Synthesis and ion-exchange properties of waste glass-derived zeolites

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1. Introduction - The quantity of waste glass generated within the European Union in 2014 was estimated to be 18.5 million tonnes with an approximate recovery ratio of 79% [1]. Poor collection infrastructure and colour mismatch restrict regional demand for coloured waste container glass that can be recycled as new bottles and jars [1-3]. For example, green and amber soda-lime-silica glasses are widely distributed as bottled alcoholic beverages; however, their effective recovery from the waste stream and subsequent recycling is limited to regions with established wine- and beer-making industries [1]. To address this problem, various projects have been carried out to upcycle surplus coloured container glass into value-added materials such as catalysts, ion-exchangers and ceramics [1-3]. In this study, waste amber container glass was evaluated as a feedstock for the hydrothermal synthesis of zeolites that have the potential to remove heavy metal ions from contaminated wastewater.

2. Experimental - To prepare the zeolites, 3.0 g of ground amber glass (< 125 µm), 0.45 g of aluminium foil and 15 cm^3 of either 4M $NaOH_{(aq)}$ or 4M $KOH_{(aq)}$ were heated at 100 °C for 10 days in a sealed PTFE autoclave. The products (*viz*. ZN and ZK, respectively) were recovered by filtration, washed with deionised water to pH ~ 8, dried in air at 40 °C and analysed by powder X-ray diffraction analysis (XRD) and scanning electron microscopy (SEM). Uptake of Cu^{2+}, Zn^{2+} and Pb^{2+} were determined by exposure of 0.1 g of zeolite product to 200 cm^3 of 0.5 mM single metal nitrate solution for up to 168 h [3]. All solutions were analysed by inductively coupled plasma spectroscopy (ICP). All preparations and analyses were carried out in duplicate.

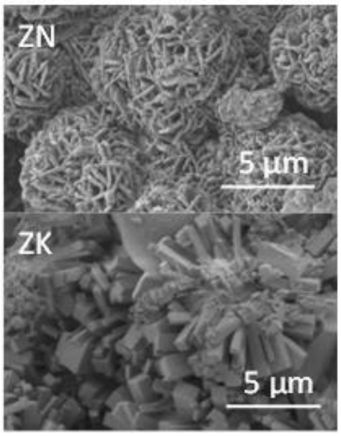

Image 1. SEM images of ZN & ZK reaction products

3. Results and Discussion - The hydrothermal reaction products were confirmed by XRD. Sample ZN was found to comprise 21% cancrinite, 17% hydroxysodalite, 12% tobermorite, 8% sodalite, 6% katoite and 36% residual amorphous glass. Sample ZK was composed of 62% zeolite F, 13% katiote and 25% residual glass. The wool-ball hydroxysodalite phase and the orthorhombic zeolite F phase of samples ZN and ZK, respectively, are shown in Image 1. Both products were granular with particle size ranges of 10 - 500 µm. The maximum Cu^{2+}, Zn^{2+} and Pb^{2+} ion uptake capacities of ZN and ZK are listed in Table I. These compare well with those of other waste-derived ion-exchangers [2.4].

Table I. Maximum metal ion uptake by ZN and ZK

Sample	Maximum metal ion uptake (mmol g^{-1})		
	Cu^{2+}	Zn^{2+}	Pb^{2+}
ZN	0.22 ± 0.12	1.95 ± 0.10	2.17 ± 0.80
ZK	1.94 ± 0.36	2.06 ± 0.10	2.27 ± 0.72

4. Conclusions – A zeolitic mixture (ZN) of cancrinite, hydroxysodalite and sodalite (with tobermorite and katoite) can be prepared by the hydrothermal treatment of waste amber container glass in sodium hydroxide. Hydrothermal conditioning of amber glass in potassium hydroxide produces a mixture of zeolite F and katoite (ZK). Both products demonstrated similar ion-exchange capacities for Zn^{2+} and Pb^{2+} ions (~2 mmol g^{-1}), although sample ZN exhibited inferior uptake of Cu^{2+} ions (~0.2 mmol g^{-1}).

5. References

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