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The use of magnetic nanoparticles for the recovery of metals from anthropogenic and environmental waste

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Sustainable extraction of critical metals, needed for renewable technologies, is essential for achieving net zero carbon. Whilst metals are currently predominantly sourced from primary ore deposits there is also a growing realisation that there is a significant worldwide abundance of metals within aqueous phase resources (including both natural and wastewaters). Such resources are currently overlooked to date due to a range of technological challenges associated with the requirement for low cost, effective and selective metal recovery.

New approaches to recover this “lost value” include sorption of the metals to redox-active magnetic nanoparticles (MNPs). MNPs have high surface area-to-volume ratios, magnetic properties and can be produced readily. These properties, coupled with redox activity, help MNPs to act as strong sorption agents for critical metals including Co, Ni and Li. Typically, unfunctionalized MNPs exhibit a net positive surface charge at circumneutral pH, however many aqueous critical metals are similarly positively charged which limits the ability for MNP to be used in sorption. However, coating of the MNPs with organic functional groups can lead to a negative surface charge at neutral pH and overcome this barrier. Functionalisation of the MNP surface can be done through synthesis in the presence of different organic ligands (e.g., citric and humic acids) or alternatively via production by bacteria (e.g., microbial Fe(III) reduction).

In this study, we investigated the use of functionalised magnetite on the extraction of critical metals such as Co and Ni. Two different concentrations of magnetite (1 gL^{-1} and 5 gL^{-1}) were subjected to several concentrations of Co^{2+} and Ni^{2+} ranging from 10 to 4000 ppm at near-neutral pH conditions under anoxic conditions. Samples were collected after 48 hrs to determine the dissolved and sorbed concentrations of metal with ICP-OES. Preliminary results showed that magnetite can remove up to 90% of Co from the solution in the lower concentration range (10-100 ppm). The data was fitted with various adsorption isotherms with the Freundlich model providing the most satisfactory fit for Co with 5 gL^{-1}, indicating multilayer adsorption. Overall, this data shows the potential for functionalised MNPs to be used to recover critical metals from waste.