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Electrochemical treatment as a pre-oxidative step for algae removal using *Chlorella vulgaris* as a model organism and BDD anodes

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HIGHLIGHTS

- A treatment of water by direct electrolysis for algae removal was studied.
- Experiments were carried out in batch and continuous mode.
- Behaviour and the role of chlorinated compounds during the treatment were studied.
- The possible mechanisms of algae removal were individuated and discussed.
- The effect of non-ideal flow conditions was studied and a simple model was proposed.

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ABSTRACT

An experimental work is presented in this paper on the inactivation of algae through electrochemical treatment. A green algae (*Chlorella vulgaris*) was adopted as a model. A commercial filter-press electrochemical reactor (Electro MP-Cell), equipped with a boron doped diamond (BDD) anode and a stainless steel cathode, was used to perform the electrolysis. The cell was inserted in a hydraulic circuit and used in either a closed loop, as a recirculating batch reactor, or in the continuous mode. The effects of current density and hydrodynamics were studied, as well as the formation of active chlorine and other chloride oxidation products. Active chlorine concentrations on the order of 0.3 mmol dm^{-3} were obtained when algae were not present in the initial solution (batch experiments) or in the feed (continuous experiments). In the presence of algae, the value was 0.03 mmol dm^{-3}. The highest values were measured with $i = 75$ A cm^{-2} and flow conditions corresponding to a Reynolds number of 100 (batch experiments) or a hydraulic residence time of 4 min (continuous experiments). The process led to the total inactivation of algae when 100 mg dm^{-3} of chlorides was present in the solution, which is a typical value for natural waters. The results indicated that, under the adopted conditions, the prevailing mechanism was inactivation by means of long-life oxidants electrogenerated. A simple model of continuous stirred tank reactors (CSTRs) in-series was adopted to account for the non-ideal flow conditions in the continuous experiments, which was able to interpret the data under all the conditions tested.

1. Introduction

Algae in water are of great concern because they adversely affect drinking water quality and water treatment processes [1,2]. In particular, in tropical and semi-tropical zones, algae can grow excessively under high nutrient contents in surface water due to contamination by agricultural activity, domestic wastewater discharge and industrial effluents [3,4]. The high concentrations of nitrogen and phosphorous can provide the ideal medium for the excessive growth of algae, which is detrimental not only from an environmental point of view but also for human health [5].

Algae may cause problems, such as poor taste and odour in the water [4], and several studies have been reported in the literature on the possible problems connected with toxins released by algae [6]. The presence of sublethal doses of cyanotoxins in drinking water is implicated as one of the key risk factors for the high occurrence of primary liver cancer [7].

Moreover, the presence of algae in water treatment plants interferes with physical and/or chemical water purification processes [8]; in particular, fouling and clogging of filtration membranes have been observed even when the coagulation and sedimentation processes removed more than 90% of the algae in the influent [9].

Different processes have been proposed for algae removal, such as flotation, sand filtration and coagulation [6,10–12]; with inorganic or organic coagulants [13,14], high removal yields were

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