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## Selective removal of metals from aqueous solutions using silica attached ligands

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In order to facilitate the selective sequestration of important radionuclides and contaminants, a surface attached ligand, (3-Aminopropyl)triethoxysilane (APTES) has been attached to 2 types of silica with very different surface areas. ZEOprep 60 HYD Silica gel, 40-63  $\mu\text{m}$  and fumed silica, 0.007  $\mu\text{m}$  were used as the solid support for APTES attachment. A further 14 ligands attached to silica substrates by PhosphonicS Ltd have also been tested for their selectivity of sequestration in a solution containing cobalt, nickel, copper, zinc, cadmium, europium and uranium at a concentration of ca. 20 ppm.

Following successful attachment of polymer to the silica surface, our focus moved to the attachment of ligands to silica and the testing of their selectivity. By utilising two different silica types, we have been able to investigate the differences in the amount of ligand we can attach but then also the ability for each of these to sequester metal. Following successful sequestration of some transition metals, our research has been extended by using radionuclides including  $^{57}\text{Co}$ ,  $^{63}\text{Ni}$ ,  $^{109}\text{Cd}$ ,  $^{152}\text{Eu}$  and  $^{238}\text{U}$ . These concentrations ranged from 2.5 ppm up to 160 ppm in some cases. To make the investigation more relevant to real case scenarios, a great excess of potentially competitive groundwater cations, such as  $\text{Na}^+$  and  $\text{Ca}^{2+}$  were added to further the study. It has been shown that the metal sequestration is not significantly affected by the addition of these ions.

Rd's for the sequestration of  $^{63}\text{Ni}$  from deionised water range from  $4 \times 10^4$  to  $1.2 \times 10^7$  ml/g compared to  $5.3 \times 10^4$  to  $7.9 \times 10^5$  ml/g for potentially competitive calcium in solution and  $1.2 \times 10^5$  ml/g to  $7.3 \times 10^6$  ml/g for potentially competitive sodium sequestration. Isotherms have also been produced across a pH range from 5.01 to 6.80 before addition of the material, to a final pH of 6.90 to 9.49 depending on the original concentration and competitive ions in solution. Similar Rd values or better have been recorded for other metals including  $^{57}\text{Co}$ ,  $^{109}\text{Cd}$ ,  $^{152}\text{Eu}$  and  $^{238}\text{U}$ .

Uranium was found to be highly selectively removed by the APTES ligand with copper being the next favourable. These results were obtained by measuring the metal concentration before and after the modified silica had been added to the aqueous solution using ICP-OES. A minor difference between the ZEOprep and fumed silica materials was also noticed in terms of quantity of metal removed.

Investigations with the PhosphonicS Ltd. samples have shown a range of selectivity with the molecules attached to the silica which include a range of sulphur, nitrogen, carbonyl and phosphonate ligands. With many nitrogen containing ligands, uranium was found to be removed from a concentration of 21.5 to 1.5 ppm over a four week period, whilst in the same solution, copper was only reduced to 8.5 ppm from an original concentration of 19.8 ppm. The remaining metals in solution did not see a noticeable change. The other tested ligands have been found, in this seven metal system to be selective for europium and copper whilst none of the other metals have seen a noticeable change.

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