EMPLOYMENT OF DUAL CHAMBER AND TUBULAR UPFLOW MICROBIAL FUEL CELL FOR ENERGY GENERATION FROM THE WASTEWATER

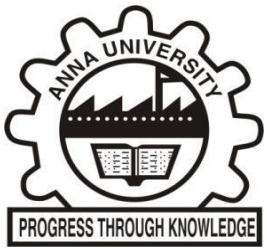
A THESIS

Submitted by

JAYASHREE C

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY



FACULTY OF SCIENCE AND HUMANITIES

ANNA UNIVERSITY

CHENNAI 600 025

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CENTRE FOR RESEARCH

ANNA UNIVERSITY, CHENNAI-600 025

CERTIFICATE

This is to certify that all corrections and suggestions pointed out by the Indian /Foreign Examiner(s) are incorporated in the Thesis titled " EMPLOYMENT OF DUAL CHAMBER AND TUBULAR UPFLOW MICROBIAL FUEL CELL FOR ENERGY GENERATION FROM WASTEWATERS " submitted by ~~Mr.~~/Ms. JAYASHREE.C

J. Rajesh
Signature of the Supervisor

Place : Tirunelveli

Date : 30/12/2016

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Proceedings of the Ph.D. Viva-Voce Examination of Mr./Ms.JAYASHREE.C held at 11.00 AM on 28.12.2016 in Conference Hall, Anna University, Regional Campus, Tirunelveli.

The Ph.D. Viva-Voce Examination of ~~Mr.~~/Ms.JAYASHREE.C (Reg. No. 1224789712) on his/her Ph.D. Thesis Entitled " EMPLOYMENT OF DUAL CHAMBER AND TUBULAR UPFLOW MICROBIAL FUEL CELL FOR ENERGY GENERATION FROM WASTEWATERS " was conducted on **28.12.2016** at 11.00 AM in the Conference Hall, Anna University, Regional Campus, Tirunelveli..

The following Members of the Oral Examination Board were present:

1.	Dr. M Nagarajan,Assistant Professor,Department of Genomic Science,Central University of Kerala,Padannakkad Kasaragod Kerala 671314	Indian Examiner
2.	Dr. S Chandran,Associate Professor,Department of Civil Engineering,Thiagarajar College of Engineering,Madurai 625 015	Subject Expert
3.	Dr. Rajesh Banu.J,Assistant Professor, Department of Civil Engineering, Regional Centre of Anna University,Tirunelveli	Supervisor & Convenor

The research scholar, ~~Mr.~~/Ms. JAYASHREE.C presented the salient features of ~~his~~/her Ph.D. work. This was followed by questions from the board members. The questions raised by the Foreign and Indian Examiners were also put to the scholar. The scholar answered the questions to the full satisfaction of the board members.

The corrections suggested by the Indian/Foreign examiner have been carried out and incorporated in the Thesis before the Oral examination.

Based on the scholars research work, his/her presentation and also the clarifications and answers by the scholar to the questions, the board recommends that ~~Mr.~~/Ms.JAYASHREE.C be awarded Ph.D. degree in the **Faculty of Science and Humanities**.

28/12/16

Indian Examiner

(Dr. M. NAGARAJAN)

Subject Expert 28/12/16

(S. CHANDRAN)

Supervisor & Convenor

ANNA UNIVERSITY
CHENNAI 600 025

CERTIFICATE

The research work embodied in the present Thesis entitled "**EMPLOYMENT OF DUAL CHAMBER AND TUBULAR UPFLOW MICROBIAL FUEL CELL FOR ENERGY GENERATION FROM THE WASTEWATER**" has been carried out in the Department of Civil Engineering, Regional Centre of Anna University, Tirunelveli. The work reported herein is original and does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion or to any other scholar.

I understand the University's policy on plagiarism and declare that the thesis and publications are my own work, except where specifically acknowledged and has not been copied from other sources or been previously submitted for award or assessment.

JAYASHREE C
RESEARCH SCHOLAR

Dr. J. RAJESH BANU
SUPERVISOR
Assistant Professor
Department of Civil Engineering
Regional Centre of Anna University
Tirunelveli.

ABSTRACT

The contamination of the water bodies with organic and inorganic contaminants is primarily due to the industrial growth and manmade activities. Retting wastewater (Coconut husk immersion in lagoons or ponds for coir production) constitutes an assortment of toxic and recalcitrant compounds which are dispersed directly into estuaries and rivers. Seafood processing wastewater is well known for its elevated organic content and contributes for the major pollution of water bodies in the coastal regions. Hence it is vital to treat these two wastewaters prior their release into the environment. One of the reviving concept which is gaining tremendous importance due to its clean, efficient, and renewable nature is Microbial fuel cells (MFC). MFC are bio electrochemical device that are capable of converting the chemical energy in organic wastes into electrical energy via the catalytic activity of the micro organism. MFC is divided into anode and cathode compartments by the proton exchange membrane (PEM). Substrate degradation by micro organisms liberates electrons and protons, of which electrons transfer via the external circuit to the cathode chamber where electrons, protons and electron acceptor (mainly oxygen) combine to produce water.

Micro organisms capable of transmitting electrons externally to the electrode are called as exoelectrogens and are the essential component for power production in MFC. They are also known as electrochemically active bacteria, anode respiring bacteria or electricigens. Electricity generation in MFC is governed by various important aspects such as MFC design and configuration, characteristics, nature and surface area of electrodes, membranes, electrolytes, nature of inoculums, operating conditions such as loading rate, pH, temperature and retention time. Numerous studies have examined power production from complex wastewaters employing MFC.

Therefore in the present study, MFC are examined for the synchronized power production and organic removal employing two wastewater namely retting and seafood processing wastewater.

The present study details on the outcomes achieved through the lab scale studies from the treatment of retting wastewater employing dual chamber and tubular upflow MFC. It also enlists the predominant anodic microbial consortium responsible for phenol removal identified through 16s rRNA sequencing. In addition, seafood processing wastewater was treated using tubular upflow MFC and predominant anodic microbial consortium was also analyzed.

During the first phase of experimentation, the retting wastewater was collected from the colachal, Kanyakumari. The dual chamber MFC with plain graphite sheet as electrode and PEM was operated at fed batch mode for the treatment of retting wastewater with activated sludge as inoculums source. Highest COD (chemical oxygen demand) and phenol removal of 91% and 93 % respectively was procured at 40 days hydraulic retention time (HRT). Maximum open circuit voltage (OCV) and volumetric power density of 0.689 V and 3.5 W/m^3 respectively was recorded at HRT of 20 days. With respect to electrode surface area, power density of 362 mW/m^2 was achieved at HRT of 20 days. Coulombic efficiency (CE) of 19 % was obtained during the treatment of the retting wastewater at HRT of 20 days. The internal resistance of the MFC varied from 97 Ω to 110 Ω at diverse HRT ranging from 40 days to 10 days. The bacterial strains in anode region, reported to be responsible for potential phenol removal, were identified as *Ochrobactrum* sp. RA1 (KJ408266), *Ochrobactrum* sp. RA2 (KJ408267) and *Pseudomonas aeruginosa* RA3 (KJ408268) using 16s rRNA sequencing.

During the second phase of the experimentation, the tubular upflow MFC with plain graphite sheet as electrode and PEM was evaluated for the

treatment of the retting wastewater at continuous mode of operation in different loading rates for a total period of 270 days. Pre acclimatized inoculums from the dual chamber MFC treating retting wastewater served as inoculums source. The highest COD removal of 70% was accomplished at a loading rate of 0.45 g COD/L reactor day. Maximum phenol removal of 95% was obtained at a loading rate of 0.28 g phenol/L reactor day. Maximum OCV and volumetric power density of 0.880 V and 3.68 W/m^3 was observed at a loading rate of 2.69 g COD/L reactor day. A maximum power density of 254 mW/m^2 was achieved during the treatment of retting wastewater with CE of 33 %. At a loading rate of 2.69 g COD/L reactor day, the internal resistance of 257 Ω was recorded.

During the third phase of the experimentation, the seafood processing wastewater was collected from the seafood industry located at Tuticorin. Tubular upflow MFC with activated carbon fibre felt (ACFF) electrode utilising seafood processing wastewater as substrate was evaluated at different organic loading rate (OLR) for a period of 205 days. At OLR of 0.6 g COD/L reactor day, the MFC accomplished highest total chemical oxygen demand (TCOD) and soluble chemical oxygen demand (SCOD) removal of 83% and 95 %, respectively. Maximum OCV and volumetric power density of 0.689 V and 2.21 W/m^3 respectively was recorded at an OLR of 2.57 g COD/L reactor day. With respect to anode electrode surface area, maximum power density of 105 mW/m^2 was achieved. At an OLR of 2.57 g COD/L reactor day, CE of 25% was procured. Employing 150 mM concentration of phosphate buffer as catholyte, the highest power density of 8.86 W/m^3 (222 mW/m^2) was recorded. The predominant bacterial communities of anode biofilm were identified as *Stenotrophomonas* sp. RB1A (LC035455), *Stenotrophomonas* sp. RB1B (LC035456), *Stenotrophomonas* sp. RB1C (LC035457) and *Stenotrophomonas* sp. RB1E (LC035458).