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Reduction of Hexavalent Chromium Present in Wastewater by Steel Wool in a Continuous Flow System

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Abstract

Continuous reduction of hexavalent chromium Cr(VI) in aqueous solution by commercial steel wool was investigated using glass column over the pH range of 3–7. Nearly 100% reduction took place within the first 10 minutes. The maximum reduction was obtained at pH 3, and the rate decreased with increasing initial pH of Cr(VI) solution. The initial substrate concentration was varied as 50 mg/L, 80 mg/L and 100 mg/L respectively. There was a gradual decrease in the extent of reduction as the initial substrate concentration increased. The breakthrough of the column was observed generally at 10 minutes whereas the complete exhaustion took 120 minutes. Results of this experiment may be utilized for modelling, simulation and scale-up in future.

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1. Introduction

Chromium is a heavy metal having wide industrial use (e.g. textile dyeing, tanneries, metallurgy, metal electroplating, and wood preservation). Therefore large quantities of chromium are discharged into the wastewater from these industries [1]. Adsorption, ion exchange and membrane separation processes are a few techniques for the decontamination of Cr(VI) polluted wastewater [2]. These methods merely transfer the pollutant from one phase to the other. Some of the conventional methods of treating Cr(VI) include its

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reduction to the trivalent state since the former is more toxic and mobile compared to the later. The reducing agents commonly used are ferrous sulfate, sulfur dioxide, sodium sulfite or sodium bisulfite. Major drawback of these methods is the high cost of chemicals used for the reduction and precipitation purposes. In recent years, zerovalent iron (ZVI) is being used for the *in situ* treatment of groundwater contaminated with Cr(VI) by chemical reduction in acidic pH. After reduction the pH of the solution is adjusted to neutral or alkaline, to precipitate Cr(III) as hydroxides [3,4]. The process is effective and economical. The reaction products like Fe(II) and Fe(III) compounds, are environmentally benign as well. Reports are there for the reduction of hexavalent chromium by zerovalent iron (ZVI) in batch processes [5], but reports on continuous reactors for the same are scarce. Ozer et al. [5] used steel wool for reduction of hexavalent chromium in a continuous column. El-Shazly et al. [6] used scrap iron for the same purpose. The treatment of Cr(VI) polluted wastewater in continuous system, by reduction with scrap iron and subsequent precipitation of the resulted cations was studied by Gheju and Balcu [8, 9]. They also studied the reduction -capacity of scrap iron particles with different shapes and sizes. Effect of change in pH on the reduction of hexavalent chromium by scrap iron in a continuous system was investigated by Gheju et al. [10]. Over the pH range of 2.0–7.3, the optimum pH for Cr(VI)- reduction was observed as 2.5. Recently we have published our work with steel wool and Cr(VI) [11] in batch mode. In the present work, we have explored the reduction of hexavalent chromium in water in a continuous flow mode using a glass-column packed with a fixed bed of steel wool. Steel wool, made out of cold drawn steel wire, is widely used for furniture finishing, domestic surface cleaning and manufacture of automotive brake fibre. It is low in carbon-content and typically has high surface area to volume ratio. It is a cheap and easily available material for such reduction. Time-concentration profiles of continuous flow experiments have been studied varying the initial solution concentrations and initial pH of the substrate solution.

2. Materials and methods

2.1. Materials

Commercial steel wool has been procured from local market. It was washed with acetone and dilute acid. Then it was heat-treated in a muffle furnace at 400°C to drive out the organic impurities and preserved in a desiccator to prevent atmospheric hydration. EDX data (not shown) revealed that this ready-to-use steel wool contains mainly iron and oxygen and a small amount of carbon. Laboratory reagent grade potassium dichromate, concentrated sulphuric acid and sodium hydroxide were procured from SRL Chemicals, India. Freshly prepared double distilled water was used for preparing solutions. pH of the solution was measured with digital pH meter (Eutech Instruments waterproof pH Testr 20).

2.2. Analytical methods

The residual concentration of Cr(VI) in solution was determined using a UV-vis spectrophotometer (Shimadzu UV-160A, Kyoto, Japan) at 370 nm in a 1 cm quartz cuvette against a standard linear ($R^2 = 0.99$) calibration curve within the concentration range 0 to 100 mg/L [5,11].

2.3. Methods

Reduction experiments were conducted by using a borosilicate glass column (30 cm. height and 3 cm. diameter) having four outlets numbered serially from the bottom. The gaps between the outlets were 5 cm. A Riviera make Rivotek peristaltic pump of flow rate 0-60mL/minute was used to deliver the simulated

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