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Removal and recovery of copper via a galvanic cementation system part II: batch-recycle reactor

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Abstract

This paper describes a batch-recycle galvanic reactor, operated in the flow-by configuration, for the removal of copper from dilute industrial effluents. A three-dimensional cathode, 80 ppi reticulated vitreous carbon, was used for this purpose. Mass transfer studies show that the average mass transfer coefficient was proportional to the Reynolds number, Re^f, where f = 0.68, which was independent of the concentration of reactant species under the experimental conditions. A comparison of the performance between a single-pass and a batch-recycle reactor was also conducted with an initial copper concentration of 10 mg l^{-1}, 100 mg l^{-1} and 500 mg l^{-1}. A 500 ml feed of 74.2 mg l^{-1} of copper in electroplating rinse water with a low conductivity of 1.2 mS cm^{-1} was reduced to less than 1.0 mg l^{-1} in 150 min at a flow rate of 500 ml min^{-1}.

List of symbols

A_e	specific surface area, m^{-1};
C_{inlet}	inlet copper (II) concentration, mol l^{-1};
C_{outlet}	outlet copper (II) concentration, mol l^{-1};
C_0	copper (II) concentration at treatment time = 0, mol l^{-1};
C_t	copper (II) concentration at treatment time t, mol l^{-1};
D	diffusion coefficient, m^2 s^{-1};
k_m	mass transfer coefficient, m s^{-1};
L	electrode length, m;
Re	Reynolds number, $uv^{-1}A_e^{-1}$;
Sc	Schmidt number, vD^{-1};
Sh	Sherwood number, $k_m \varepsilon A_e^{-1} D^{-1}$;
u	superficial velocity (volumetric flow rate/electrode cross sectional area), m s^{-1};
V_e	cathode volume, cm^3;
V_T	total volume of catholyte (cell + reservoir), cm^3;
ε	porosity;
ν	kinematic viscosity, m^2 s^{-1}

1. Introduction

Electrochemical techniques offer an efficient means for the prevention and remedy of pollution problems particularly in the plating, metal finishing and electronic industries [1, 2]. Besides being a clean and versatile approach, recovering and recycling both the metal and the water provide great economic benefits. For dilute metal-bearing waste waters, porous three-dimensional electrodes in the form of carbon [3], metallic felt or foams [4, 5], reticulated vitreous carbon (RVC) [6–8], carbon felt [9–10] and stainless steel wool [11] are often considered to provide high specific surface area and overall mass transfer rates. In recent years, several papers have been published concerning the use of electrochemical reactors for the removal of heavy metals in a continuous single-pass mode and batch recirculation mode [12–15]. However, no specific publication focuses on the difference between the two approaches.

In the previous paper, removal and recovery of copper utilizing a single-pass galvanic cementation system was described [16]. It was confirmed that a single-pass system allows efficient copper removal below the maximum permissible level for simulated solutions. However, an outlet copper concentration below 1.0 mg l^{-1} was not achieved under any conditions when treating industrial wastewater. Hence, for solutions with very low electrical conductivities, another mode of operation, the batch-recycle system needs to be used for higher efficiency copper removal.

In this work, a batch-recycle galvanic system is studied along with its mass transfer characteristics. Furthermore, comparative studies between single-pass