ECOTOXICITY ASSESSMENT OF NANOFILTRATION PRODUCTS AS THE FIRST STEP OF SCANDIUM PRODUCTION FROM TITANIUM DIOXIDE PRODUCTION WASTE

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Abstract

Nanofiltration can be the first technological step to produce scandium from the acidic liquid waste of TiO_2 production. Prior to nanofiltration, micro and ultrafiltration were applied. To assess the potential environmental impacts that the filtration products (permeates, retentates) may have an ecotoxicity study was performed. We found that the ecotoxicity of the permeates decreased after each filtration step and the retentates are less toxic, than the original material.

Introduction

The acidic liquid from TiO_2 production may be re-used for the production of scandium[1]. Nanofiltration can be applied to successfully remove impurities and recover Sc selectively[2], however further filtration steps may be necessary to protect the nanofiltration membrane from clogging[2]. We applied a series of filtration steps: 1st microfiltration, 2nd ultrafiltration, 3rd nanofiltration. Following the filtering sequence, we applied ecotoxicity tests to assess the potential adverse environmental effects if such liquids were to be emitted accidentally.

Materials and methods

Nanofiltration samples originated from the laboratory experiments of the SCALE project (Table 1). From the solid samples, both solid (whole soil tests) and 1:10 aqueous extracts (shaken for 24 h at 300 rpm, filtered) were tested. Chemical analysis of the extracts was carried out by inductively coupled plasma-mass spectrometry (ICP-MS 7'500cx/8800, Agilent Technologies). The ecotoxicity test battery applying testorganisms from three trophic levels included: *Aliivibrio fischeri*

(bacteria) bioluminescence inhibition test[4], *Lemna minor* (plant) reproduction inhibition test by frond number and chlorophyll content measurement[5], *Daphnia magna* (crustacean) immobilization test[6]. Effective Concentrations (EC_{20}, concentration causing 20% inhibition) were calculated from the inhibition % (compared to the control) of a sample dilution series. The EC was expressed as x-fold dilution of the initial sample. EC_{20} values can be regarded as the lowest dilution that have a significant toxic impact[7]. We considered median EC_{20} values from all tests as the threshold dilution with tolerable toxic effect.

Table 1. Samples from the filtration steps

Sample name	**Nanofiltration technology steps**
ALW	TiO_2 production Acidic Liquid Waste (aq)
MFP	Microfiltration Permeate (aq) (pH adjusted to 1.5 with NaOH before filtration, 1 µm pore size)
MFR	Microfiltration Retentate (s)
UFP	Ultrafiltration Permeate (aq) (150 kDa molecular weight cut-off)
NFP	Nanofiltration Permeate (aq)
NFR	Nanofiltration Retentate (aq)

Results and discussion

The ecotoxicity results (Table 2) show that the ALW was highly toxic to the aquatic environment, as approx. 3000 times dilution was needed to reach the acceptable toxicity threshold (EC_{20}). The EC_{20} values of the permeate decreased with each filtering step: by 25% after micro-, by 71% after ultra- and by 99% after nanofiltration compared to ALW. This trend is in accordance with chemical analytical data, as the concentration of all the measured metals decreases with each step. In addition, also the amount of the suspended solids decreased with each step. Similarly, the water extract of MFR was less toxic than the ALW, but it would still need approx. 100 times dilution to reach the acceptable toxicity level. The ecotoxicity of the nanofiltration retentate was similar to MFR.

Table 2. EC_{20} values for the wastes generated in the SCALE technology alternatives

		ALW	**MFP**	**MFR**	**UFP**	**NFP**	**NFR**
		EC_{20} (dilution)					
A. fischeri	30 min acute	1140x	2279x	100x	1748x	27x	173x
	60 min acute	4344x	2697x	934x	1611x	27x	165x
D. magna	48 h acute	1039x	904x	103x	169x	25x	104x
	72 h acute	1829x	996x	282x	170x	37x	154x
L. minor	7 d acute chlorophyll	46671x	43271x	43x	1720x	120x	91x
	7 d acute frond	23814x	2373x	44x	128x	20x	142x
Median		**3086x**	**2326x**	**102x**	**890x**	**27x**	**148x**

Conclusions

Ecotoxicity testing of permeates and retentates from membrane filtration showed a decrease of toxicity in permeates after each filtration step. The retenates proved also to be less toxic than the original acid waste.

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