Towards the first recovery of scandium from waste acid: pilot-scale nanofiltration

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Abstract

Scandium, a rare earth metal, can save fossil fuel (for example as an alloy in lighter aircraft) and make energy generation greener (as its oxide in solid oxide fuel cells). Nevertheless, the global supply of scandium is low, crucially restricting its application. The work presented here contributes to the establishment of a novel European scandium supply and processing chain using wastes as ore. Starting from real-world TiO_2 production waste, acid resistant nanofiltration (NF) was used to selectively concentrate scandium in amounts sufficient for the subsequent production of the first pure Sc recovered from European waste.

Introduction

Today's society faces the consequences of anthropogenic global warming. To reduce greenhouse gas emissions to a minimum, scandium, a rare earth metal, can be one piece of the puzzle. For instance, scandium-aluminium alloys enable the construction of up to 15-20% lighter aircraft, offering considerable fuel savings. Further, ceramics of Sc_2O_3 are crucial for solid oxide fuel cells, converting natural gas into electrical power efficiently. However, the use of scandium-based technologies is hampered by its low market availability (~12 t/a world production, two thirds of which comes from China) and the resulting high price (200 $/g).[1] There are some industrial waste products available in the million ton scale (e.g. red mud and TiO_2 production's acid waste). Their utilization provides several advantages: a) Sc concentrations in the wastes are 5 – 10 times higher than average concentrations in Earth's crust, b) no additional mining is required and c) the environmental impact as well as the costs for landfill are reduced.[2] The work presented here aimed to develop and pilot a nanofiltration process for the recovery of scandium from TiO_2 acid waste.

Results & prospect

The acid waste originates from the so-called chloride route of white pigment production and consists of dissolved metal chlorides, unreacted ores/coke in ~15 % HCl. To remove fine particles detrimental to nanofiltration (NF), solid-/liquid separation by microfiltration (MF) and ultrafiltration (UF) was used. Interfering or potentially hazardous naturally occurring radioactive materials (e.g. uranium and thorium) were selectively precipitated (> 95 %) by appropriate pH adjustment prior to filtration, while the scandium concentration decreased only slightly (~20 %).[3] Six commercial acid resistant thin film composite membranes were tested for their selective Sc retention. The most suitable one was used to produce a Sc concentrate with doubled Sc concentration (further metals were concentrated to only about +20 %) and reduced volume (-60%). After the NF, Sc has been successfully recovered from the concentrate through solvent extraction (SX).

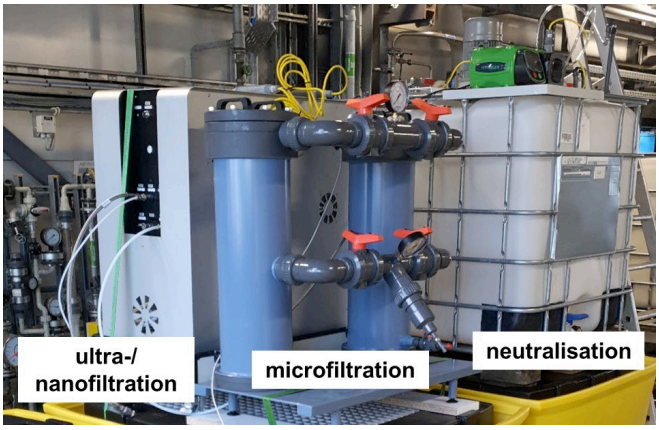

Figure 1: Photography of the pilot installation. The units are labelled according to the process step.

Based on the laboratory process, an acid-resistant pilot plant was constructed (Figure 1). For the pH adjustment stage, a reactor with a capacity of 1000 L was built. In order to carry out the microfiltration, a bag filtration plant (2-EF6-F, Eurowater) was used. The UF/NF unit is computer-controlled and works with different membrane modules at up to 60 bar. In the case of the best membrane, an 1812 spiral wound module was chosen. The pilot can produce 200 L of nanofiltration concentrate at 60 % permeate recovery. Subsequently, Sc is separated by solvent extraction and refined into pure ScF_3 and Sc_2O_3. These valuable scandium products are metallothermically reduced to give either Sc metal or Sc-Al master-alloys. This is the first time that Sc has been obtained from the TiO_2 acid waste by means of a combined NF+SX process. Through this approach, Europe has the chance to meet its

future scandium demand, which will decisively promote the application of Sc based technologies.

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