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Review

Review on landfill leachate treatment by electrochemical oxidation: Drawbacks, challenges and future scope

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ABSTRACT

Various studies on landfill leachate treatment by electrochemical oxidation have indicated that this process can effectively reduce two major pollutants present in landfill leachate; organic matter and ammonium nitrogen. In addition, the process is able to enhance the biodegradability index (BOD/COD) of landfill leachate, which make mature or stabilized landfill leachate suitable for biological treatment. The elevated concentration of ammonium nitrogen especially observed in bioreactor landfill leachate can also be reduced by electrochemical oxidation. The pollutant removal efficiency of the system depends upon the mechanism of oxidation (direct or indirect oxidation) which depends upon the property of anode material. Applied current density, pH, type and concentration of electrolyte, inter-electrode gap, mass transfer mode, total anode area to volume of effluent to be treated ratio, temperature, flow rate or flow velocity, reactor geometry, cathode material and lamp power during photoelectrochemical oxidation may also influence the system performance. In this review paper, past and present scenarios of landfill leachate treatment efficiencies and costs of various lab scale, pilot scale electrochemical oxidation studies as a standalone system or integrated with biological and physicochemical processes have been reviewed with the conclusion that electrochemical oxidation can be employed as a complementary treatment system with biological process for conventional landfill leachate treatment as well as a standalone system for ammonium nitrogen removal from bioreactor landfill leachate. Furthermore, present drawbacks of electrochemical oxidation process as a landfill leachate treatment system and relevance of incorporating life cycle assessment into the decision-making process besides process efficiency and cost, have been discussed.

Contents

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1. Introduction

Expeditious extension of industrial, commercial sectors and enormous consumption of packaged product as a consequence of high living standard boosted solid waste generation in recent years. Global municipal solid waste (MSW) generation is projected to attain a value of 2.2 billion tons per year by 2025 (Hoornweg and Bhada-Tata, 2012). Among the most embraced solid waste management practices worldwide, such as recycling, landfilling, composting and incineration (Hoornweg and Bhada-Tata, 2012), sanitary landfilling is by far the most ubiquitous strategy (Deng and Englehardt, 2006; Bolyard and Reinhart, 2016) in both developed and developing countries owing to its simplicity and economic advantages (Calace et al., 2001; Ahmed and Lan, 2012; Hassan et al., 2016). Hoornweg and Bhada-Tata (2012) reported that conventional landfilling manages solid waste of around 335 million tons/year (out of total MSW disposal of 775 million tons/year approximately) globally.

Though a large number of old conventional landfills worldwide are non-engineered, nowadays landfills are instrumented with proper liner and leachate collection system. However, even after providing proper cover, it may not be able to eliminate rainwater percolation completely. Rainwater percolation through the landfill, groundwater inflow, surface water runoff, innate moisture content of buried solid waste, moisture content of cover soil, seasonal weather variation and a group of heterogeneous chemical, biological transformation of solid waste control leachate production quality and quantity (Wiszniowski et al., 2006; Renou et al., 2008; Ahmed and Lan, 2012). However, conventional landfill acts as a waste containment unit. Bioreactor landfill is invented with the intention of transition of conventional landfill from waste containment unit to treatment unit. Nowadays, bioreactor landfills are in trend for a better economic benefit. In bioreactor landfill, control of moisture through leachate recirculation helps in rapid stabilization of solid waste through accelerated microbial activity, improvement of leachate quality and enhancement of gas production. Landfill leachate (LL) is complex in nature due to the presence of a variety of compounds such as organic, inorganic fractions, heavy metals (Aziz et al., 2004) and xenobiotic organic compounds (Christensen et al., 2001; Kjeldsen et al., 2002). The paramount risk exhibited by LL is its potential of polluting surface water, groundwater (Ehrig, 1984; Christensen et al., 2001) as well as soil (Fatta et al., 1999; Deng and Englehardt, 2006; Eggen et al., 2010). Stringent regulations owing to protect our water resources and environment aspire us towards the exploration of technologies that are capable of treating LL to such extent that safe discharge of LL either in surface water bodies or into sewer lines is possible (Abbas et al., 2009).

The crucial challenges associated with LL treatment is its varied composition and amount, toxicity exhibited by ammonia (Im et al., 2001; Deng and Englehardt, 2006; Wiszniowski et al., 2006) and heavy metals, presence of bio-refractory compounds like humic and fulvic acids (Wiszniowski et al., 2006; Renou et al., 2008) and varied concentration of pollutants over leachate generation period. Biological process with nitrification and denitrification steps followed by membrane technology is by far the most commonly adopted combination for LL treatment (Fernandes et al., 2015b). However, certain toxic substances such as polyaromatic hydrocarbons, adsorbable organic halogens, and polychlorinated biphenyls may create an inhibitory effect and abate the process efficiency of the microbial system (Wiszniowski et al., 2006). Furthermore, during the post-closure monitoring period, biodegradability index (BOD/COD) decreases as landfill ages (Ahmed and Lan, 2012) causing the stabilization of organics burdensome for microbes. In addition, the breakdown of certain higher molecular organic compounds also becomes onerous for microbes. Thus, insertion of some other technologies such as air stripping (Wiszniowski et al., 2006), coagulation-flocculation (Amokrane