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Study on the treatment of photovoltaic wastewater using electrocoagulation: Fluoride removal with aluminium electrodes — Characteristics of products

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abstract

In this work, treatment of synthetic fluoride-containing solutions by electrocoagulation method using aluminium electrodes has been studied. Electrocoagulation was investigated for applied potential (10–30 V), electrolysis time and supporting electrolyte (NaCl) concentration (0–100 mg/L). The results showed that with increasing applied potential and electrolysis time, the Al^{3+} dosage increases, and thereby favouring the fluoride ions removal. It was also observed that defluoridation is dependant on the concentration of supporting electrolyte. Finally, X-ray diffraction, scanning electron microscopy, energy dispersive spectroscopy of X-rays and Fourier transform infrared spectroscopy were used to characterize the solid products formed by aluminium electrodes during the EC process.

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1. Introduction

Photovoltaic (PV) energy conversion is increasingly regarded as a technology which may contribute to the world energy supply in a way that is compatible with the concept of sustainable development. However, to ensure that PV energy can indeed fulfil this expectation, a careful consideration of potential environmental risks of PV energy conversion is necessary [1].

PV manufacturing process, which requires extremely high precision, generates both conventional and hazardous wastes. The management of waste has become an important issue in the industry as a result of stringent environmental regulation and possible liability. Among varieties of pollutants, hydrofluoric acid (HF) is a major concern. It is used extensively in PV manufacturing for wafer etching and quartz cleaning operations [2]. Fluoride con- centrations of 500–2000 mg/L are found in typical wastewater of local PV industry [3]. Fluoride contamination in certain aquatic systems worldwide has caused health concern. Due to its high toxi- city, industrial wastewater containing fluoride is strictly regulated. In Algeria, the discharge standard is of 15 mg/L from wastewater treatment plant [4].

Various treatment technologies, based on the principle of precipitation, ion exchange, membrane and adsorption process have been proposed and are tested for removal efficiency of excess of fluoride from drinking water as well as industrial effluents [5].

In recent years, there is growing interest in electrocoagulation (EC). This technique can be used to treat effectively restaurant wastewater [6], textile wastewater [7], electroplating wastewater [8], and fluoride-containing wastewater [9,10]. It has also proven its good efficiency for drinking water defluoridation [11–13]. EC technique uses a direct current source between metal electrodes immersed in polluted water. The electrical current causes the dissolution of metal electrodes commonly iron or aluminium into wastewater. The metal ions, at an appropriate pH, can form wide ranges of coagulated species and metal hydroxides that destabilize and aggregate the suspended particles or precipitate and adsorb dissolved contaminants [14]. EC is attractive in that no contaminants are introduced and beneficial contents present in raw water can be remained during defluoridation. In the case of aluminium electrodes, the main reactions involved are as follows:

$$Al \rightarrow Al^{3+} + 3e \quad \text{at the anode} \tag{1}$$

$$Al^{3+} + 3H_2O \rightarrow Al(OH)_3 + 3H^+ \tag{2}$$

$$Al(OH)_3 + xF^- \rightarrow Al(OH)_{3-x}F_x + xOH^- \tag{3}$$

$$2H_2O + 2e \rightarrow H_2 + 2OH^- \quad \text{at the cathode} \tag{4}$$

Defluoridation is achieved by forming $Al(OH)_{3-x}F_x$. The fine hydrogen gas bubbles generated at the cathode can enhance F^- mass transfer and float the $Al(OH)_{3-x}F_x$ flocs to the top of the

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