Tobermorite ion-exchanger from paper recycling ash and waste glass

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1. Introduction – 11 Å tobermorite ($Ca_5(Si)_6O_{16}(OH)_2.4H_2O$) and its Al-substituted counterpart are layer-lattice cation-exchangers that are of interest with respect to their applications in nuclear and hazardous wastewater treatment [1-3]. In 2015, the European Declaration on Paper Recycling reported that 71.5% of all paper consumed in Europe was recycled, corresponding to 1.2 million tonnes more than their 70% target [4]. Waste paper recycling ash (PRA) arising from this activity contains reactive calcium aluminosilicate phases that can be used for the hydrothermal synthesis of tobermorite when stoichiometrically adjusted with additional silicate-bearing reagents [1]. Waste soda-lime-silica container glass (SCG) has also been used as a partial feedstock for the preparation tobermorite in alkaline media [2]. This research tested the feasibility of a one-step synthesis of tobermorite from a combination of PRA and SCG under alkaline hydrothermal conditions at 100 °C. Reaction products were analysed by powder X-ray diffraction (XRD) and scanning electron microscopy (SEM). This study also evaluated the Cs^+ cation-exchange capacity (CEC), selective Cs^+ distribution coefficients (K_d, from Na^+ and Ca^{2+} background solutions) and the uptake kinetics of Cd^{2+} and Pb^{2+} by the waste-derived tobermorite product.

2. Experimental – PRA (Aylesford Newsprint, Kent, UK) and SCG were ground to pass 250 μm. To prepare the tobermorite, 3.5 g of PRA, 3.5 g of SCG and 2.35 g of CaO were mixed with 60 cm^3 of 4 M $NaOH_{(aq)}$, sealed in a PTFE autoclave and heated at 100 °C for 1, 2 and 5 days. Solid reaction products were separated by filtration, washed to pH ~8 with deionised water and dried in air at 60 °C prior to characterisation by XRD and SEM. Cs^+ CEC of the final 5-day tobermorite product was determined by the saturation of the ion-exchange sites with K^+ ions and their subsequent displacement by Cs^+ ions at 25 °C [1]. Cs^+ selectivity was evaluated by the uptake of Cs^+ from solutions having molar ratios $[Cs^+]$:$[Na^+]$ or $[Cs^+]$:$[Ca^{2+}]$ equal to 1:100 [1]. K_d values were calculated as the ratio of the amounts of Cs^+ sorbed and Cs^+ remaining in solution (in cm^3/g) [1]. Uptake kinetics of Cd^{2+} and Pb^{2+} were determined by exposure of 50 mg of tobermorite product to 200 cm^3 of 0.5 mM metal nitrate solution for up to 24 h [3]. All solutions were analysed by atomic absorption spectroscopy. All preparations and analyses were carried out in triplicate.

3. Results and Discussion - PRA comprises gehlenite ($Ca_2Al_2SiO_7$), åkermanite ($Ca_2MgSi_2O_7$), β-dicalcium silicate (Ca_2SiO_4), anorthite ($CaAl_2Si_2O_8$) and an amorphous silicate phase [1]. XRD analysis indicated that, during the hydrothermal reaction with SCG, the constituent mineral phases of PRA are progressively replaced by 11 Å tobermorite with hydrogarnet as a minor phase. SEM images confirmed that the product particles were in the size range 2 – 50 μm and displayed the typical foliaceous morphology of tobermorite. Cs^+ CEC of the tobermorite product was found to be 59 ± 4 meq/100g, and K_d values were 574 ± 13 and 658 ± 34 cm^3/g from Na^+ and Ca^{2+} background solutions, respectively. The sorption of Cd^{2+} and Pb^{2+} ions followed pseudo-second order kinetics with maximum uptake values of 130 ± 4 and 357 ± 7 meq/100g, respectively, at 24 h.

4. Conclusions - A candidate Cs^+-selective tobermorite cation exchanger with a high uptake-capacity for Cd^{2+} and Pb^{2+} ions can be prepared by a facile one-step hydrothermal reaction between paper recycling ash and waste container glass.

5. References

[1] N.J. Coleman, *Mater. Res. Bull.*, **40**, (2005) p. 2000.
[2] N.J. Coleman, C.J. Trice and J.W. Nicholson, *Int. J. Miner. Process.*, **93**, (2009) p. 73.
[3] N.J. Coleman, *Int. J. Environ. Waste Manage.*, **8**(3/4), (2011) p. 366.
[4] Paper Recycling Final Monitoring Report 2015, www.paperforrecycling.eu/publications/ (30:04:18)