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Remove of phosphorous and turbidity of swine wastewater using electrocoagulation under continuous flow

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A B S T R A C T

Electrocoagulation (EC) is a process of hydroxides generating by passing electric current through electrodes of aluminum and/or iron, to remove impurities in some effluent. Thus, this study investigated the EC process for turbidity and total phosphorus (TP) removal of swine wastewater. For this purpose, two central composite rotatable design (CCRD) 2^2 were applied aiming at investigating the effects of current density (CD) (16.3–57.5 mA/cm^2) and the hydraulic retention time (HRT), where different times were evaluated for the aluminum electrode (31.8–88.2 mL/min) and for iron electrode (61.8–118.2 mL/min). The removals of turbidity using aluminum and iron electrodes were of 91%. For aluminum electrode the removals of TP were 93% and for iron were 96%. The central composite rotatable design showed that the current density (DC) is the most important process variable for both electrode materials (Al and Fe) evaluated, since the removal efficiency was enhanced with increasing CD. The hydraulic retention time (HRT) had no significant effect. For aluminum electrode the energy and electrode consumption was of 2.2–15.3 kW h/L and of 0.56–2.01 g, respectively. For iron electrode the energy and electrode consumption was of 2.1–17.2 kW h/L and of 0.74–2.77 g. EC could be considered a promisor post-treatment effluent of the anaerobic digestion for the simultaneous removal of turbidity and TP. In the conditions of HRT and CD of this study, the iron electrode presented best removals efficiencies in relation to aluminum electrode.

1. Introduction

The growth of swine production has contributed to solve the animal protein supply problem for human consumption and promote economic development. However, this growth also contributes to the worsening environmental pollution, since wastewater from swine contains high levels suspended solids and of nutrients such as phosphorus, which is causing the eutrophication of water [1]. Thus, it is essential to remove these pollutants from wastewater before discarding it in the soil and/or water.

Among the anaerobic digestion technologies, anaerobic upflow (Upflow Anaerobic Sludge Blanket-UASB) has been applied as an alternative treatment of swine wastewater. However, the effluent from the UASB reactor does not meet the standards release compared to the turbidity content, organic matter and total phosphorus [2].

In recent years, the electrocoagulation technology (EC) shows an effective treatment technology for wastewater such as: wastewater poultry [3], oily water [4], textile effluents [5], metals [6], industrial effluents [7], poultry industry [8], phosphorus [9] and nitrite [10].

Thus, the electrocoagulation attracts much attention as a promising and powerful way to remove the wastewater pollutants because of some advantages, such as: no addition of chemical additives, simple operation, high efficiency, low sludge production and robustness to different wastewater [11].

The EC operating principle involves the application of an electrical potential to an aqueous solution using metal electrodes generating an electrodissolution of the anode, which leads to the formation of hydrolysis products (hydroxo-metal species) which are effective in destabilization of pollutants and/or formation of particles with low solubility that retain pollutants [12,13].

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According to Kobya et al. [14] insoluble hydroxide species for Fe and Al electrodes are $Al(OH)_3$, $Fe(OH)_2$, $Fe(OH)_3$, $FePO_4{\cdot}2H_2O$ and $AlPO_4{\cdot}2H_2O$. The electrochemical reduction of water at the cathode produces hydrogen bubbles that promote a smooth turbulence in the system and these bubbles bind with pollutants decreasing their specific weight relative. Consequently, they improve the flocculation process and separation of the flocculated contaminants by flotation. In addition, hydrogen can be collected and used as fuel for energy production [12].

According to Lu et al. [15], studies about the electrocoagulation technology are based on systems in batch, and only in recent years researchers are turning their attention to the continuous system. The continuous system becomes more economical than the batch and more adequate in the productive systems with high rates of waste generation [16].

Therefore, this study aimed at evaluating an electrocoagulation reactor in continuous flow using different metals as the anode (aluminum and iron). The effect of the independent variables hydraulic retention time (HRT) and the current density (CD) were evaluated under simultaneous removal of turbidity and total phosphorus (TP).

2. Material and methods

2.1. Swine wastewater pre-treated by UASB

Wastewater was collected from a swine manure treatment system located at Embrapa Swine and Poultry, Concordia, Santa Catarina, Brazil. Residual water used in the experiments was collected at the exit of anaerobic upflow (UASB). Samples were collected in containers of polyethylene 5 L and stored at −10 °C until use. The characterization of the wastewater used in experiments with aluminum and iron electrode is presented in Table 1.

Table 1
Characterization of wastewater from UASB outlet for continuous flow experiments using aluminum and iron electrodes.

Parameters	Aluminum electrode	Iron electrode
Conductivity (mS/cm)	6.44 ± 0.73	6.82 ± 0.29
Turbidity (NTU)	515 ± 213	857 ± 312
TP (mg/L)	73.41 ± 3.30	64.93 ± 19.57

2.2. Experimental procedure

A continuous flow reactor EC was made of acrylic (Fig. 1). The experiments were carried out in continuous mode at room temperature, in an open reactor with a useful volume of 1.8 L. The aluminum and iron electrodes had dimensions of 130 mm of height and 70 mm of width. At the center of the electrode there was a hole of 12 mm of diameter for passage of the nylon screw and a 4 mm hole at the top to attach the electrode connections/power supply to a power source of direct current (DC power supply FA-3005 Intrutherm). The five electrodes (2 anodes and 3 cathodes) were installed vertically with a distance between electrodes of 2 cm. The cleaning of electrodes was carried out using steel wool, rinsed with distilled water and drying in an oven (520 FANEM) at 105 °C for 1 h. A peristaltic pump (Masterflex L/S) was used to provide flow to the reactor. Before the experiments, the wastewater had the pH adjusted with sulfuric acid and sodium hydroxide (Vetec) and this parameter was controlled during the EC process (pH 6.0 for the aluminum electrode and pH 7.0 for iron electrode).

2.3. Experimental design

In this study, two central composite rotatable design (CCRD) 2^2 were carried out aiming at evaluating the effect of the independent variables hydraulic retention time (HRT) and current density (CD) turbidity and TP. A total of 22 experiments were performed, 11 for the Al electrode and 11 for Fe electrode. In the experimental planning, were used 4 factorial points, three central points and 4 axials points at a distance of ±1.41 from the central point as shown in Table 2.

2.4. Analitical methods

The performance of the EC was assessed through the responses: turbidity, and total phosphorus (TP). The turbidity was measured by nephelometry using a Hach 2100P portable turbidimeter (Loveland, CO, USA) following the APHA 2130 B methodology described by APHA [17]. The determination of the total phosphorus

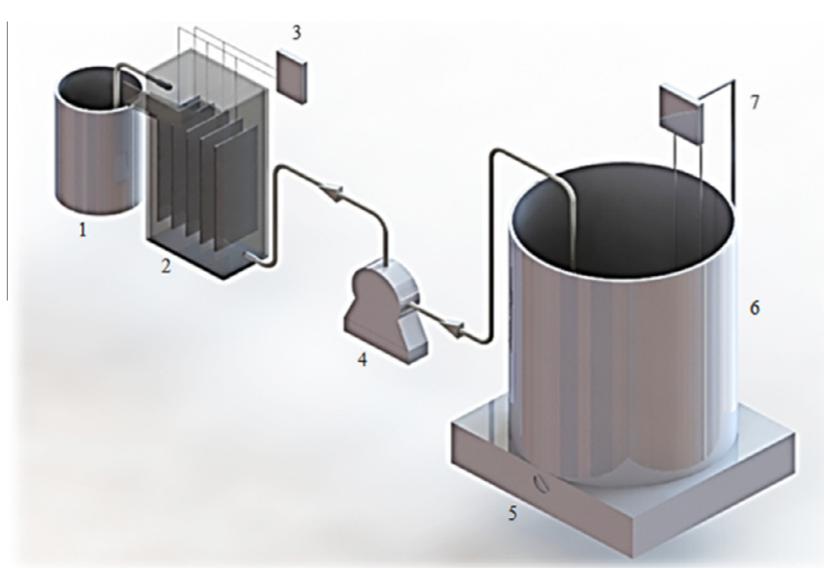

Fig. 1. Experimental scheme. 1 – Storage tank of treated effluent; 2 – electrocoagulation reactor in continuous flow; 3 – CD source; 4 – peristaltic pump; 5 – magnetic stirrer; 6 – effluent storage tank; 7 – pH controller.