

## DEBAJYOTI BOSE

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**Career Objective:** To obtain a responsible position where my teaching and research experience will add to the accolades of the organization.

Email: [debajyoti1024@gmail.com](mailto:debajyoti1024@gmail.com) ,  
Alternate Email: [surjoiamback@gmail.com](mailto:surjoiamback@gmail.com)

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Phone (1): +91-98317-80513, Phone (2): +91-85850-73389

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## EDUCATION

2016-2019 Ph.D (Thesis Submitted) MFC applications in Wastewater Treatment, UPES, Dehradun, Uttarakhand.

2016 M.Tech. in Renewable Energy Engineering, UPES, Dehradun, Uttarakhand.

2014 B.Tech. in Chemical Engineering, West Bengal University of Technology, Durgapur, West Bengal.

## EXPERIENCE

2016-2019: Doctoral Research Fellow at University of Petroleum & Energy Studies (UPES).

2014-16: Research Assistant or Graduate Teaching Assistant, Department of Chemistry, UPES.

## PROFESSIONAL HONORS, AWARDS, and REGISTRATIONS

Research covered in NEWS Section of *Science Last Fortnight* (Nov 2018), Indian Academy of Sciences

First Prize in Mentorship for RISE 2018, engineering innovation Exhibition

Fellow- University of Petroleum & Energy Studies, research fellowship (Elected in 2016)

Acted as peer reviewer for special issue on "International Conference on Design and Concurrent Engineering 5th iDECON 2016" of the Jurnal Teknologi (E ISSN 2180-3722), Universiti Teknikal Malaysia Melaka/ Technical University of Malaysia Malacca (2016)

Fellow- State Bank of India (SBI) Youth for India Fellowship, Gurgaon (Elected in 2015)

## AWARDS TO STUDENTS AND RESEARCH GROUP MEMBERS

S. Sridharan, R. Rawat, Research Initiative for Students in Engineering (**RISE-UPES**), Nov 15<sup>th</sup>2018, **First Prize**, Dehradun, India. [Newspaper Link: <http://garhwalpost.in/innovations-recognised-rewarded-during-rise-exhibition/>]

V Kandpal, H Dhawan, Rural Innovator Startup Conclave (RISC), March 23-24, 2017, Centre for Innovations and Appropriate Technologies, National Institute of Rural Development and Panchayati Raj (**NIRDPR**), Hyderabad, India.

N Raj, Tech briefs Create the Future Design Contest, June 28, 2017, **NASA Tech Briefs**, Tech Briefs Media Group, Washington, D.C., USA.

## PROFESSIONAL MEMBERSHIPS

Society of Chemical Industry (SCI), London, United Kingdom (Membership ID: 75566). [Since 2017]  
International Association of Engineers (IAENG), Hong Kong, China (Membership ID: 215839). [Since 2018]

## COURSES TAUGHT

At UPES: Thermal Utilities (PSEG337)  
Waste Heat Recovery & Cogeneration (ETEG411)  
Carbon Trading (ETEG441)  
Nuclear Power Generation (PSEG433)

**TOTAL JOURNAL CITATIONS: 151** [<https://scholar.google.com/citations?user=WvjmfwwAAAAJ&hl=en>]  
[Since 2016]

## JOURNAL PUBLICATIONS : 14

[SCI / SCOPUS]

**Bose, Debajyoti**, Margavelu Gopinath, Parthasarthy Vijay, Shanmathi Sridharan, Ritika Rawat, and Robin Bahuguna. "Bioelectricity generation and biofilm analysis from sewage sources using microbial fuel cell." *Fuel, Elsevier*, 255 (2019): 115815. [Journal IF: 5.8]

**Bose, Debajyoti**, Sridharan, S., Dhawan, H., Vijay, P. and Gopinath, M., 2019. Biomass derived activated carbon cathode performance for sustainable power generation from Microbial Fuel Cells. *Fuel, Elsevier*, 236, pp.325-337. [Journal IF: 5.8]

**Bose, Debajyoti**, Amarnath Bose, Deepak Kundani, Deepika Gupta, and Himanshu Jain. "Comparative Analysis of Carbon Cloth and Aluminum Electrodes Using Agar Salt-Bridge Based Microbial Fuel Cell for Bioelectricity Generation from Effluent Derived Wastewater." *Nature Environment & Pollution Technology* 17, no. 4 (2018). [Journal IF: 2.2]

**Bose, Debajyoti**, Deepali Yadav, Ravi Kumar Patel, Anubhav Dhoundiyal, Laxman Gusain, and Anubhav Tyagi. "Biodiesel Wastewater Treatment and Power Generation Using Earthen Membrane Microbial Fuel Cell." *Nature Environment & Pollution Technology* 17, no. 4 (2018). [Journal IF: 2.2]

**Bose, Debajyoti**, Caneon Kurien, Abhishek Sharma, Sakshi Sharma, and Aakash Sharma. "Low Cost Cathode Performance of Microbial Fuel Cell for Treating Food Wastewater." *Nature Environment & Pollution Technology* 17, no. 3 (2018). [Journal IF: 2.2]

**Bose Debajyoti**, Dhawan H, Kandpal V, Vijay P, Gopinath M. Bioelectricity generation from sewage and wastewater treatment using two-chambered microbial fuel cell. **WILEY**, Int. J Energy Res. 2018; 42: 4335–4344. [Journal IF: 3.5]

**Bose, Debajyoti**, Dhawan, H., Kandpal, V., Vijay, P. & Gopinath, M. Sustainable Power Generation from Sewage and Energy Recovery from Wastewater with variable resistance using Microbial Fuel Cell. *Enzyme Microb. Technol.* Elsevier **118**, 92–101 (2018). [Journal IF: 3.6]

**Bose, Debajyoti**, Margavelu Gopinath, and Parthasarthy Vijay. "Sustainable power generation from wastewater sources using Microbial Fuel Cell." *Biofuels, Bioproducts and Biorefining*, **WILEY**, 12, 559–576 (2018). [Journal IF: 3.3]

**Bose, Debajyoti**, Amarnath Bose, Shikha Mitra, Himanshu Jain, and Pragy Parashar. "Analysis of Sediment-Microbial Fuel Cell Power Production in Series and Parallel Configurations." *Nature Environment and Pollution Technology* 17, no. 1 (2018): 311-314. [Journal IF: 2.2]

Mukherjee, Mainak., **Bose, Debajyoti.**, Haroon, Salam., "Experimentation in procuring and characterizing Biofuel Obtained from Micro Algae from Sewage Treatment Plant and Municipal Waste." *Int. J. of Chemtech Research*, 10.6 (2017): 152-157. [Journal IF: 0.6]

Leena Kapoor, **Bose, Debajyoti** & Aditya Mekala (2017): Biomass pyrolysis in a twin-screw reactor to produce green fuels, Taylor & Francis, Biofuels, DOI: 10.1080/17597269.2017.1345360. [Journal IF: 1.3]

**Bose, Debajyoti**, and Amarnath Bose. "Electrical Power Generation with Himalayan Mud Soil Using Microbial Fuel Cell." *Nature Environment and Pollution Technology* 16.2 (2017): 433. [Journal IF: 2.2]

**Bose, Debajyoti**, and Amarnath Bose Meenal Arora. "Renewable Electrolysis using Graphene electrodes for Solar water splitting." *Int. J. of Chemtech Research*, 10.4 (2017): 103-114. [Journal IF: 2.2]

**Bose, Debajyoti**, and Amarnath Bose. "Graphene-based Microbial Fuel Cell Studies with Starch in sub-Himalayan Soils." *Indonesian Journal of Electrical Engineering and Informatics (IJEEI)* 5.1 (2017). [Journal IF: 1.5]

## JOURNAL REVIEWER

Biofuels, Bioproducts & Biorefining	Publisher: John Wiley & Sons.
International Journal of Hydrogen Energy	Publisher: Elsevier
International Journal of Energy Research	Publisher: Wiley-Blackwell.
Environmental Progress & Sustainable Energy	Publisher: Wiley-Blackwell
ACS Sustainable Chemistry & Engineering	Publisher: American Chemical Society
3Biotech	Publisher: Springer
Chemical Engineering Science	Publisher: Elsevier
Integrated Environmental Assessment and Management	Publisher: Wiley-Blackwell
Waste and Biomass Valorization	Publisher: Springer
Energy Science & Engineering	Publisher: Wiley-Blackwell
Australian Journal of Mechanical Engineering	Publisher: Taylor & Francis

## CHAPTERS AND ARTICLES IN BOOKS : 3

**Bose, Debajyoti**, Vaibhaw Kandpal, Himanshi Dhawan, P. Vijay, and M. Gopinath. "Energy Recovery with Microbial Fuel Cells: Bioremediation and Bioelectricity." In *Waste Bioremediation*, pp. 7-33. **Springer**, Singapore, 2018.

**Bose, Debajyoti**, Ritika Rawat, Robin Bahuguna, P. Vijay, and M. Gopinath. "Sustainable approach to wastewater treatment and bioelectricity generation using microbial fuel cells." In *Current Developments in Biotechnology and Bioengineering*, pp. 37-50. **Elsevier**, 2020.

Sharma, M., & **Bose, Debajyoti**. "High Temperature Energy Storage and Phase Change Materials: A Review." In *Latent Heat-Based Thermal Energy Storage Systems Materials, Applications, and the Energy Market*. **Apple Academic Press**, 2020.

## PATENTS : 1

D. Bose, P Vijay, A Novel Air Cathode MFC Reactor System (Patent Filed- In Process)

## BOOKS : 2

D. Bose, K. Goyal, and V. Bhardwaj, *Design and development of a solar parabolic concentrator and integration with a solar desalination system*. Munich, Germany, GRIN Publishing, 2017.

D. Bose, D. Mukherjee, D. Bhattacharyya. *Oil Refinery Unit Design: Hydrodesulphurization*. Saarbrücken, Germany: Lambert Academic Publishing, 2015.

## CONFERENCE / OTHER PUBLICATIONS : 17

Arora, M., Sharma, M., & **Bose, Debajyoti**, (2018). Step Towards E-Waste Management (STEM). In *Advances in Health and Environment Safety* (pp. 83-88). **Springer**, Singapore.

Nandan, Abhishek, **Bose, Debajyoti**, "Assessment of Water Footprint in Paper & Pulp Industry & its Impact on Sustainability." *World Scientific News* 64 (2017): 84-98.

Nandan, Abhishek, **Bose, Debajyoti**, "Recent Scenario of Solid Waste Management in India." *World Scientific News* 66 (2017): 56-74.

Mondal, Prasenjit, Soumyadeep Baksi, and **Bose, Debajyoti**. "Study of environmental issues in textile industries and recent wastewater treatment technology." *World Scientific News* 61.2 (2017): 98-109.

Mondal, Prasenjit, Soumyadeep Baksi, K. Dharni Kumar, and **Bose, Debajyoti**. "Challenges in Sustainable Development of Agriculture Sector: an Indian Scenario." *World Scientific News* 62 (2017): 1-11.

Kapoor, L., Mekala, A. and **Bose, Debajyoti**, Auger Reactor for Biomass Fast Pyrolysis: Design and Operation. ICTFCN 2016, IIT Kharagpur, West Bengal, India [IEEE Xplore, DOI: [10.1109/ICTFCEN.2016.8052749](https://doi.org/10.1109/ICTFCEN.2016.8052749)].

**Bose, Debajyoti**, "Electrical Power Generation with Microbial Fuel Cell", 7<sup>th</sup> World Renewable Energy Technology Congress & Expo-2016, New Delhi, Aug, 2016, Vol. 7, Issue 1.

**Bose, Debajyoti**, S. Gupta, "Proposed Parking System Model for Vehicles in Smart Cities", **Jawaharlal Nehru University** (JNU), New Delhi, Journal of Basic and Applied Engineering Research, Volume 3, Issue 3; January-March, 2016, pp. 282-285.

**Bose, Debajyoti**, KS Rajmohan, "Potential biomass combination to produce sustainable pellets for co-firing application Bioenergy assessment in Gujarat", 68th Annual Session of Indian Institute of Chemical Engineers, **IIT Guwahati**, Assam, Volume: 68, Jan 2016.

**Bose, Debajyoti**, "Fuel Cells: The Fuel for Tomorrow", **Jawaharlal Nehru University** (JNU), New Delhi, Journal of Energy Research and Environmental Technology, Vol. 02, pp. 71-75, Jan. 2015.

**Bose, Debajyoti**, Aditya Mekala, and Leena Kapoor. "Twin Screw Reactor Design for Biomass Pyrolysis." *World Scientific News* 49.2 (2016): 321.

**Bose, Debajyoti**. Bose, "Electricity Generation & Other Applications using Microbial Fuel Cell", *World Scientific News*, WSN 37 (2016) 320-333.

**Bose, Debajyoti**, Divyesh Arora, and Aditya Mekala. "On the effect of hydrothermal pretreatment of biomass and catalytic conversion mechanism in pyrolysis process with a review of flash pyrolysis of lignocellulosic biomass using effective catalyst." *World Scientific News* 10 (2015): 140-152.

**Bose, Debajyoti**, "Design of a Naphtha Preheater for Hydrodesulphurization (HDS) Unit of Petroleum Naphtha with Given Feed Rate of 3500 Barrels per Day (BPD)", *International Letters of Chemistry, Physics and Astronomy*, Vol. 51, pp. 87-93, May. 2015.

**Bose, Debajyoti**, "Design Parameters for a Hydro desulfurization (HDS) Unit for Petroleum Naphtha at 3500 Barrels per Day", *World Scientific News*, Vol. 03, pp. 99-111, May 2015.

**Bose, Debajyoti**, "The Renewable Curiosity: A Review", *International Journal of Science and Research*, Vol. 04, Issue 02, pp. 968-971, Feb. 2015.

**Bose, Debajyoti**, "The Hydrogen Alternative", *International Letters of Chemistry, Physics and Astronomy*, Vol. 49, pp. 15-26, Apr. 2015.

## PRESENTATIONS- Contributed

Rural Innovator Startup Conclave (RISC), March 23-24, 2017, Centre for Innovations and Appropriate Technologies, National Institute of Rural Development and Panchayati Raj (**NIRDPR**), Hyderabad, India.

Petroleum & Renewable Energy Conclave 2017, March 22-24, 2017, organized by the Department of Petroleum Engineering, **DIT University**, Dehradun, UK, India.

## FUNDED RESEARCH- Completed

- a) P. Vijay, **Debajyoti Bose**, M Gopinath, Development of novel indigenous cathode for MFC performance Optimization, UPES, SEED Project, April 2018-December 2019, 2.55 lacs.
- b) Electricity generation from mud and top-soil using Microbial Fuel Cell (MFC), University of Petroleum & Energy Studies (UPES) – **RISE** Initiative, Project ID: M10, September 2014- March 2015, Rs. 20,000.
- c) V. Kandpal, H. Dhawan, Study of inoculation media of wastewater in microbial fuel cell with Nafion™ 117 membrane and carbon electrodes, September 2016- December 2016, UPES, **RISE 2016, Completed**, Rs. 30,000.
- d) H. Jain, S. Mitra, P. Parashar, Sediment Microbial Fuel Cell scale up and optimization processes, Project ID: SR1711, **Completed**, UPES, **RISE 2017, Phase II**, Rs.20,000.
- e) D. Kundani, D. Gupta, Comparative study of wastewater cleaning and bio-electricity generation in carbon cloth based and aluminium mesh based microbial fuel cell, Project ID: R201742, **Completed**, UPES, **RISE 2017**, Rs.20,000.
- f) S. Sridharan, R. Rawat, Development of AC cathode for two chambered Microbial Fuel Cell with Nafion membrane, April 2018-Nov 2018, **Completed**, UPES, **RISE 2018**, Rs. 19, 800.

## STUDENTS

### M. Tech Students (2 total: 2 Completed)

A. Joshi, G. Petakar, Ammonia doped air cathodes for improved MFC performance. August 2019- December 2019. **Completed**.

KU Madhuri, Simulation studies on hydrogen storage in carbon nanotubes. August 2019- December 2019. **Completed**.

## B. Tech Students (9 total: 9 completed)

S Deepak, S Sharma, Modelling next generation microbial reactors with biomass based cathodes, August 2019- December 2019. **Completed.**

T. Baneerjee, K. Jafar, Preparation of permanganate and iron oxide air cathodes for improved MFC performance. August 2018- December 2018. **Completed.**

M. Bohra, A. Dhakar, Air Cathode MFC design and fabrication to convert Waste to Watts. August 2018-Dec 2018. **Completed.**

S. Sridharan, R. Rawat, Activated Carbon cathodes for Power generation in MFCs from Wastewater, Jan 2018- .Nov 2018, **Completed.**

A. Kapoor, N. Verma, A. Verma, D. Dwivedi, "Activated Carbon catalyst performance evaluation with Platinum based MFC cathodes", Sept 2017- Dec 2017, **Completed.**

A. Tyagi, A. Dhoundiyal, L. Gusain, Design and development of a "Low cost Microbial Fuel Cell" using Earthen Pot membrane to analyze Biodiesel and pharmaceutical wastewater, **Completed.**

D. Kundani, D. Gupta, Comparative study of wastewater cleaning and bio-electricity generation in carbon cloth based and aluminum mesh based microbial fuel cell, **Completed.**

H. Jain, S. Mitra, P. Parashar, Sediment Microbial Fuel Cell scale up and optimization processes, **Completed.**

V. Kandpal, H. Dhawan, Study of inoculation media of wastewater in microbial fuel cell with Nafion™ 117 membrane and carbon electrodes, September 2016- December 2016, **Completed.**

## -Conferences and Workshops

Workshop on "Buildings and Climate Change", August 22, 2019, CSIR- Indian Institute of Petroleum (IIP), Dehradun, India.

Development of a Statistical Model For Trade-Off Between Fuel Economy and CO<sub>2</sub> Emission for In-use 2-Wheelers in India, AFLAD-2017, November 17, 2017, CSIR- Indian Institute of Petroleum (IIP), Dehradun, India.

Art of Converting Science and Technology for Rural Development , April 2017, RuTAG-GoI, UPES, UK, India.

International Conference on Nano for Energy and Water (NEW)-2017 & "Indo-French workshop on Water Networking", Organizing /Technical Committee, Feb 2017, R&D, UPES, UK, India.

International Conference on the Advances in the Field of Health, Safety, Fire, Environment, Allied Sciences and Engineering, "HSFEA 2016", November 18, 2016, UPES.

National Seminar on Upgradation and Commercialization of Biogas, Delegate and event coordinator, 8<sup>th</sup> July 2016, R&D, UPES.

## -Department of Electrical, Power & Energy Engineering Activities

- Research Committee

-Member (2016-2019).

-Planning for departmental research directions, patents and other related activities (2017-2019).

- NAAC representative with coordinator

-National Assessment and Accreditation Council filing requirements (2017-2019)

-Procedures to be followed and maintained for each departmental activity.

## Academic Background

Year(s)	Qualification – Degree / Certificate	Board/University	College/Institute/ University	Percentage/ CGPA
2016-19	PhD- Thesis Submitted (Chemical Engineering)	University of Petroleum and Energy Studies	School of Engineering	Course Work (First Division)
2014-16	M.TECH (Renewable Energy Engineering)	University of Petroleum and Energy Studies	College of Engineering Studies	3.31/4 (First Division)
2010-14	B.TECH (Chemical Engineering)	West Bengal University of Technology	DIATM, Durgapur	79.6% (First Division)
2010	12 <sup>th</sup>	ISC	Julien Day School	69% (First Division)
2008	10 <sup>th</sup>	ICSE	Julien Day School	84.8% (First Division)

## OTHER PROJECTS/ TRAINING- Completed

Solid Biofuel analysis & testing methods; waste to energy practices and methane production, June 2015- August 2015, Abellon Clean Energy, Ahmedabad, Gujarat.

Pyrolysis of biomass feedstock (pine needles, sawdust, bagasse) in a twin screw reactor to produce bio-oil, December 2015- June 2016, UPES, Dehradun, Uttarakhand.

Design of an oil refinery unit for a given volume of Petroleum naphtha, hydrodesulphurization (HDS) Unit Design for Petroleum naphtha with material and energy balance calculations. Design of heat exchangers, absorption tower, high pressure separator, distillation column and related auxiliary equipment; process design of the entire setup to bring percentage of sulfur in petroleum naphtha down from 4% in the crude fraction to 40ppm, August 2013- June 2014, WBUT, Durgapur, West Bengal.

Industrial practices report in the following plants at The Jay Shree Chemicals & Fertilizers: Sulphuric Acid plant, superphosphate plant, water Treatment Plant, effluent Treatment Plant, June 2013 to August 2013, Khardah, West Bengal.

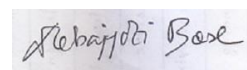
Techno economic feasibility report on steam producing boiler plant, designing a pulverized coal fired steam boiler for the production of 50 Ton Steam/ hour with given specific parameters and to find if project is feasible, January 2013- April 2013, WBUT, Durgapur, West Bengal.

Study the lubrication system and practices being followed at M/s Haldia Petrochemicals Ltd- Haldia Plant. Survey Report with recommendation of suitable SERVO Brand Lubricants. December 2012- January 2013. Prepared at IOCL, Dhakuria, West Bengal. Study at Haldia, West Bengal.

## REFERENCES

Name and Designation	Institute	Contact Details
Dr. Shailey Singhal Senior Associate Professor Department of Chemistry	University of Petroleum & Energy Studies, Dehradun, Uttarakhand, India	Email: shailey@ddn.upes.ac.in Ph: +91-75792-16817
Dr. Vijay Parthasarthy Senior Associate Professor and Head Department of Chemical Engineering	University of Petroleum & Energy Studies, Dehradun, Uttarakhand, India	Email: pvijay@ddn.upes.ac.in Ph: +91-81713-39087
Dr. Margavelu Gopinath Associate Professor Department of Biotechnology	Vel Tech High Tech Dr.Rangarajan Dr.Sakunthala Engineering College, Tamil Nadu, India	Email: mpgopinath1980@gmail.com Ph: +91-99940-41130
Dr. KS Rajmohan Assistant Professor Department of Chemical Engineering	National Institute of Technology (NIT) Warangal, Telengana, India	Email: rajmohan@nitw.ac.in Ph: +91- 99946-46610
Dr. Amit Mondal Assistant Professor Department of Mechatronics	Manipal Academy of Higher Education, Dubai, UAE	Email: amit.mondal@manipaldubai.com Ph: +971-52-984-1645

I do hereby **declare** that above particulars of information and facts stated are true, correct and complete to the best of my knowledge and belief.



Debajyoti Bose





## Full Length Article

# Biomass derived activated carbon cathode performance for sustainable power generation from Microbial Fuel Cells

Debajyoti Bose<sup>a,\*</sup>, Shanmathi Sridharan<sup>b</sup>, Himanshi Dhawan<sup>b</sup>, Parthasarthy Vijay<sup>b</sup>, Margavelu Gopinath<sup>c</sup>

<sup>a</sup> Department of Electrical, Power & Energy, University of Petroleum & Energy Studies, Energy Acres, Bidholi, Dehradun 248007, UK, India

<sup>b</sup> Department of Chemical Engineering, University of Petroleum & Energy Studies, Energy Acres, Bidholi, Dehradun 248007, UK, India

<sup>c</sup> Department of Biotechnology, Selvam College of Technology, Salem Road (NH-7), Pappinaickenpatti (Post), Namakkal 637003, Tamil Nadu, India



## ARTICLE INFO

## Keywords:

Activated carbon

Bioelectricity

Biofilm

Cathodes

Fouling

## ABSTRACT

Significant amount of wastewater is generated from Sewage, and treating this wastewater consumes huge amount of energy. Microbial Fuel Cells can be used to treat this wastewater and generate electricity in the process. Traditionally, Platinum catalyst on Carbon Cloth is used as the cathode for oxygen reduction. In this work, an advanced cathode material in the form of an activated carbon derived from biomass sources was evaluated in terms of cathode performance, stability of operation and cost. For activated carbon cathode, an open circuit voltage of  $580 \pm 30$  mV was achieved between fed-batch cycles. Constant external load produced a peak current density and power density of  $0.40 \text{ mA/m}^2$  and  $110 \pm 6.58 \text{ mW/m}^2$  respectively. Further polarization curves reveal system stability with varying resistances with a change in COD for the wastewater from  $780 \pm 20 \text{ mg/l}$  to  $260 \pm 30 \text{ mg/l}$  over two weeks of operation, achieving a removal efficiency of around 64%, the BOD content of the wastewater also reduced from  $520 \pm 20 \text{ mg/l}$  to  $165 \pm 25 \text{ mg/l}$  with a dissolved solutes removal efficiency of 51% during time of operation. Activated carbon derived from biomass sources is a promising alternative to expensive platinum; further it has a low surface pH, lacks any acidic surface functional group, and can be regenerated to more than 85% of its initial performance with dilute acid wash as compared to platinum which cannot be reused once fouled, thus implicating a sustainable solution.

## 1. Introduction

When we talk about sustainable energy for the future generations, much of the debate shifts to exploring non-combustion based pollution free technologies [1]. An added incentive to these clean forms of energy is if it can be successfully integrated with the water treatment infrastructure. Wastewater generation from both domestic and industrial sources contribute significantly to the inadequate water supply for sanitation and for industries, [2] this contributes to use of expensive chemicals to treat the wastewater before discharging them to an environmentally acceptable level [3,4].

Microbial Fuel Cells or MFCs can effectively treat the wastewater, and at the same time, use the process to generate electrical power [5,6]. This is possible by the bacteria present in the wastewater, which grows on one electrode, consumes the organic matter and releases electrons, thus reducing the organic load from the water, and the electrons released travel through the length of the circuit where the load is connected and the reaction completes at the cathode [7]. In recent years,

while evaluating feasibility of making MFCs a commercial success, a key area of exploration has been the material used for the development of the cathode [8]. Traditionally Platinum (as a catalyst) on carbon cloth is used as the cathode, which is expensive and gets fouled over six months of operation [9]. Thus, finding low cost alternatives to Platinum, which can produce comparable power densities are a key area of exploration. The criteria for a new MFC cathode should include; good catalyst for oxygen reduction, can be derived from carbon-based sources, less susceptible to fouling and can be easily regenerated [10].

In this work, a novel indigenous activated carbon (AC) cathode is prepared with PVDF (Polyvinylidene fluoride) used as a binder on a Stainless Steel Mesh (Type 316L) through a single step phase inversion method [11]. Activated carbon is prepared from sugarcane refuse using a pre-treatment method, and a comparative assessment is made for AC cathode performance derived from other biomass sources [4]. Surface characteristics and functional group analysis for the prepared AC is done using XRD (X-Ray Diffraction) and FTIR (Fourier Transform Infrared Spectroscopy) respectively. Particle size analyser is used to

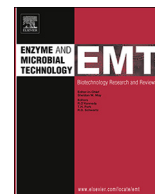
\* Corresponding author.

E-mail address: [dbose@ddn.upes.ac.in](mailto:dbose@ddn.upes.ac.in) (D. Bose).

<https://doi.org/10.1016/j.fuel.2018.09.002>

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# Sustainable power generation from sewage and energy recovery from wastewater with variable resistance using microbial fuel cell

Debajyoti Bose<sup>a,\*</sup>, Himanshi Dhawan<sup>b</sup>, Vaibhaw Kandpal<sup>b</sup>, Parthasarthy Vijay<sup>b</sup>, Margavelu Gopinath<sup>c</sup>

<sup>a</sup> Department of Electrical, Power & Energy, University of Petroleum & Energy Studies, Energy Acres, Bidholi, Dehradun 248007, UK, India

<sup>b</sup> Department of Chemical Engineering, University of Petroleum & Energy Studies, Energy Acres, Bidholi, Dehradun 248007, UK, India

<sup>c</sup> Department of Biotechnology, Selvam College of Technology, Salem Road (NH-7), Pappinaickenpatti (Post), Namakkal, 637003, Tamil Nadu, India

## ARTICLE INFO

### Keywords:

Wastewater  
MFC  
Bacteria  
Nanowires  
Bioelectricity

## ABSTRACT

Wastewater from sewage sources contribute significantly to water pollution from domestic waste; one way to recover energy from these sources while at the same time, treating the water is possible using Microbial Fuel Cell. In this work, a two chambered microbial fuel cell was designed and fabricated with carbon cloth electrodes and Nafion-117 membrane, having Platinum as the catalyst. Wastewater from an organic load of  $820 \pm 30$  mg/l reduced to around 170 mg/l, with the change in pH from  $7.65 \pm 0.6$  to  $7.31 \pm 0.5$ ; over the time of operation the biochemical oxygen demand from an initial  $290 \pm 30$  mg/l reduced to  $175 \pm 10$  mg/l. Open circuit voltage was achieved mostly between 750–850 mV, with inoculated sludge produced a peak open circuit voltage of 1.45 V between fed-batch cycles. For characterization of power generated, polarization curves are evaluated with varying resistance to examine system stability with varying resistance. The current density and power density are reported to peak at  $0.54$  mA/m<sup>2</sup> and  $810 \pm 10$  mW/m<sup>2</sup> respectively. The development of stable biofilms on the anode contributes to the power generation and was evaluated using microscopic analysis, this shows bacteria present in wastewater are electroactive microbial species which can donate electron to an electrode using conductive appendages or nanowires, while consuming the organic matter present in the wastewater. Such systems employ microbial metabolism for water treatment and generate electricity.

## 1. Introduction

Economic growth of nations has always depended on fossil fuels, over the past century, however with their depleting reserves and continuing damaging impact to the environment means they cannot sustain the global economy indefinitely. The Paris accord (COP 21) famously spoke about bringing down net CO<sub>2</sub> emissions significantly with a global commitment. [1] One projection of population growth coupled with current economic growth shows a requirement of global demand of 41 TW by 2050, at current energy consumption rate [2]. As the population grows exponentially, energy requirements do too. Thus, using conventional sources to power these requirements, will release additional CO<sub>2</sub> emissions over and above what is released now, thereby accelerating environmental damage and climate change. [3] An efficient method of energy production to meet this global demand on carbon neutral basis has to be emphasized.

Microbial Fuel Cells or MFCs represent an efficient route to convert the energy in wastewater to electricity, while at the same time treating

the wastewater. [4] The trend in the energy economy to move towards clean form of energy and its recovery from waste are key drivers for this technology [5]. Further, such systems can support the Water infrastructure, with the advantage being non-combustion based processes that represent a direct conversion of organic matter to energy using bacteria present in it. One projection showed about 2.4 billion people globally lack adequate sanitation and the means to afford it [3], one major constituent in this regard is the wastewater generated from Sewage. For instance, in India an estimated 28, 354 million Litres per day. (MLD) of sewage is generated by the major cities, and the sewage treatment capacity is around 11, 786 MLD and reuse of this treated water is restricted to agricultural and industrial purpose. [6] While these numbers change every year, the important thing is to interpret them, as in the context of MFCs these represent an opportunity for energy recovery and wastewater treatment.

Any wastewater treatment plant has 4–10% amount of energy in that water than we use to treat that wastewater, so if this energy can be extracted, even a small fraction of it, we can make wastewater self-

\* Corresponding author.

E-mail address: [dbose@ddn.upes.ac.in](mailto:dbose@ddn.upes.ac.in) (D. Bose).

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## RESEARCH ARTICLE

# Bioelectricity generation from sewage and wastewater treatment using two-chambered microbial fuel cell

Debajyoti Bose<sup>1</sup>  | Himanshi Dhawan<sup>2</sup> | Vaibhaw Kandpal<sup>2</sup> | Parthasarthy Vijay<sup>2</sup>  | Margavelu Gopinath<sup>3</sup> 

<sup>1</sup>Department of Electrical, Power and Energy, University of Petroleum & Energy Studies, Dehradun, India

<sup>2</sup>Department of Chemical Engineering, University of Petroleum & Energy Studies, Dehradun, India

<sup>3</sup>Department of Biotechnology, Selvam College of Technology, Namakkal, India

## Correspondence

Debajyoti Bose, Department of Electrical, Power and Energy, University of Petroleum & Energy Studies, PO Bidholi via Prem Nagar, Dehradun 248007, UK, India.

Email: dbose@ddn.upes.ac.in

## Summary

In this study, sewage was simultaneously treated and used to produce electricity using a two-chambered microbial fuel cell (MFC) with carbon cloth electrodes having platinum coating on the cathode. Porous carbon electrodes are found to be the more suitable for MFCs as the power generation value is high when compared with nonporous surfaces and has a significant impact on the development of stable biofilms on the anode. Wastewater having an initial chemical oxygen demand (COD) of  $830 \pm 20$  mg/L had a removal efficiency from the MFC of around 78%. The initial pH of sewage in the range of  $7.69 \pm 0.2$  saw a shift towards neutral (around 7.4) and biochemical oxygen demand ranging from  $300 \pm 20$  mg/L in the system decreased up to  $175 \pm 15$  mg/L. The cell open circuit voltage peaked at 800 mV. Current and power density was calculated using an external resistance (of 250  $\Omega$ ) followed by normalizing to the anode surface area. This bioelectricity generation is attributed to the decomposition of the organic matter and is reported to peak at  $0.54$  mA/m<sup>2</sup> and  $204 \pm 0.38$  mW/m<sup>2</sup>, respectively. Power generation has faster COD removal rates with external resistors compared with open circuit analysis, and MFCs can be effective to support the wastewater treatment infrastructure while at the same time generate electrical power as a value added product.

## KEYWORDS

bioelectricity, current density, MFC, power density, wastewater

## 1 | INTRODUCTION

Our energy infrastructure dominated by coal, oil, and natural gas is now observing a pattern to step back and reduce net CO<sub>2</sub> emissions from these energy conversion processes and to focus on energy sources that are renewable and environment friendly. Cost analysis for replacing 70% of fossil fuel sources would range between \$170 and 200 billion per year over the next 30 years.<sup>1</sup> Although these economic statistics are challenging but are not very difficult. Given such a long timeframe, it is also likely to

develop new technologies that can emerge and help reshape the economic assessment.

When we look at wastewater treatment infrastructure, energy cost is an important factor, ie, the electricity consumption for running these plants coupled with cost of the expensive chemicals and the cost associated with system maintenance. For instance, if we look at the sewage generated from households, these streams undergo physical, chemical, and biological procedures to remove contaminants present in it before discharging the water at an environmentally acceptable level.<sup>2</sup> The process can



## Full Length Article

## Bioelectricity generation and biofilm analysis from sewage sources using microbial fuel cell

Debajyoti Bose<sup>a,\*</sup>, Margavelu Gopinath<sup>b</sup>, Parthasarthy Vijay<sup>c</sup>, Shanmathi Sridharan<sup>c</sup>,  
Ritika Rawat<sup>c</sup>, Robin Bahuguna<sup>c</sup>

<sup>a</sup> Department of Electrical & Electronics, School of Engineering, University of Petroleum & Energy Studies, Energy Acres, Bidholi, Dehradun 248007, Uttarakhand, India

<sup>b</sup> Department of Biotechnology, Selvam College of Technology, Namakkal, Tamil Nadu 637003, India

<sup>c</sup> Department of Chemical Engineering, School of Engineering, University of Petroleum & Energy Studies, Energy Acres, Bidholi, Dehradun 248007, Uttarakhand, India

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## ABSTRACT

Six species of exoelectrogenic bacteria were identified in this work that degrade organic matter in wastewater derived from sewage, and produce electrons from their cell surface to electrodes, Pt-Catalyst and AC-Catalyst MFCs were used to evaluate wastewater performance. Pt-Cat system generated power density of  $790 \pm 30$  mW/m<sup>2</sup> with a COD removal of 75%, and a reduced BOD content up to  $120 \pm 20$  mg/l, AC-Cat system generated  $430 \pm 35$  mW/m<sup>2</sup> with reduced COD of  $160 \pm 20$  mg/l and a BOD removal up to 63%. 16S rDNA PCR revealed the electricity generating microbes present in the wastewater were predominantly of the *Firmicutes* phyla, along with *Proteobacteria*, and *Actinobacteria*, further, power generation was stable in both MFCs, these results indicate biofilm communities in mixed cultures do not go for colony competition, and in turn has a symbiosis prospect for colonization, contamination removal and bioelectricity production.

## 1. Introduction

Microbial Fuel Cells or MFCs represent an approach that can address both the fuel economy and raise the standards of power generation, by using wastewater from household and industries to generate electrical power [1]. These systems can integrate power generation with water treatment and are key drivers to a sustainable future that can generate power from non-fossil sources while at the same time help clean wastewater [2]. MFCs generate power by using bacteria metabolism, the bacteria present in the wastewater use the chemical contamination as substrate, and generates electron to an electrode (anode) inside the MFC, and this electron then travels the load circuit and completes the reaction at another electrode (cathode) [3]. The amount of electricity generated by the bacteria depends primarily at the growth of electro-active biofilms on the anode [4], as these become the source for electron generation.

Evaluating biofilm growth and community analysis using 16S rDNA sequencing techniques for PCR products reveal the bacteria specie present in the wastewater [5], and it can directly be related to colony competition or symbiosis depending on power generation curves from the MFC. Over the years, several bacterial species, through community analysis [6], have been identified individually or in mixed cultures that

produce high power densities ( $> 2$  W/m<sup>2</sup>), which are a key to bring MFCs close to the commercial platform, these metabolisms include exocellular electron transfer, via cellular respiration and cell to cell communication [7].

In this work, two MFCs based on platinum catalyst (Pt-Cat) and activated carbon catalyst (AC-Cat) were employed to evaluate performance of sewage derived wastewater; along with chemical characterization and power generation from the wastewater, the biofilm community at the anode was isolated and analyzed using 16S rDNA PCR, which revealed the community diversity that contributed to stable power generation over fixed periods of operation for both the MFC reactors. Corresponding microscopic analysis revealed the settlements on the anode by the microbial community.

## 2. Materials and methods

## 2.1. Wastewater

Wastewater was collected from the Sewage Treatment Plant (STP) inlet of the University, this channel of wastewater has some amount of sludge mixed with it, which from the perspective of MFC operation is desirable [8], as studies have shown sludge reduction is possible in

\* Corresponding author.


E-mail address: [dbose@ddn.upes.ac.in](mailto:dbose@ddn.upes.ac.in) (D. Bose).

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# Sustainable power generation from wastewater sources using Microbial Fuel Cell

**Debajyoti Bose,**  Department of Electrical, Power & Energy, University of Petroleum & Energy Studies, Dehradun, India

**Margavelu Gopinath,** Department of Chemical Engineering, University of Petroleum & Energy Studies, Dehradun, India

**Parthasarthy Vijay,** Department of Chemical Engineering, University of Petroleum & Energy Studies, Dehradun, India

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**Abstract:** Microbial fuel-cell performance depends primarily on five factors: the nature of the electrodes, pH, concentration, temperature, and period of operation. The present work describes work on optimization that has resulted in improved system performance of processes for energy recovery from wastewater by addressing these five parameters. This optimization is related to Monod kinetics, which forms the basis for microbial growth and substrate depletion rate. A difference in energy recovery from wastewater sources has been reported for studies with pure microbial culture and with undefined mixed microbes. Energy utilization research with microbial reactors has grown significantly with varying electrogenic reactor configurations, reductions in material costs, and a global need for power with reduced net CO<sub>2</sub> emissions. The potential for future developments of these electrogenic reactor systems is also discussed, including how these systems can be integrated with existing wastewater treatment sources such as anaerobic digesters, and the positive impact they can have on energy security, which is linked with economic stability. Treatment of industrial and domestic wastewater using the microbial reserves can contribute significantly to advancing wastewater treatment infrastructure through effective COD (Chemical Oxygen Demand) removal, and in the process generate value-added product in the form of bioelectricity. © 2018 Society of Chemical Industry and John Wiley & Sons, Ltd

**Keywords:** microbial fuel cell; concentration; bioelectricity; electrodes; microbes

## Introduction

The advent of industrialization and its rapid growth has contributed to the generation of large quantities of wastewater. Its treatment is energy intensive and involves, in some cases, expensive chemicals. Reducing the

cost for wastewater treatment, and using it to obtain useful products, is critical from the standpoint of sustainability.<sup>1</sup> Major sources of wastewater are chemical processes, bulk drugs, pharmaceuticals, pesticides, and other process industry units where such treatment is carried out. In the existing system for wastewater treatment, chemicals are