Enhanced leaching of copper and arsenic from mine tailings using biodegradable acids for resource recovery and remediation

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Mine wastes and tailings can present both a source of environmental pollution and also an opportunity for secondary mining for resource recovery, with the metals/metalloids of environmental concern often being of economic value - raising the possibility of remediation costs being offset by metal(s) recovery. Many sites are also valuable from other perspectives (e.g. social, cultural value) and so low intensity *in situ* methods might have applicability being relatively non-invasive techniques for combined metal extraction and environmental remediation. Within this context this paper presents a study of the geochemical characterisation, leaching and enhanced leaching of mine tailings from an abandoned historic Cu/As mine in the UK. The enhanced leaching utilised the non-conventional biodegradable acids citric acid ($C_6H_8O_7$) and methanesulfonic acid (CH_3SO_3H) used because of their reduced environmental impact. The efficacy of these acids is compared to standard enhanced leaching with sulfuric (H_2SO_4) and hydrochloric (HCl) acid. A composite was created from 18 multi-kilogram samples collected from the tailings pile. The tailings composite had relatively coarse particle size (d_{50} = 1 mm), a paste pH of 3.33, and predominantly comprised quartz bearing minerals and muscovite. As and Cu were recorded to be present in concentrations of 19,800 and 1800 mg/kg respectively. The Cu and As leaching potential of each acid was investigated and a kinetic model developed for *in situ* leaching. It was found that in general HCl, H_2SO4 and CH_3SO_3H exhibited relatively similar leaching ability for As despite their different pKa, with recovery after 48 hrs of 58, 56, and 55 % for 1M H_2SO_4, HCl and CH_3SO_3H respectively, compared with only 44 % by $C_6H_8O_7$. H_2SO_4 was generally the most effective acid type for Cu removal with 38 % removal for 1M solutions after 48 hrs, compared to 32, 29 and 22 % recorded for HCl, CH_3SO_3H and $C_6H_8O_7$ respectively. The results demonstrate that As and Cu can be recovered using biodegradable acids and that this has significant applicability for the *in situ* leaching of metal(loids) for the simultaneous decontamination and recovery of economically valuable metal from mine tailings waste.