Landfill Leachate Treatment by Electrocoagulation and Fiber Filtration

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ABSTRACT: Landfilling is widely adopted as one of the most economical processes for solid waste disposal. At the same time, landfill leachate is also a great environmental concern owing to its complex composition and high concentrations of contaminants. This research investigated electrocoagulation and fiber filtration for the treatment of landfill leachate. Besides electrical current (i.e., current density) and reaction time, pH played a very important role in arsenic and phosphorus removal by electrocoagulation. The combination of electrocoagulation with fiber filtration achieved a 94% chemical oxygen demand (COD), 87% arsenic, 96% iron, and 86% phosphorus removal. During electrocoagulation, the micro-particles that could not be settled by gravity were removed by the first stage of fiber filtration. Organic contaminants in the leachate were further removed by biodegradation in the second stage of fiber biofiltration. *Water Environ. Res.*, **89**, 2015 (2017).

KEYWORDS: arsenic, iron, phosphorus, removal, landfill leachate, electrocoagulation, fiber filtration.

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Introduction

Landfilling is widely adopted as one of the most economical processes for solid waste disposal. At the same time, landfill leachate is also a great environmental concern owing to its complex composition and high concentrations of contaminants (Masoner et al., 2014). In Northwest Florida, arsenic release has been proven to be from unlined construction and demolition debris landfills. Currently, elevated concentrations of arsenic have also been detected in the leachate from lined landfills. Arsenic is believed to be released from the decomposition of wood treated with chromated copper arsenate, which is primarily disposed within the landfills when coming out of circulation as construction debris. In the leachate, As(V) and As(III) are the most commonly found arsenic species. As(V) is the predominant arsenic species, which readily undergoes reduction in anaerobic environments to As(III) by microbial mediated biogeochemical interactions. So far, a handful of microorganisms capable of respiring As(V) have been isolated, which include *Sulfurospirillum*, *Clostridium*, *Caloramator*, *Clostridium*, and *Bacillus*, and others (Gaskin et al., 2008; Rutigliano et al., 2014). In addition, iron reducing bacteria such as *Shewanella* species are also able to reduce As(V) to As (III).

Electrocoagulation can effectively remove arsenic with mechanisms of coagulation, adsorption, precipitation, and flotation (Darcovich et al., 2009; Sanchez and Bourhrara, 2011). During electrocoagulation, coagulation is achieved in situ by electrolytic oxidation of the anode, while the cathode is subjected to passivation. Electrocoagulation has four main processes: (1) electrolytic oxidation of the sacrificial electrode, (2) coagulant formation in the aqueous phase, (3) destabilization of the contaminants and subsequent adsorption of colloidal pollutants on coagulants, and (4) aggregation of the destabilized colloidal contaminants to form flocks and removal by sedimentation or floatation (Garg and Prasad, 2016). When electrocoagulation is used for landfill leachate treatment, ionization, electrolysis, hydrolysis, and free-radical formation also exist, which can alter the physical and chemical properties of the landfill leachate as landfill leachate moves through the applied electric field. As a result, the reactive and excited state makes contaminants to be more easily removed from the leachate (Hassani et al., 2016; Oumar et al., 2016). Usually, the electrode materials for electrocoagulation are aluminum and iron, which, after corrosion and hydrolysis, can function as coagulants. During electrocoagulation, these electrodes (i.e., Fe or Al) release aluminum and iron cations that form highly charged polymeric metal hydroxides to the aqueous media to neutralize suspended solids and facilitate coagulation and

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separation from the aqueous phase. This treatment technology also prompts the precipitation of certain metals and salts.

The electrocoagulation can be used for landfill leachate treatment in terms of iron, arsenic, and phosphorus removal. In addition, electrocoagulation also can reduce leachate chemical oxygen demand (COD). To remove micro-sized particles and decomposed residual organic contaminants, fiber filtration can be used. The overall objective of this research was to investigate electrocoagulation and fiber filtration for the treatment of landfill leachate. After electrocoagulation, the leachate was further treated with two stages of fiber filtration. This treatment achieved a 94% COD, 87% arsenic, 96% iron, and 86% phosphorus removal. During electrocoagulation, the micro-particles that could not be settled by gravity was removed by the first stage of fiber filtration. Organic contaminants in the leachate was removed by biodegradation in the second stage of fiber biofiltration.

Methodology

Multiple anodic electrodes arranged in parallel were used in this research. In parallel arrangement, the electric current was divided between all the electrodes in relation to the resistance of the individual cells, and each electrode had a different polarity. A digital multimeter (34410A; Agilent, Santa Clara, California) was used to measure the operating current supplied by a DC power supply (E3631A; HP, Palo Alto, California). Both iron and aluminum anodic electrodes were examined in this research. The surfaces of the iron and aluminum anodes were mechanically cleaned prior to experiments to remove any passive film that might have formed. The effect of electrical current was evaluated in terms of current density and the relationship of the current density (A/cm^2) and the quantity of the metals dissolved (g/cm^2) was described by the Faraday's law (Butler et al., 2011):

$$W = \frac{i \times t \times M}{n \times F} \quad (1)$$

where W is the amount of dissolved electrode (g/cm^2); i is the current density (A/cm^2); t is the electrocoagulation time (sec); M is the relative molar mass of the electrode (g); n is the number of electrons involved in the oxidation/reduction reaction (-); and F is the Faraday's constant (96 500 C/mol).

Landfill leachate was collected from Springhill Landfill, located in Campbellton, Florida. Springhill Landfill currently accepts domestic wastes from Leon County through the transfer station at the Gum Road. The leachate was collected in temperature-controlled containers at 4 °C and transported to the laboratory immediately. After electrocoagulation with aluminum or iron electrodes, the treated landfill leachate was applied to two stages of fiber filters with a dimension of 2.5 cm ID × 10 cm length. The first-stage fiber filter was used to retain the flocs formed during electrocoagulation and the second-stage biofilter was used for the removal of organics by biodegradation. Continuous cultivation and enrichment of organic degrading consortia were carried out in the second-stage biofilter using organic-enriched landfill leachate as the inocula. The final effluent was collected and measured for COD, iron, arsenic, and phosphorus. The COD was characterized in the laboratory following the standard methods. For iron quantification, 1,10-Phenanthroline Method was utilized and quantified using a spectrophotometer (UV-1650 PC; Shimadzu, Columbia, Maryland) at a wavelength of 520 nm (Williams et al., 2012). For phosphorus quantification, the ascorbic acid method was used (van Zanten and Weber, 1987). Impact of pH was investigated separately for arsenic and phosphorus removal, which was adjusted to 4 to 10 with sulfuric acid or sodium hydroxide.

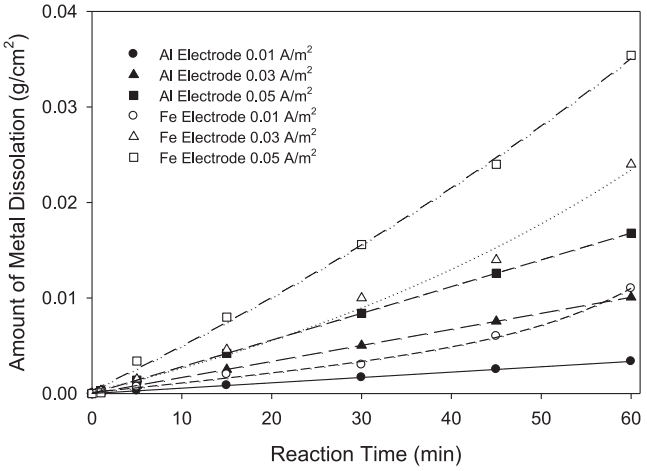

Figure 1—Current intensity and reaction time on electrode dissolution.

Results and Discussion

The aluminum and iron release was calculated according to the relationship of the current density with the quantity of the dissolved metal following the Faraday's law because the quantity of passed-through electricity was responsible for the dissolution of metal ions at the electrodes. Aluminum release linearly increased with the increase of reaction time (Figure 1). However, iron release exponentially increased with the increase of reaction time. During electrocoagulation, the generated Fe^{3+} or Al^{3+} ions immediately underwent further spontaneous reactions to produce corresponding hydroxides and/or poly-hydroxides. These insoluble iron and aluminum hydroxides reacted with the concerned contaminants and precipitated. Besides coagulation, adsorption also helped contaminant removal together with precipitation. High current density led to increased decomposition of the electrode material and enhanced coagulation and COD removal (Figure 2). Similarly, enhanced coagulation and COD removal was also observed for prolonged reaction time, that is, COD removal increased with the increase of reaction time until 30 minutes, after which the increase became moderate. It should be noted that over longer reaction time, formation of ferrous and ferric hydroxide or aluminum hydroxide coatings on the electrode surfaces started to block electron transfer and caused deactivation of the electrodes during electrocoagulation for both aluminum and iron electrodes. This gradually reduced the occurrence of electrochemical reactions and the production of salt coagulants. A clearer