QUALITATIVE ASSESSMENT OF THE ECOTOXICOLOGICAL EFFECTS OF RESIDUES GENERATED IN SCANDIUM PRODUCTION TECHNOLOGIES

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Abstract

Scandium production from wastes, such as bauxite residue or TiO_2 production wastes are gaining focus due to the high economical value of this element. To evaluate the environmental impact of such production technologies a scoring and classification system was developed and adapted to the residues generated during the entire technological process chain. The system enabled us to rank the input and output materials and the residues in each technological step based on environmental toxicity and potential environmental effects.

Introduction

Bauxite residues (BR) and TiO_2 production wastes contain an economically important amount of scandium that can be exploited[1]. There is a long technological process chain from the original waste material to the final scandium containing product[2]. One aspect of such technologies is their environmental impact, which can be integrated into Life Cycle Assessment (LCA). However, the inclusion of the ecotoxicity data into LCA of complex wastes containing a mixture of chemicals in various forms is difficult[3]. Therefore, we developed and adapted an ecotoxicity data-based scoring and classification system for the qualitative assessment of the input and output materials and residues generated within each process step of the scandium producing technology. This paper presents the results of the qualitative evaluation system through two selected process steps.

Materials and methods

The samples for ecotoxicity assays originated from the laboratory experiments performed within the SCALE project by different partners (Table 1).

Table 1. Samples evaluated by the score system from ecotoxicological point-of-view

Sample name	**Leaching technologies**
BR	Bauxite Residue (s) (Greek)
LIL SR	Leaching with Ionic Liquids, Solid Residue (HbetTf2N [betainium bistrifluoromethylsulfonylimide] by Iolitec Ltd.) sample by NTUA LabMet*
HTLMA SR	High Temperature Leaching with Mineral Acid, Solid Residue (4M H_2SO_4, 95 °C, 2 h, 400 rpm, S:L=1:5, washed, dried) sample by NTUA LabMet
ATLMA SR	Ambient Temperature Leaching with Mineral Acid, Solid Residue[5] (2M H_2SO_4, 1 h, 550 rpm, S:L=1:10) sample by NTUA ChemLab**
LMC SR	Mechanochemical Leaching, Solid Residue (3M H_2SO_4, 1 h milling, S:L=1:5) sample by Fraunhofer-Gesellschaft
Sample name	**Nanofiltration technology steps** samples by FHNW***
ALW	TiO_2 production Acidic Liquid Residue (aq)
MFP	Microfiltration Permeate (aq) (pH adjusted to 1.5 with NaOH before filtration)
MFR	Microfiltration Retentate (s)
UFP	Ultrafiltration Permeate (aq)
NFP	Nanofiltration Permeate (aq)
NFR	Nanofiltration Retentate (aq)

*NTUA LabMet: School of Mining and Metallurgical Engineering, National Technical University of Athens, Greece
**NTUA ChemLab: School of Chemical Engineering, National Technical University of Athens, Greece
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The ecotoxicity tests were carried out with testorganisms from three trophic levels. Effective Concentrations (EC_{20} and EC_{50} – concentration causing 20% and 50% inhibition) were calculated from the inhibition % (compared to the control) of sample dilution series. The EC was expressed as x-fold dilution of the initial sample. EC20 values can be regarded as the lowest dilution that have a significant toxic impact[4]. We considered median EC20 values from all tests as the threshold dilution with tolerable toxic effect. Scores were assigned to the EC_{50} values and the samples were grouped into five acute aquatic toxicity categories (I-V, V is very high acute toxicity)[4]. A SCALE-specific scoring system was created from all EC values to assess the potential environmental effect of the samples on the aquatic environment. Each EC value was assigned a score as per the eco score system[5] (scores ranging between 0–10, 10 is the highest effect). The scores obtained per ecotoxicity assay were averaged giving an average eco score for each sample. Then the samples were grouped into 5 effect classes starting from potentially weak effect to potentially very strong effect.

Results and discussion

Table 2 shows the EC values, the scores and classes for the solid residues generated from various leaching procedures of BR. The two-fold dilution of the LIL SR did not indicate acute aquatic toxic effect. The HTLMA SR gave lower EC values than the BR and consequently a lower eco score. This may be explained by the washing step introduced after the leaching process in the first two cases. The ATLMA SR showed higher EC values and was categorized as “acute toxic for the aquatic environment” and having “moderate environmental effect” on the aquatic environment. The LMC SR showed the highest EC values and was classified as “highly acute toxic for the aquatic environment”. This may be due to the 1 hour milling resulting in more digested material with smaller particle size.

Table 2. Classification of solid residues from BR leaching technologies

		BR	**LIL SR**	**HTLMA SR**	**ATLMA SR**	**LMC SR**
Minimum dilution for acceptable toxicity (EC_{20})	Dilution	5.0x	<2.0x	3.0x	17.0x	26.4x
EC_{50}	Dilution	5.0x	<2.0x	<2.0x	9.4x	13.5x
Acute aquatic toxicity category class	Class	I/II	I	I/II	III/IV	IV
Acute aquatic toxicity classification	Description	Slight acute toxicity	No acute toxicity	Slight acute toxicity	Acute toxicity	High acute toxicity
Eco score	Score	1.3	0.0	0.5	3.8	5.0
Potential environmental effect classification	Description	Weak effect	No effect	Weak effect	Moderate effect	Moderately strong effect

Table 3. Classification of residues from nanofiltration process steps

		ALW	**MFP**	**MFR**	**UFP**	**NFP**	**NFR**
Minimum dilution for acceptable toxicity (EC_{20})	Dilution	3086x	2326x	102x	890x	27x	148x
EC_{50}	Dilution	882x	1026x	81x	288x	22x	121x
Acute toxicity category class	Class	V	V	IV/V	IV/V	IV	IV/V
Acute toxicity	Description	Very high acute toxicity	Very high acute toxicity	Very high acute toxicity	Very high acute toxicity	High acute toxicity	Very high acute toxicity
Eco score	Score	9.8	9.9	6.9	8.4	4.0	6.7
Potential environmental effect	Description	Very strong	Very strong	Strong	Very strong	Moderate	Strong

Table 3 presents the results for the nanofiltration technology steps. Although the EC values for the permeates decrease effectively with each filtration step (ALW > MF > UF > NF), they are still in the potentially "very high acute aquatic toxicity" category, if they were accidentally released to the environment. This general classification method does not allow us to differentiate between the samples. In this case the eco scores reflect better the decrease of the potential environmental effects on the aquatic environment. The two retentates resulted in similarly potentially "very high acute toxicity" and "strong potential environmental effect". However, their EC values and eco scores were much lower than the ALW's. MFR and NFP may be considered as wastes from the whole filtration process, with lower eco scores, than the ALW.

Conclusions

The classification system developed for the SCALE technological process steps was applied successfully in our two examples. The resulted scores and classes aim to raise the attention of process developers on the most critical materials and residues in the process from environmental toxicity point of view in order to enhance the environmental efficiency of the technology.

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