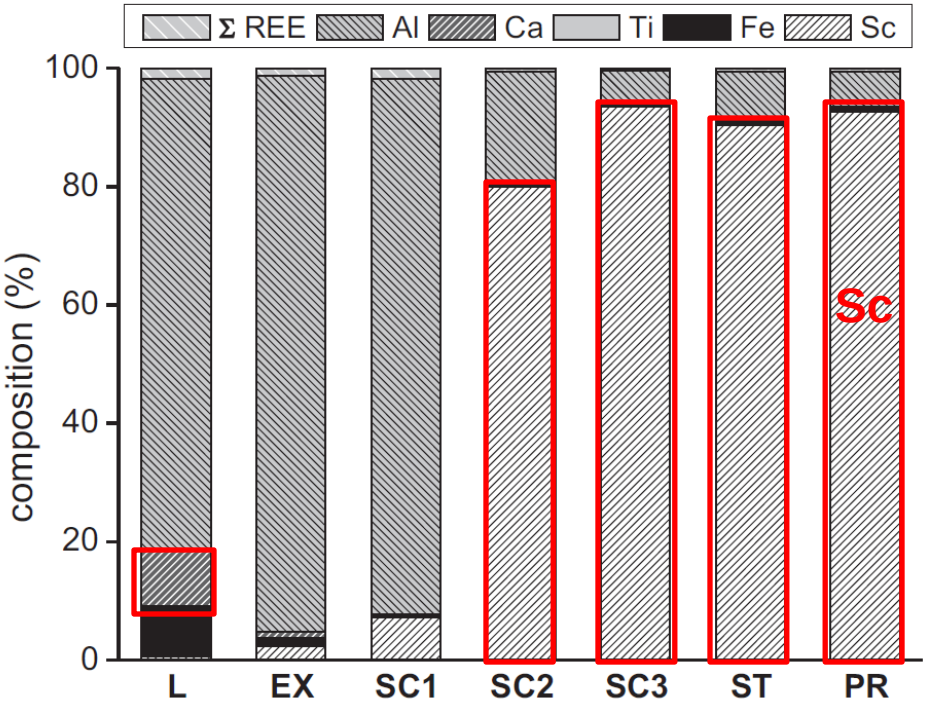


Betainium bis(trifluoromethylsulfonyl)imide [Hbet][Tf_2N]

Used for recovery of scandium from sulfation-roasted leachates of Greek bauxite residue by solvent extraction.



B. Onghena, C. R. Borra, T. Van Gerven, K. Binnemans, Sep. Purif. Technol., 2017, **176**, 208–219.



L: sulfate leachate after 5-stage leaching,
EX: ionic liquid phase after extraction
SC1: IL phase after scrubbing step 1
SC2: ionic liquid phase after scrubbing step 2
SC3: ionic liquid phase after scrubbing step 3
ST: aqueous phase after stripping
PR: precipitate after precipitation with NaOH (pH 12.5).

Cycle	1	5
pH	3.12	3.08
Sc	**14.6±0.2**	**47.7±0.1**
Fe	59±1	271±1
Ti	<0.5	0.42±0.01
Ca	540±10	585±7
Na	3850±30	16100±6
Al	1078±1	4360±60
Y	12.7±0.2	25.1±0.1
La	16.0±0.2	25.1±0.1
Ce	44.4±0.8	53.8±0.3
Nd	11.0±0.1	11.5±0.1
Dy	2.09±0.01	2.65±0.01

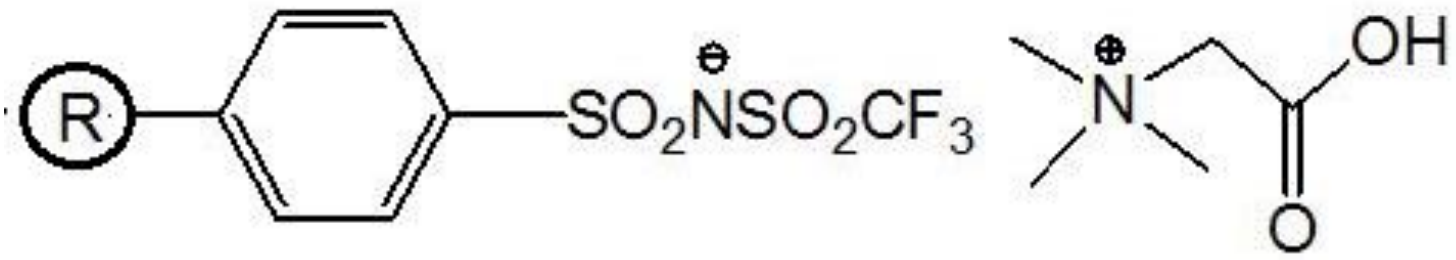
✓ Multi-stage leaching = increase the Sc concentration (mg L^{-1}) in the leachate.

B. Onghena, C. R. Borra, T. Van Gerven, K. Binnemans, Sep. Purif. Technol., 2017, **176**, 208–219.

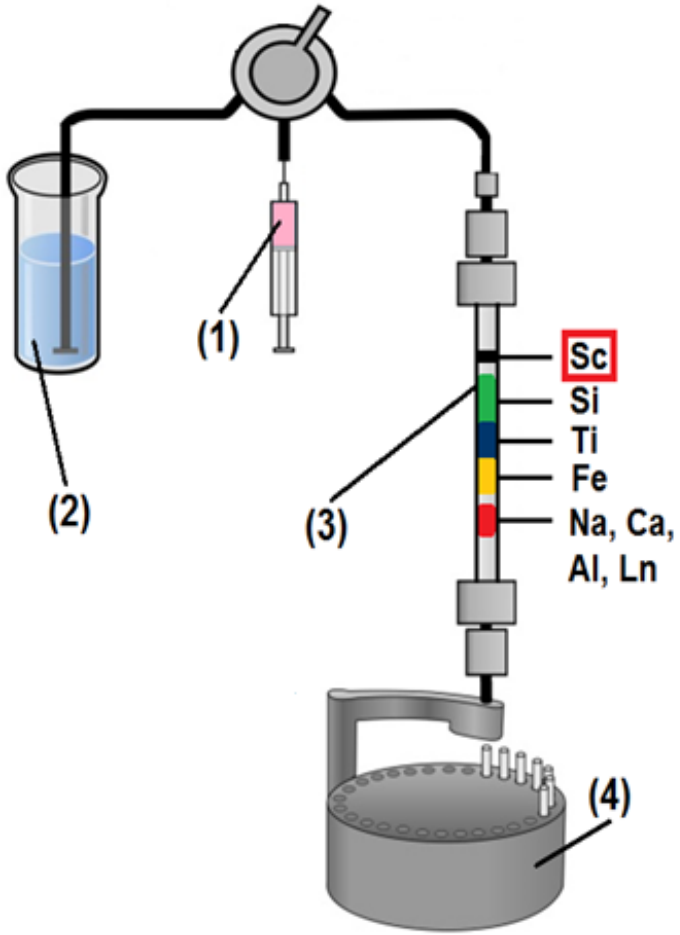
- The **viscosity** of ionic liquids is generally higher than that of common organic solvents.
- Supported ionic liquids (SILPs) were introduced to avoid the disadvantage of high viscosity of ionic liquids. SILPs include combination of ionic liquids and porous solid supports.

SILP betainium sulfonyl(trifluoromethanesulfonylimide) poly(styrene-*co*-divinylbenzene)

[Hbet-STFSI-PS-DVB]



D. Avdibegović, M. Regadío, K. Binnemans, RSC Adv., 2017, 7, 49664-49674.



(1) = bauxite residue leachate
(2) = solution for removal of ions (e.g. nitric acid)
(3) = column filled with sorbent (e.g. SILP or biopolymers)
(4) = fraction collector

✓ High purification/preconcentration factors.

Roosen, J., Van Roosendael, S., Borra, C., Van Gerven, T., Mullens, S., Binnemans, K. (2016). Green Chem., *18* (7), 2005-2013.

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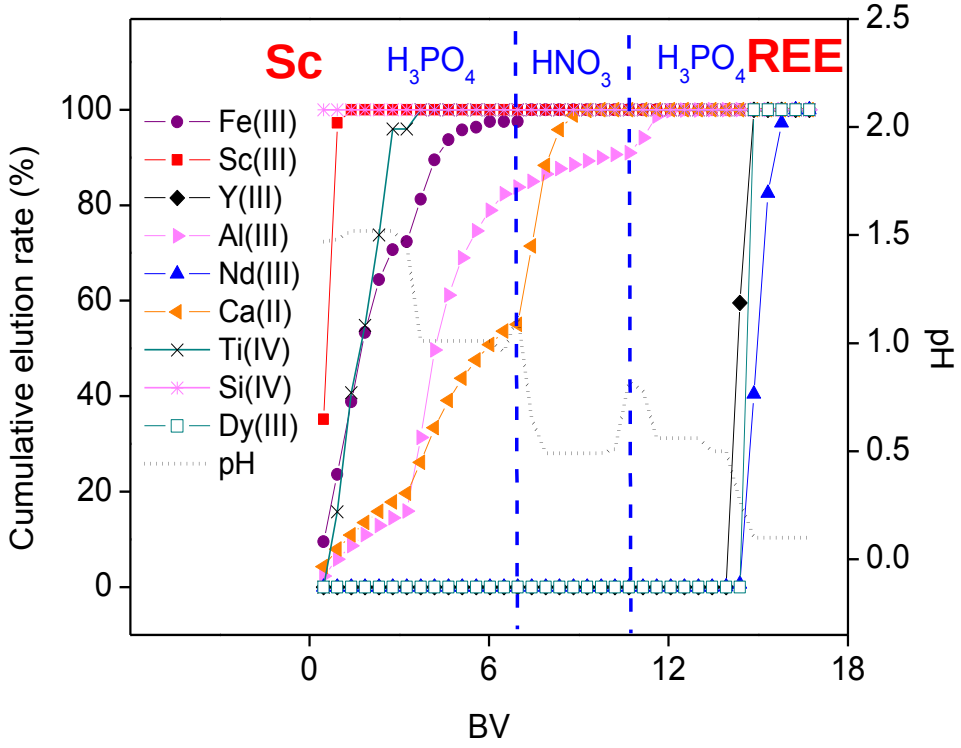


SILP

Optimised pH gradient elution with H_3PO_4 and HNO_3 as a function of the bed volume (BV).

Feed 2 mL of BR leachate with HCl prepared from a BR slag performed after smelting reduction for Fe recovery.

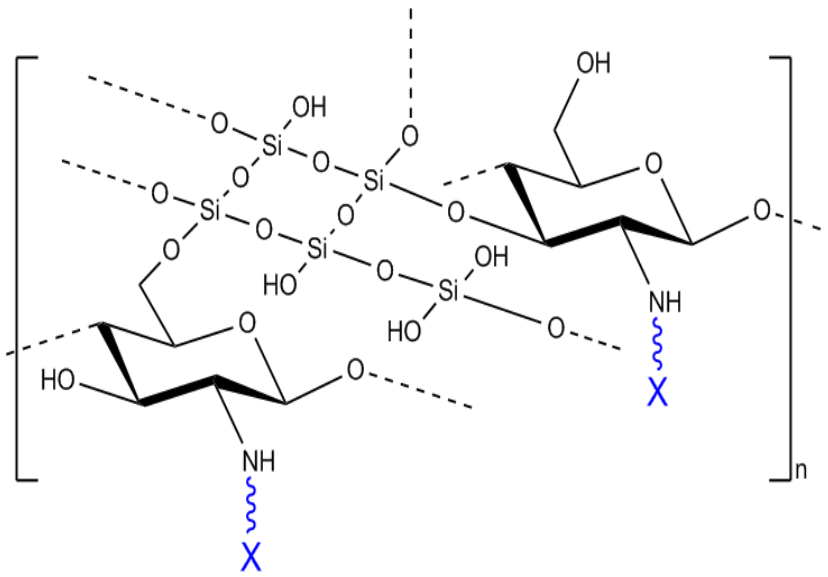
pH_{ini}=1.5. Flow rate 0.5 mL min^{-1}.
Bed volume = 10.8 mL

	Ca	Al	Fe	Si	Ti	Nd	Sc	Y	Dy
Concentration in the **HCl** feed (mg L^{-1})	4209	1972	518	49	3.3	7.7	1.0	7.5	0.9
Recovery by the SILP (%)	49.8	71.7	34.3	0.00	100	**100**	**100**	**97.7**	**100**

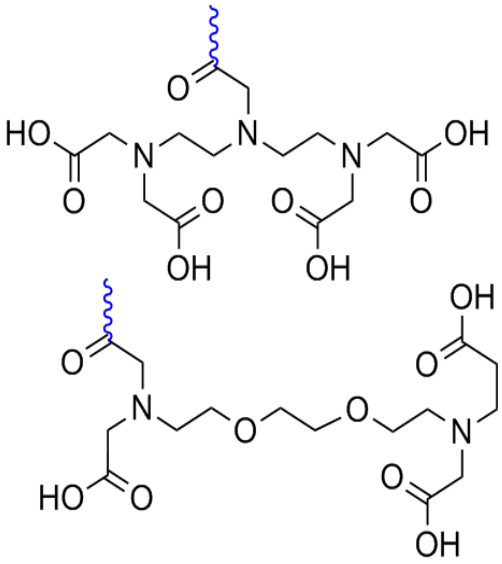
Elution sequence: Sc(III) > Fe(III) > Ca(II) > Al(III) ≈ Dy(III) ≈ Y(III) ≈ Nd(III).

D. Avdibegović, M. Regadío, R.M. Rivera, G. Onoughene, T. Van Gerven, K. Binnemans, in: *Y. Pontikes (ed) Proceedings of the 2nd International Bauxite Residue Valorisation and Best Practices Conference*. 7-10 May 2018, Athens, Greece, 381-386.

Recovery of **Sc(III)** from leachate of Greek bauxite residue by functionalization of chitosan-silica with **EGTA**



X =



(DTPA)

(EGTA)

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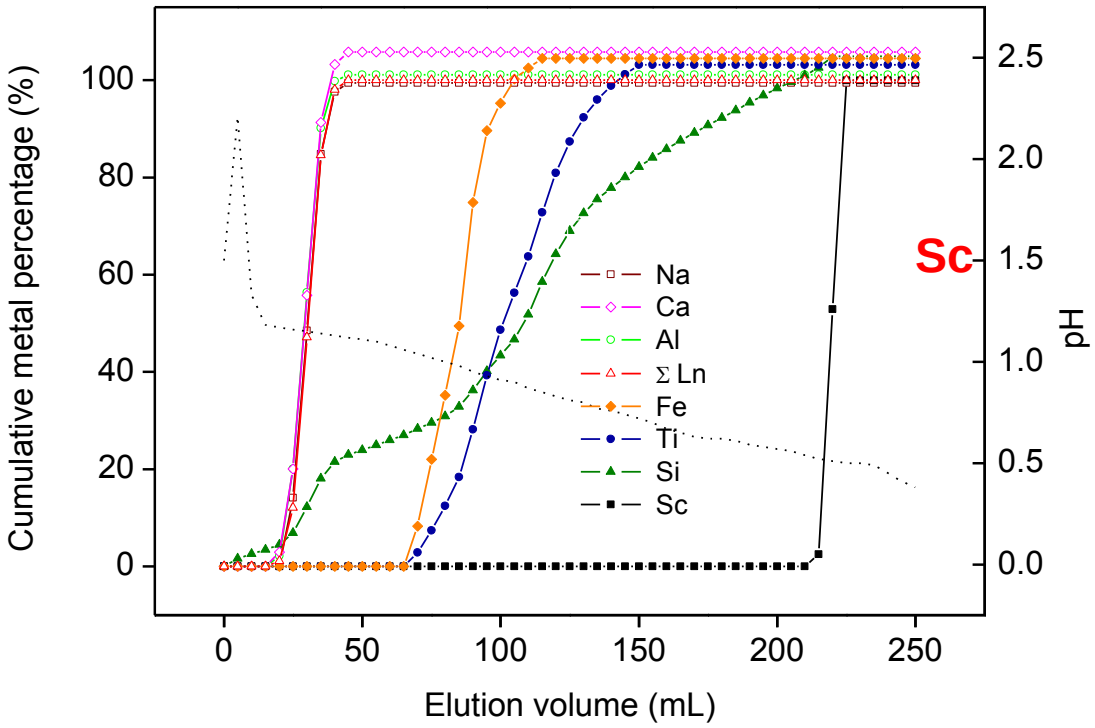

Biopolymers

Optimised pH gradient elution with HNO_3 as a function of the elution volume.

Feed 10 mL of BR leachate with HNO_3.

pH_{ini}=1.5. Flow rate 40 mL h^{-1}.
Bed volume = 8.3 mL.

	Na	Ca	Al	Fe	Si	Ti	Sc	ΣLn
Concentration in the **HNO_3** feed (mg L^{-1})	1104	939	670	106	558	106	2	6

Roosen, J., Van Roosendael, S., Borra, C., Van Gerven, T., Mullens, S., Binnemans, K. (2016). Green Chem., *18* (7), 2005-2013.

Acknowledgement

Prof. Koen Binnemans (KU Leuven, Belgium)

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http://redmud.org/

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Thank you!

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