Mechano-chemical processing of Bauxid Residue solids in the "Horizon 2020 EU project SCALE"

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Motivation

During aluminum production, about 1-1.5 tons of bauxite residue (BR; red mud) are produced per ton of Al_2O_3 resulting in an annual global red mud production of 120-140 million tons. Additionally about 3-4 billion tons (2017) are already landfilled worldwide. The increasing amount of red mud, decreasing landfill areas, as well as a large potential value from the metals contained in the red mud Fe, Al, Ti, Sc and other rare earth elements (REEs) make it a promising secondary raw material source. For example the scandium content in red mud can reach values up to 390 ppm, depending on the composition and the origin of the bauxite and the efficiency of the Bayer process.
The aim of the Horizon 2020 EU project SCALE is to recover Sc from red mud and refine it to an industrial usable grade by using alternative methods, such as mechano-chemical activation.

Summary and Outlook

With regard to the efficiency of the chemical extraction, it is possible to dissolve up to 65 % of the scandium from the red mud, using 3 molar sulfuric acid. The l/s-ratio can be lowered to 5 without significant losses and 60 minutes in the mill are sufficient as a leaching time. Even the molarity can be reduced below 3M without major losses in recovery.
An already pregnant solution can be used again. This can save acid and increase the concentration in the solution.

Characterization of the starting material

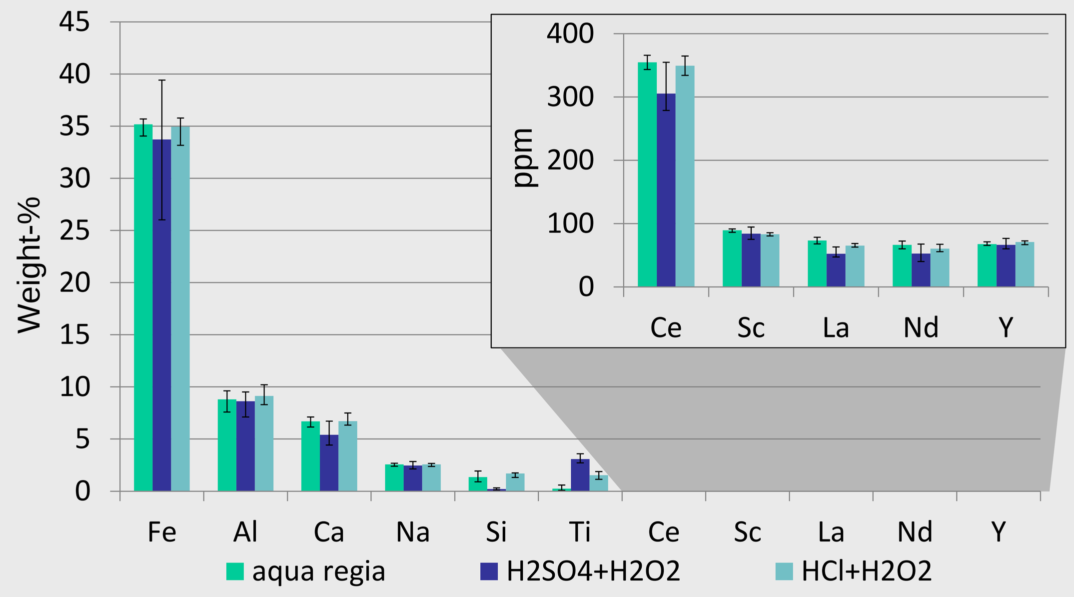

Fig. 1: Elementary composition of the bauxite residue from AoG

The starting material consists of red mud from ALOUMINION AE (AoG), who are also partners in the EU project. The BR consist of particles with a fine fraction of 1-100 µm and a main fraction of 1-4 mm (Fig. 2; left). During the mechano-chemical milling process this changes and the whole material attains a particle size of 1-30 µm (Fig. 2; right). The elementary basis of the red mud is iron, aluminum and calcium which are present as hematite (Fe_2O_3), calcinite ($CaCO_3$), cancrinite ($(Na_6Ca_2[(CO_3)|Al_6Si_6O_{24}]*2H_2O)$), katoite ($(Ca_3Al_2(OH)_{12})$), geothite ($FeO(OH)$) and ilmenite ($FeTiO_3$) amongst other minerals. Additionally rare earth elements such as cerium, scandium, lanthanum, neodymium and yttrium are contained in the range of 50-350 ppm (Fig. 1).

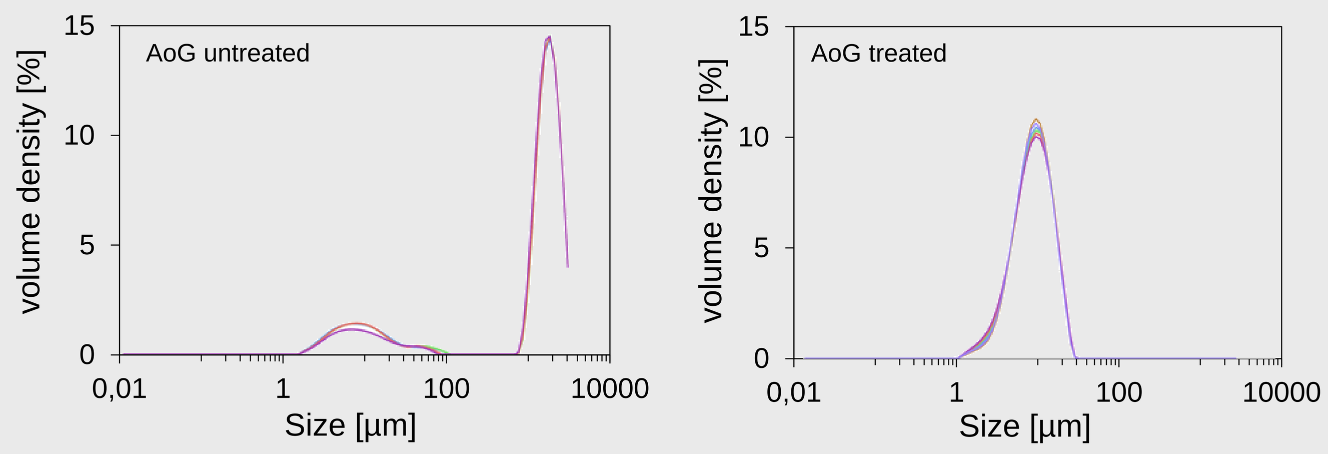

Fig. 2: The particle size of untreated and treated Red Mud

Mechano-chemical leaching


Fig. 3: Planetary ball-mill (Fritsch)

Mechano-chemistry is aiming at an enhanced chemical reactivity of materials by mechanical activation, e.g. in a high-energy ball-mill (Fig. 3). At rotation numbers above 500 rotations per minute, the resulting ball collisions create – for a very short time – hydrothermal conditions, i.e. with very high temperatures and pressures. This may lead to the solubility of grinding material phases which – under ambient conditions – are stable. Since the relevant effects anneal on a very short timescale one has to simultaneously introduce a suitable solvent to take advantage of the effects. In terms of hydrometallurgical leaching the mechano-chemical treatment may lead to a higher recovery yield while using less concentrated acids or less leaching time. The process steps are very simple (Fig. 4), the separation of solid and liquid after wet grinding happens easily via a centrifuge. As a grinding material - of grinding bowl and grinding balls - zirconia is the first choice due to the use of sulfuric acid as a leaching agent.


Fig. 4: Process steps (①-⑧) during mechano-chemical leaching

Results

There are many parameters that can be changed to optimize the process. Some of them have already been varied, others still have to be investigated or have been determined from the beginning due to the requirements.

Variable:

- Liquid/solid-ratio (Fig. 6)
- Leaching time (Fig. 7)
- Molarity of the acid (Fig. 8)
- Temperature (only conditionally adjustable; about 50-65°C)

Same for all shown results:

- Amount of grinding balls (about 150g)
- Type of acid (sulfuric acid)
- Rotational speed of the mill (600 min^{-1})
- Grinding material (zirconia; ball diameter ~10mm)

Figure 5 also shows an experiment in which a pregnant solution was used again. In the context of the general distribution of the results (Fig. 6), it can be said that the pregnant solution can be used again with almost no losses.

Fig. 5: Use of pregnant solution

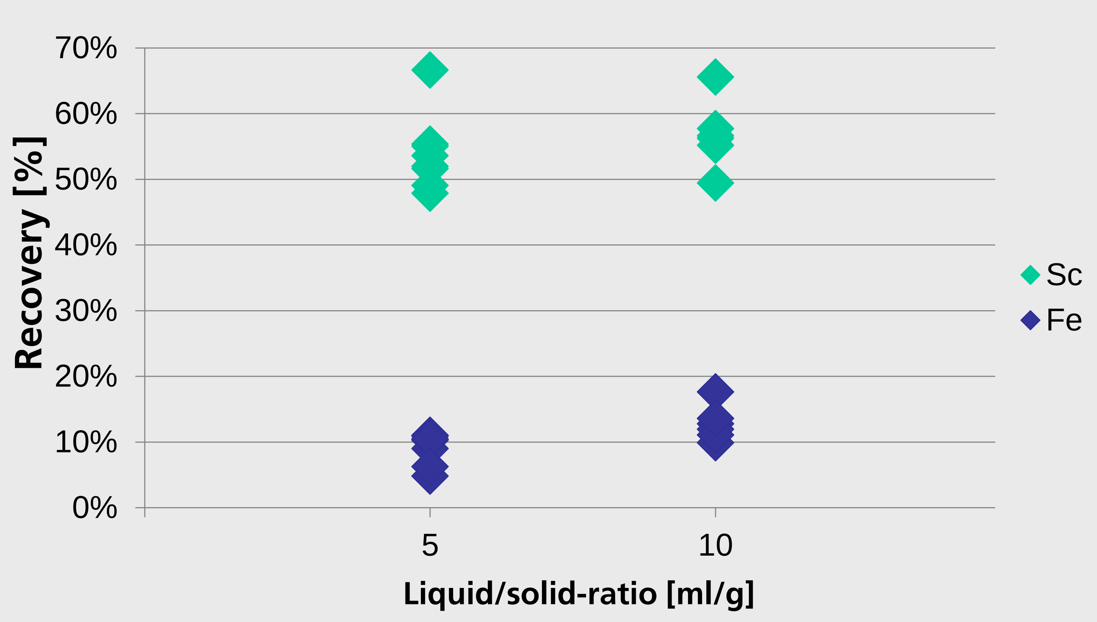

Fig. 6: Reproductions with 3M H2SO4 and 60min leachingtime

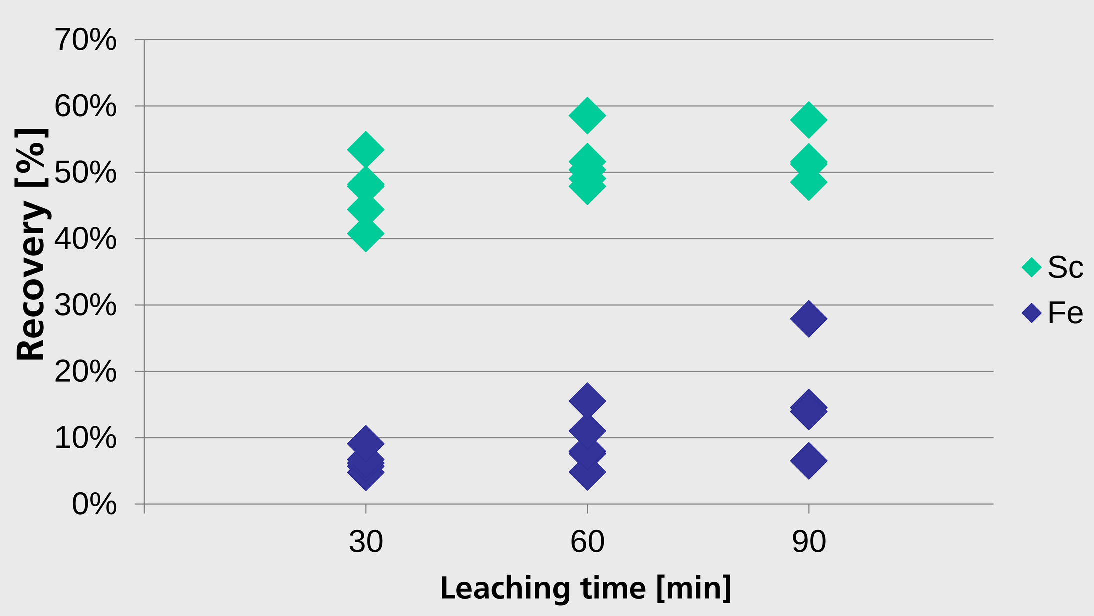

Fig. 7: Variation of the Leachingtime

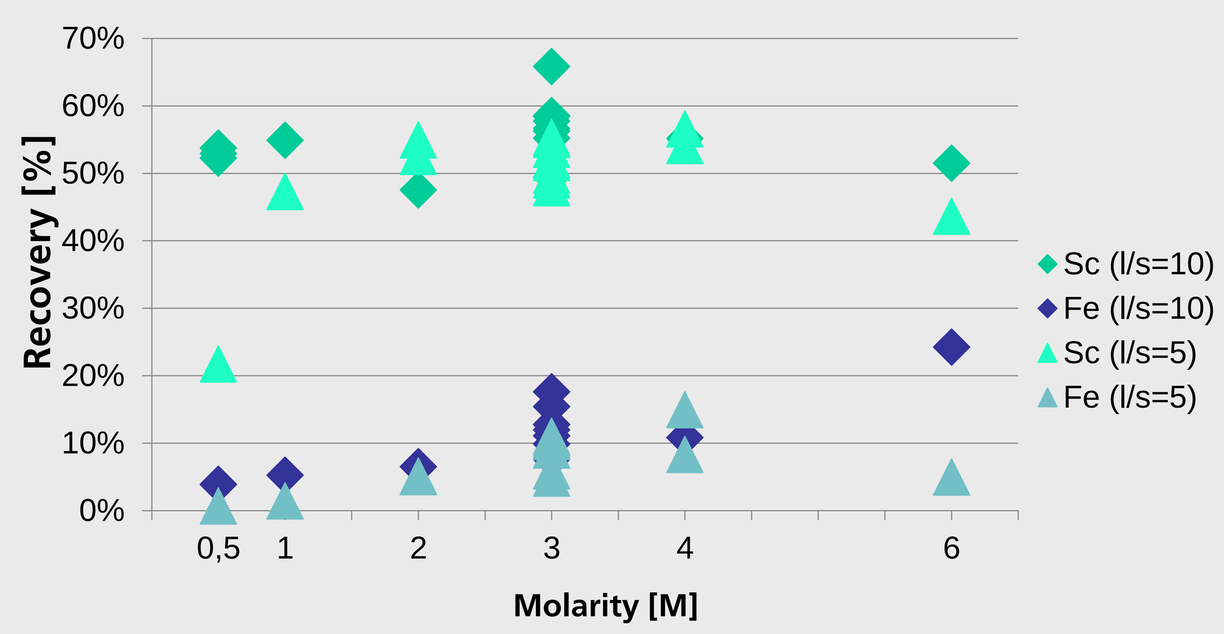

Fig. 8: Variation of the acid molarity

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