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Cobalt Removal from Simulated Wastewaters Using a Novel Flow-by Fixed Bed Bio-electrochemical Reactor

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ABSTRACT

In this study, the performance of a new design of flow-by fixed bed bio-electrochemical reactor was investigated for cobalt removal from simulated wastewater. The influence of operation parameters such as applied cell potential, initial cobalt concentration, pH of the catholyte, and the mesh size of the cathode on the performance of the bio-electrochemical reactor were investigated. The results showed that the applied cell potential had the largest effect on cobalt removal efficiency. An increased cell potential resulted in an increase in removal efficiency, while an increased initial cobalt concentration led to a decrease in removal efficiency. The results confirmed that using a pH < 3 caused a sharp decrease in removal efficiency while a pH > 7 led to a slightly decrease in removal efficiency. Using a mesh no. > 30 gave a lower removal efficiency. The best operating conditions were a cell potential of 1.8 V, an initial cobalt concentration of 50 ppm, and a pH of 7. Under these conditions with a stack of stainless no. 30 steel mesh as a packed bed cathode, a removal efficiency $> 99\%$ was obtained, in which the final cobalt concentration was reduced to < 1 ppm at 100% current efficiency and a low energy consumption of 1.564 kW h/kg cobalt.

1. Introduction

Cobalt is a very toxic heavy metal which poses serious health and environmental threats. Its presence in the environment can cause numerous health problems such as heart disease, low blood pressure, nausea, vomiting, sterility, vision problems, thyroid damage, bleeding, hair loss, bone defects, and diarrhoea, and can cause mutations (genetic changes) in living cells [1,2]. To avoid these health hazards, its concentration in livestock wastewater and irrigation water is regulated to not exceed 1.0 and 0.05 mg/L, respectively [1].

Cobalt and its compounds have various applications such as in medicine, nuclear power plants, metallurgy, mining, paints, pigments, fertilisers, electronics, and electroplating [3,4]. Cobalt is contained in extensively used lithium-ion batteries as well as super alloys [5,6]. In spite of these vital applications of cobalt and its compounds, environmental responsibility and legal constraints dictate that effluents from these industries should be effectively treated before discharging to avoid environmental problems and hazards to human health.

Multiple techniques for the removal of cobalt ions have been used, such as coagulation, adsorption, oxidation, chemical precipitation, reverse osmosis, solvent extraction, ion exchange, and membrane electrolysis [7]. However, in the application of most these methods, many practical limitations occur due to their inefficiency at low concentrations, high operational costs accompanied by use of chemicals, sludge generation at high volume, and low selectivity [5]. Alternatively, cobalt can be removed by electrochemical processes such as cathodic deposition which has been proven to be efficient in controlling pollution via removal of heavy metals using redox reactions. In this approach, the main reagent is a supply of electrons, which present no environmental concerns. Therefore, this approach is environmentally friendly [8].

During the last two decades, application of cathodic deposition in the environmental treatment of wastewater containing heavy metals has increased because of the development of three-dimensional electrodes using porous materials for the construction of electrochemical reactors [9]. The main advantage of this type of electrode is its capability to deliver a high mass transfer rate in addition to high specific surface area. Numerous designs of three-dimensional electrode have been utilised for removal of heavy metals, such as those based on carbon or metal particles [10,11], felts, metallic or metal-plated foams [12,13], reticulated vitreous carbon [14], and screens and expanded metals [15–18]. The use of screens in constructing three-dimensional electrodes has proved to be better than other types of electrode due to many advantages, such as their availability at modest cost, high specific area, high porosity, high ability for promotion of turbulence, low

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