Chemical and Sonochemical Reduction of Cr (VI) in Soil Slurry and Aqueous Solution using Reducing Agents

ABSTRACT

Cr (VI) is a priority pollutant almost all over the world including India. Reduction of Cr (VI) to Cr (III) is environmentally favourable as the latter species is not toxic to most living organisms and also has a low mobility and bioavailability. Chemical and sonochemical reduction of hexavalent chromium using ascorbic acid, sodium sulphite, hydrazine and iron sulfide in aqueous solution as well as in slurry of contaminated soil have been investigated over a wide range of parameter values, namely, the initial Cr(VI) concentration, molar ratio of Cr (VI) to reducing agent, soil loading in the slurry, pH and temperature. Reduction experiments were carried out in a batch stirred reactor. Almost complete conversion of Cr (VI) occurs in 180 minutes with stoichiometric dosing of ascorbic acid ensuring maximum utilization of the reagent. Complete reduction of hexavalent chromium by sodium sulphite was achieved within 60 min at a molar ratio of 1:4. Soil in suspension causes a significant enhancement of the rate of reduction. With 33.3% soil in suspension, complete reduction of Cr (VI) could be achieved in 4 hrs with 33% excess hydrazine dosing. But the time reduces to merely 20 minutes if four times the stoichiometric quantity of hydrazine is used. Five times the stoichiometric quantity of iron sulfide (i.e., Cr (VI): FeS = 1:15) is required to obtain complete conversion of Cr (VI). The reaction rates increased with decreasing pH, increasing dosing of reductants and with increasing soil fraction in the slurry. It is obvious that presence of soil in suspension has a strong catalytic effect on the process, a phenomenon not hitherto reported in the literature. A simplified mechanistic model for the reduction reactions have been developed on the basis of two electron transfer pathway leading to a second order rate form. Experimental rate data fitted satisfactorily in the equation and the rate constant could be evaluated using the integrated form of the equation. The calculated second order rate constant varies linearly with soil fraction in the slurry and pH. The redox reactions display a moderate dependence on the temperature. Cr (VI) reduction in soil slurry was faster compared to aqueous solution. Sonication of the solution significantly enhances the rate of reactions, an observation not reported before. Effect of sonication on reduction rate of Cr (VI) is more prominent in presence of soil in suspension. Since reduction of Cr (VI) in an aqueous suspension of soil is a practically feasible strategy for Cr (VI) remediation, the findings of this work will be useful in soil remediation in the field. The reduction rates of Cr (VI) are in the order: ascorbic acid > sodium sulphite > hydrazine > iron sulfide.

Keywords: Cr (VI)-contaminated soil, hexavalent chromium, chemical reduction of Cr (VI), sono-assisted reduction of Cr (VI), ascorbic acid, sodium sulphite, hydrazine, iron sulfide, dehydroascorbic acid.