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A lab-scale anoxic/oxic-bioelectrochemical reactor for leachate treatments

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HIGHLIGHTS

- Liter-scale membraneless BES with biocathode was setup for leachate treatment.
- Anoxic/oxic (A/O) zones connected with a reflux facilitate nitrogen removal.
- With raw landfill leachate, the BES reached >90% COD and NH_4^+–N removal.
- The species in biofilms support the functions of the A/O-BES.

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ABSTRACT

A membraneless, liter-scale bioelectrochemical reactor with both bioanode and biocathode was established for landfill leachate treatment. Anoxic/oxic (A/O) zones at anode compartment and cathode compartment, respectively, were connected with a reflux to facilitate nitrogen removal. With raw landfill leachate of 17,500–22,600 mg L^{-1} chemical oxygen demand (COD) and 1170–1490 mg L^{-1} NH_4^+–N, the tested reactor removed 89.1 ± 1.6% of chemical oxygen demand and 99.2 ± 0.1% of NH_4^+–N at 3.0 kg COD m^{-3} d^{-1}. The corresponding maximum power density was 2.71 ± 0.09 W m^{-3}, with internal resistance of 46.7 ± 1.6 Ω and open circuit voltage of 727 ± 7 mV. The species of *Pseudomonas*, *Desulfovibrio*, *Bacillus*, *Enterococcus*, *Pelospora*, *Dehalobacter* dominated the anodic community, while those of methylotrophs, *Rhodobacter*, Verrucomicrobiaceae, *Geobacter*, *Flavobacterium*, *Thauera*, *Desulfovibrio* and *Aeromonas* dominated the cathodic community. The proposed A/O bioelectrochemical reactor is a prototype for practical treatment of landfill leachate at affordable costs.

1. Introduction

Bioelectrochemical system (BES) which combines biological and electrochemical processes could produce useful products and/or remove pollutants from wastewaters (Kelly and He, 2014). The BES has been used to deal with various waste streams such as industrial wastewaters (Kong et al., 2014), domestic wastewater (Feng et al., 2014), sediments (Yang et al., 2014), sludge (Abourached et al., 2014), and many others. Landfill leachates are wastewaters of complicated organic compounds and high levels of ammonium–nitrogen (Lu et al., 2008, 2009), which are one of the most difficult effluents to handle in practice (Alkalay et al., 1998). Several studies confirmed the feasibility of using the BES for simultaneous pollution removal and energy generation from leachates (You et al., 2006; Zhang et al., 2008; Greenman et al., 2009).

One of the contemporary BES research focus is on its use in fields (Ledezma et al., 2013; Haeger et al., 2014; Feng et al., 2014). Most leachate-BES studies adopted expensive ion exchange membrane, cathode catalyst and catholyte additives (such as potassium ferricyanide) in the tests but had reached insufficient removals of chemical oxygen demand (COD) and NH_4^+–N (Table 1). For instance, You et al. (2006) used a single-chambered MFC of 40 mL with membrane and cathodic catalyst to recover energy from diluted leachate, giving a COD removal of 69.5–98% but with no removal of NH_4^+–N. Greenman et al. (2009) proposed column-type MFC (900 mL) with membrane on treatment of raw

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Table 1
References for leachate treatment using MFC technologies.

Reference	D: dual chamber; S: single chamber	Recycle	Membrane	Cathodic catalysis	Landfill leachate	COD removal (%)	NH_4^+ removal (%)	P_{max} (W m^{-3})	OCV (V)	R_{int} (Ω)
You et al. (2006)	D (125 mL) & S (40 mL)	No	Yes	C/Pt powders	Diluted	69.54–98	NA	7.0	0.73	150
Zhang et al. (2008)	S (170 mL)	No	No	30% wet proofing on carbon cloth with fine C/Pt powders	Diluted	58.5–89.4	23.3	12.8	NA	93
Greenman et al. (2009)	D (900 mL)	No	Yes	Carbon veil as cathode	Raw & diluted	56	NA	0.259 m W m^{-2}	NA	NA
Gálvez et al. (2009)	Series D (900 mL × 3)	No	Yes	Carbon veil as cathode	Raw with 1% Na_2SO_4	79 (COD) 82 (BOD_5)	NA	5.5 m W m^{-2}	NA	NA
Li et al. (2010)	D (850 mL)	No	Yes	Pyrrhotite-coated graphite cathode	Raw	78	NA	4.2	0.43	92
Puig et al. (2011)	S (343 mL)	No	Yes	C-cloth 0.35 mg cm^{-2} Pt catalyst with 30% wet-proofing	Diluted (20%) and raw	37	43 (TN)	0.344	0.4	1462
Tugtas et al. (2013)	D & S (230 mL)	No	Yes	Air cathode with 1 mg cm^{-2} Pt	Pretreated by UASB&MBR	90 (VFA)	40	2.48	NA	35
Özkaya et al. (2013)	D (550 mL)	No	Yes	Mixed metal oxide titanium	Young/raw	45	NA	1.35	NA	NA
Ganesh and Jambeck (2013)	S (570 mL) & semi-continuous (5500 mL)	No	NO	Carbon cloth with 10% Pt	Raw	74.7 ± 5.5	0	0.575	0.531	NA
Lee et al. (2013)	D (no volume date)	No	Yes	G. metallireducens	Diluted	NA	92 or 94	12 m W m^{-2}	NA	NA
Vázquez-Larios et al. (2014)	S (73 mL)	No	No	20 wt% dispersed in Vulcan carbon $Ru_xMo_ySe_z$ and Pt	Raw	NA	NA	0.00124	NA	44
Damiano et al. (2014)	S (934 and 1830 mL)	No	No	Wet-proofed woven carbon cloth coated with 1 mg cm^{-2} Pt	NA	74 (BOD), 27 (TOC)	25	0.824	0.65	NA
This study	D (3500 mL)	Yes	No	Biocathode	Raw	95.1 ± 1.8	99	2.71	0.819	46.7

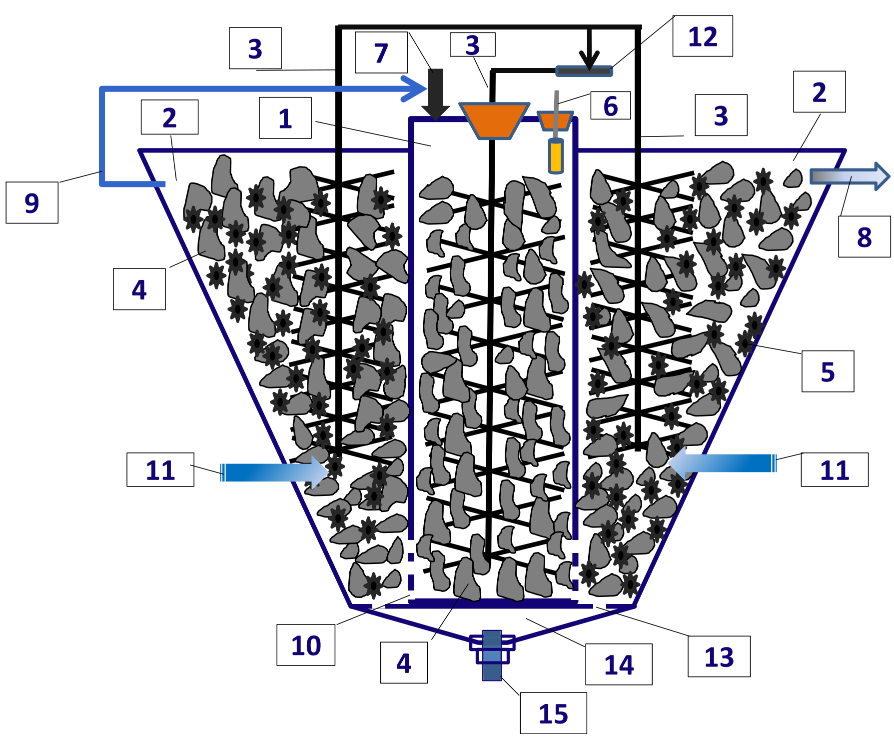

Fig. 1. Schematic of the A/OBES reactor. (1) anode compartment; (2) cathode compartment; (3) graphite fiber brush; (4) graphite granules; (5) scrap iron; (6) Ag/AgCl reference; (7) inlet blade stirrer; (8) outlet; (9) recirculation pipe; (10) holes on wall of anode compartment; (11) air; (12) external resistance; (13) holes for sludge flux; (14) sludge collector; (15) sludge discharge.