# Curriculum Vitae

Name: **Dr. Sandeep Kumar Malyan**
Present Position: Post-doctoral Fellow
Institute of Soil, Water and Environmental Sciences,
Agricultural Research Organization (ARO),
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| Correspondence address | Sandeep K. Malyan C/o Dr. Karan Singh,<br>L-08, School of Computer Science and Systems Sciences (SCSS),<br>Jawaharlal Nehru University, New Delhi, Delhi-110067, India |
| Date of birth | 28-03-1988 |
| Gender | Male |
| Research area | **Greenhouse gas emission from soils, Microbial fuel cells, and Water pollution** |

Academic Qualification (Undergraduate Onwards)

| S. No. | Degree | Year | Subject | University | % of marks |
|---|---|---|---|---|---|
| 1. | B.Sc. | 2009 | Chemistry, Botany, Zoology | MS College, Saharanpur/ CCS University, Meerut | 55.03 |
| 2. | M.Sc. | 2011 | Environmental Sciences | Main Campus/ CCS University, Meerut | 71.33 |
| 3. | Ph.D. | 2017 | Environmental Sciences | IARI, New Delhi | 74.40 |

## Ph.D. details

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| Ph.D. thesis title | **Reducing methane emission from rice soil through microbial interventions** |
| Awards and Fellowships | 1. UGC-NET(JRF) (Environmental Science) December 2011<br>2. ICAR-NET(Environmental Science) February, 2013<br>3. CSIR-NET (Earth Science) June 2013<br>4. ARO-Postdoctoral Fellowship-India and China (2017), Ministry of Agriculture and Rural Development, Israel<br>5. ICAR-Jawaharlal Nehru Award for P.G. Outstanding Doctoral Thesis Research in Agricultural and Allied Sciences 2018 - Natural Resource Management. |
| Professional Recognition | 1. Society for Conservation of Nature (Life Member no: LM/K/024)<br>2. Indian Association of Soil and Water Conservation (Life Member no: LM2157)<br>3. Society for Agriculture Innovation & Development (Life Member no: LM/183/MSL) |

**Academic/ Research Positions**

1. Postdoctoral Fellow in Institute of Soil, Water and Environmental Sciences, The Volcani Research Center, Agricultural Research Organization (ARO), Bet Dagan, 50250, Israel, from 4-07-2018 to till date.
2. Research Associate in Environmental Hydrology Division, National Institute of Hydrology, Roorkee, 246776, Uttarakhand, India, from 04-12-2017 to 29-06-2018.

**Publications**

**Total no. of manuscript published: 28**
Google scholar citation till date: **141 [**with **h-index 6** and **i10-index 6]**
**Publication in journals: 23 [**Cumulative impact factor: **33.880**)
**Book chapters: 5**

| S. No | Author's (Year) | Title | Name of Journal (IF) | Vol. | Page no |
|---|---|---|---|---|---|
| 1 | **Sandeep K Malyan**, Arti Bhati, Smita S Kumar, Ram Kishor Fagodiya, Arivalagan Pugazhendhi, Pham Anh Duc (2019) | Mitigation of greenhouse gases intensity by supplementing Azolla and moderate dose of nitrogen fertilizer | Biocatalysis and Agricultural Biotechnology (IF: Awaited) | **20** | **101266** |
| 2 | Ram Kishor Fagodiya, Himanshu Pathak, Arti Bhatia, **Sandeep K Malayn,** Niveta Jain, Dipak Kumar Gupta, Rachana Dubey, Sheetal Radhakrishnan, Ritu Tomer (2019) | Nitrous oxide emission and mitigation from maize-wheat rotation of upper Indo-Gangetic Plains | Carbon Management (IF: 1.463) | | **In press** |
| 3 | Smita S Kumar, Pooja Ghosh, **Sandeep K Malyan**, Jyoti Sharma, Vivek Kumar (2019) | Mechanistic Approaches for Enzyme Level Biodegradation of Organophosphate Pesticide Malathion in the Environment | Journal of Environmental Science and Health, Part C (IF: 3.517) | | Accepted |
| 4 | Amrish Kumar, Bharti Chaudhary, **Sandeep K. Malyan**, Smita S Kumar, Dharm Dutt, Vivek Kumar (2019) | An assessment of trace element contamination in groundwater aquifers of Saharanpur, Western Uttar Pradesh, India | Biocatalysis and Agricultural Biotechnology (IF: Awaited) | 20 | 101213 |
| 5 | **Sandeep K. Malyan**, Rajesh Singh, Meenakshi Rawat, Arivalagan Pugazhendhi, Amrish Kumar, Mohit Kumar, | An overview of carcinogenic pollutants in groundwaters of India | Biocatalysis and Agricultural Biotechnology (IF: Awaited) | | Accepted |

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|---|---|---|---|---|---|
| | Vivek Kumar, Smita Kumar | | | | |
| 6 | Smita S Kumar, Vivek Kumar, Ritesh Kumar, **Sandeep K Malyan**, Arivalagan Pugazhendhi (2019) | Microbial Fuel Cell Technology for Sustainable Bioenergy, Biosensing, Environmental Monitoring, and other Low-Power Devices | Fuel (IF: 5.128) | 255 | 115682 |
| 7 | Smita S Kumar, Vivek Kumar, **Sandeep K Malyan**, Jyoti Sharma, Thangavel Mathimani, Marshal S. Maskarenj, Prakash C. Ghosh, Arivalagan Pugazhendhi (2019) | Microbial Fuel Cells (MFCs) for bioelectrochemical treatment of different wastewater streams | Fuel (IF: 5.128) | 254 | 115526 |
| 8 | Smita S. Kumar, Vivek Kumar, Ritesh Kumar, **Sandeep K. Malyan**, Narsi R. Bishnoi (2019) | Ferrous sulfate as an *in-situ* anodic coagulant for enhanced bioelectricity generation and COD removal from landfill leachate | Energy (IF: 5.537) | 176 | 570-581 |
| 9 | Kaptan Singh, Rajesh Singh, **Sandeep K. Malyan,** Meenakshi Rawat, Pradeep Kumar, Sumant Kumar, M. K. Sharma, Govind Pandey (2018) | Health risk assessment of drinking water in Bathinda district, Punjab, India. | Journal of Indian Water Resources Society (IF: Awaited) | 38 | 34-50 |
| 10 | Smita S. Kumar, **Sandeep K. Malyan**, Suddhasatwa Basu, Narsi R. Bishnoi (2017) | Syntrophic association and Performance of Clostridium, Desulfovibrio, Aeromonas and Tetrathiobacter as anodic biocatalysts for Bioelectricity Generation in Dual Chamber Microbial Fuel cell. | Environmental Science Pollution Research (IF:2.914) | 24 | 1-12 |
| 11 | Smita S Kumar, **Sandeep K. Malyan**, Narsi R. Bishnoi (2017) | Performance of Buffered Ferric Chloride as Terminal Electron Acceptor in Dual Chamber Microbial Fuel Cell. | Journal of Environmental Chemical Engineering (IF: Awaited) | 5 | 1238-43 |
| 12 | A Kumar, A Bhatia, RK Fagodiya, **SK Malyan**, BL Meena (2017) | Eddy Covariance Flux Tower: A Promising Technique for Greenhouse Gases Measurement | Advances in Plants & Agriculture Research | 7 | 1-4 |

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| 13 | Jyoti Sharma, Smita S Kumar, Panjak Sharma, Soloni Gupta, Manju Toor, **Sandeep K Malyan**, Narsi R Bishnoi (2017) | Effect of Different Nitrogen Sources on Growth of Algal Consortia | Annals of Agri Bio Research (IF: Awaited) | 22 | 150-153 |
| 14 | Dushyant Kumar, Smita S. Kumar, Jagdeesh Kumar, Om Kumar, Shashi Vind Mishra, Rahul Kumar, **Sandeep K. Malyan** (2017) | Xylanases and their industrial applications: A review | Biochemical and Cellular Archives (IF: Awaited) | 17 | 353-60 |
| 15 | **Sandeep K. Malyan**, Arti Bhatia, Amit Kumar, Dipak Kumar Gupta, Renu Singh, Smita S. Kumar, Ritu Tomer, Om Kumar, N. Jain (2016) | Methane production, oxidation and mitigation: A Mechanistic understanding and comprehensive evaluation of influencing factors. | Science of Total Environment (IF:5.589) | 572 | 874-96 |
| 16 | **Sandeep K. Malyan**, Arti Bhatia, Om Kumar, Ritu Tomer (2016) | Impact of Nitrogen Fertilizers on Methane Emissions from Flooded Rice. | Current World Environment (IF: Awaited) | 11 | 846-850 |
| 17 | S.S. Kumar, **S.K. Malyan**, A. Kumar, Narsi R. Bishnoi. (2016) | Optimization of Fenton's oxidation by Box-Behnken Design of Response surface methodology for landfill leachate | Journal of Material and Environment Science (IF: 0.65) | 7 | 4456-66 |
| 18 | Smita S. Kumar, Chanderhash Yadav, **Sandeep K. Malyan**, Manju, Kulvinder Bajwa, Narsi R Bishnoi (2016) | Dose optimization for aluminium and iron based coagulants viz. aluminium sulphate, ferric chloride and ferrous sulphate for COD removal from landfill leachate at its natural pH. | Annals of Agri Bio Research (IF: Awaited) | 21 | 120-23. |
| 19 | Smita S. Kumar, **Sandeep K. Malyan** (2016) | Nitrification inhibitors: a perspective tool to mitigate greenhouse gas emissions from rice soils. | Current World Environment (IF: Awaited) | 11 | 423-28 |
| 20 | Dipak Kumar Gupta, A. Bhatia, A, Kumar, T.K. Das, N. Jain, R. Tomer, **Sandeep K. Malyan**, R.K. | Mitigation of greenhouse gas emission from rice–wheat system of the Indo-Gangetic plains: Through tillage, irrigation and fertilizer management. | Agriculture, Ecosystems and Environment (IF: 3.954) | 230 | 1-9 |

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| | Fagodiya, R. Dubey, H. Pathak (2016) | | | | |
| 21 | Om Kumar, Arun A. David, Rakesh Kumar, Brijesh Yadav, **Sandeep K. Malyan**, Devesh Pratap (2016) | Effect of primary nutrient and zinc on nutrient uptake and yield attributes of maize (*Zea mays L.*). | The bioscan (IF: Awaited) | 11 | 513-17 |
| 22 | Simta S. Kumar, S. Mery Celin, Narsi R. Bishnoi, **Sandeep K. Malyan** (2014) | Phytoremediation of HMX contaminated soil through *Jatropha Curcas* | International Journal of Recent Scientific Research (IF: Awaited) | 5 | 1444-50 |
| 23 | **Sandeep K. Malyan**, Jagdeesh Kumar, Smita S. Kumar. (2014) | Assessment of groundwater of Saharanpur district, western Uttar Pradesh, India. | International Journal of Recent Scientific Research (IF: Awaited) | 5 | 1112-15 |

**Book Chapters (5)**

| S. No | Author's (Year) | Title | In Book and publisher (ISBN) page no |
|---|---|---|---|
| **1** | **Sandeep K. Malyan** Amit Kumar, Shahar Baram, Jagdeesh Kumar, Swati Singh, Smita S. Kumar (2019) | Role of Fungi in climate change abatement through carbon sequestration | In: Yadav, A.N., Mishra, S., Singh, S., Gupta, A. (Eds.) Recent Advancement in White Biotechnology through Fungi (Springer), (ISBN: 978-3-030-25506-0) doi: 10.1007/978-3-030-25506-0 |
| **2** | Amit Kumar, Ashish K. Chaturvedi, Kritika, KP, Arunkumar, **Sandeep K. Malyan**, P. Raja, Ram Kumar, Divjot Kour, Ajar Nath Yadav | Current Scenario and Future Prospects on Fungal-Phytoremediation of Heavy Metal Contaminated Resources | In: Yadav, A.N., Mishra, S., Singh, S., Gupta, A. (Eds.) Recent Advancement in White Biotechnology through Fungi (Springer), ISBN: 978-3-030-25506-0) doi: 10.1007/978-3-030-25506-0 |
| **3** | Smita S Kumar, Abudukeremu Kadier, **Sandeep K Malyan**, Altaf Ahmad, Narsi R. Bishnoi (2017) | Phytoremediation and Rhizoremediation: Uptake, mobilisation and sequestrationof heavy metals by plants. | In: Dhananjaya Pratap Singh, Harikesh Bahadur Singh, Ratna Prabha, (eds) Plant-Microbe Interactions in Agro-Ecological Perspectives (Springer), pp 367-394. (ISBN: 978-981-10-6593-4) |
| **4** | **Sandeep K. Malyan**, Amit Kumar, Jagdeesh | A water management tool in rice to combat two | In: Sanjay Kumar and Masroor Ahmed Beg (eds) Environmental concerns of |

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|---|---|---|---|
| | Kumar, Smita S. Kumar (2016) | major environmental issues: Global warming and water scarcity. | 21st century: Indian and global context (Book Age Publications), ( **ISBN:978-93-83281-65-7),** pp. 45-58 |
| **5** | Smita S. Kumar, **Sandeep K. Malyan**, Amit Kumar, Suddhasatwa Basu, Narsi R. Bishnoi (2016) | Microbial fuel cells Technology: Food to energy conversion by Anode respiring bacteria. | In: Sanjay Kumar and Masroor Ahmed Beg (eds) Environmental concerns of 21st century: Indian and global context (Book Age Publications), **(ISBN:978-93-83281-65-7),** pp. 13-29 |
| | | | |

**Conference Proceedings with full paper (3)**

| S. No | Author's (Year) | Title | Conference | Place |
|---|---|---|---|---|
| **1.** | **Sandeep K. Malyan**, Arti Bhatia, Renu Singh, Smita S. Kumar, Om Kumar, Joni Kumar, Rumesh Ranjan, Ritu Tomer (2017) | Impact of Azolla application on nitrous oxide emission from rice soils | International Conference on Advances in Agricultural & Applied Sciences for Promoting Food Security | Hotel Mirage Lord Inn, Battishputli, Kathmandu, Nepal |
| **2.** | **Sandeep K. Malyan**, Jyoti Sharma, Manju Toor, Smita S. Kumar (2017) | Methane mitigation from rice soils through fertilizer management | International Conference on Emerging Areas of Environmental Science & Engineering | Guru Jambheshwar University of Science & Technology, Hisar-125001, Haryana, India |
| **3.** | Smita S. Kumar, Shiskha, Jyoti Sharma, Manju Toor, **Sandeep K. Malyan**, Narsi R. Bishnoi (2017) | Exploring power generation and COD removal efficiency of Sulphate reducing and Sulphur oxidising bacteria in consortium. | International Conference on Emerging Areas of Environmental Science & Engineering | Guru Jambheshwar University of Science & Technology, Hisar-125001, Haryana, India. |

**Conferences/Training/Workshops/Seminars/Symposium (21)**

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| **International Conferences:** | **04** |
| **National Conferences:** | **04** |
| **Trainings/workshops:** | **08** |
| **Seminars/symposium:** | **05** |

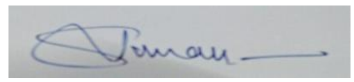
1. Participated in Indo-UK workshop on "Bioremediation of LNAPL polluted groundwater" held on 26-27 March, 2018 at Department of Hydrology, Indian Institute of Technology Roorkee, Uttarakhand, India.

2. Participated in 5 days training on "Water quality: Concepts and analysis" held on 19-23 March, 2018 at National Institute of Hydrology, Roorkee.
3. Participated in International Conferences on "Sustainable Technologies for Intelligent Water Management" held during 16-19 February 2018 at IIT Roorkee.
4. Participated in 21 days training on "Remote Sensing and GIS Applications in Carbon Forestry" (Conducted by IIRS, Dehradun, India).
5. Participated in Indo-UK workshop on "Challenges and Opportunities for Agricultural Nitrogen Science in India" held on 3-5 October, 2017 at National Academy of Agricultural Science, New Delhi.
6. Paper presentation in National Conference on "Agriculture Renewal for Evergreen Revolution: Concept & Approaches", held 10 March 2017 at Gochar Mahavidyalaya, Saharanpur-247001, Uttar Pradesh, India.
7. Paper presentation in International Conference on "Emerging Areas of Environmental Science & Engineering", held 15- 17 February. 2017 at Guru Jambheshwar University of Science & Technology, Hisar-125001, Haryana, India.
8. Poster presentation in International conferences on "Advance in Plant and Microbial Biotechnology" held on 2-4 February, 2017 at Jaypee Institute of Information, Technology, India.
9. Participated in national Seminar on "Challenges of Climate Change and Green Environmental Solutions" held on 10, December, 2016, at CCSU Meerut, India.
10. Poster presentation in national symposium on "Managing Agriculture in a Changing Environment" held on 1-2 December, 2016 at Centre for Environment Science and Climate Resilient Agriculture, IARI New Delhi-110012.
11. Participated in workshop on " DST's knowledge network on Climate Change and Agriculture" held on 28-29 April, 2016 at NASC Complex, DPS Marg, Pusa, New Delhi-110012.
12. Poster presentation in national seminar on "Recent innovative change in science and Technology, Humanities, Law & Commerce in context of human welfare" held on 29, March, 2016, at D.A.V. (P.G) College, Muzaffarnagar (U.P)-251001.
13. Poster presentation in national symposium on "Environmental Toxicology" held on 25-26 March, 2016, at Department of Zoology, CCS University, Meerut (U.P)-250001.
14. Participated in national conference on "Environmental concerns of 21$^{st}$ century: Indian and global context" held on 21-22, March, 2016, at Zakir Husain Delhi College (Evening), University of Delhi.
15. Poster presentation in national conference on "Amelioration of air pollution effects in agricultural crops" on 15 March, 2016, at Department of Botany, Ch. Chhotu Ram (P.G.) College, Muzaffarnagar (U.P)-251001.
16. Poster presentation in 1$^{st}$ National Agricultural Research & Innovation Conference on "Balanced Fertilization: A Key to Food Security and Environmental Sustainability" February 24-25, 2016, held at Amity University- Noida.
17. Participated in training programme on "Experimental Data Analysis" held on 07-11, December, 2015, at ICAR- Indian Agriculture Statistics Research Institute, Library Avenue, New Delhi-110012.
18. Participated in IPPC Congress 2015 on "3$^{rd}$ International Plant physiology Congress on Challenges and Strategies in Plant Biology Research" held on 11-14, December, 2015, at JNU New Delhi.

19. Participated in 100 days training on "Remote Sensing, Geographical Information System & Global Navigation Satellite System" (Conducted by IIRS, Dehradun).
20. Participated in national seminar of Plant Physiology on "Physiological and molecular approaches for development of climate resilient crops" held on 12-14, December, 2012.
21. Participated in five days training on "Climate Change & its mitigation" (Conducted by IIPA, New Delhi).

**References**

- **Available upon request**



**Date: 04-08-2019** **(Sandeep Kumar Malyan)**

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Review

# Methane production, oxidation and mitigation: A mechanistic understanding and comprehensive evaluation of influencing factors

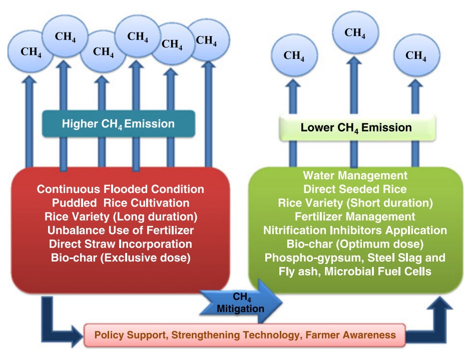
Sandeep K. Malyan [a], Arti Bhatia [a,*], Amit Kumar [a], Dipak Kumar Gupta [b], Renu Singh [a], Smita S. Kumar [c], Ritu Tomer [a], Om Kumar [a], Niveta Jain [a]

[a] Centre for Environment Science and Climate Resilient Agriculture, ICAR-Indian Agricultural Research Institute, New Delhi, 110012, India
[b] ICAR-Central Arid Zone Research Institute, Regional Research Station, Pali-Marwar, Rajasthan 342003, India
[c] Department of Environmental Science and Engineering, Guru Jambheshwar University of Science and Technology, Hisar, Haryana 125001, India

## HIGHLIGHTS

- Water management (controlled irrigation and midseason drying) is the best $CH_4$ mitigating option in irrigated rice field.
- Ammonium based fertilizer having up to 60% $CH_4$ mitigation potential.
- Biofertilizer (Azolla and Cynobacteria) are best for sustainable rice cultivation.
- Microbial fuel cells are the least explore mitigation option in flooded rice field.

## GRAPHICAL ABSTRACT

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## ABSTRACT

Methane is one of the critical greenhouse gases, which absorb long wavelength radiation, affects the chemistry of atmosphere and contributes to global climate change. Rice ecosystem is one of the major anthropogenic sources of methane. The anaerobic waterlogged soil in rice field provides an ideal environment to methanogens for methanogenesis. However, the rate of methanogenesis differs according to rice cultivation regions due to a number of biological, environmental and physical factors like carbon sources, pH, Eh, temperature etc. The interplay between the different conditions and factors may also convert the rice fields into sink from source temporarily. Mechanistic understanding and comprehensive evaluation of these variations and responsible factors are urgently required for designing new mitigation options and evaluation of reported option in different climatic conditions. The objective of this review paper is to develop conclusive understanding on the methane production, oxidation, and emission and methane measurement techniques from rice field along with its mitigation/abatement mechanism to explore the possible reduction techniques from rice ecosystem.



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# Mitigation of greenhouse gas emission from rice–wheat system of the Indo-Gangetic plains: Through tillage, irrigation and fertilizer management

Dipak Kumar Gupta[a,b], A. Bhatia[a,*], A. Kumar[a], T.K. Das[a,c], N. Jain[a], R. Tomer[a], Sandeep K. Malyan[a], R.K. Fagodiya[a,d], R. Dubey[a,e], H. Pathak[a]

[a] Center for Environment Science and Climate Resilient Agriculture, ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India
[b] ICAR-Central Arid Zone Research Institute, Regional Research Station, Pali-Marwar, Rajasthan 306 401, India
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Zero tilled wheat
Direct seeded rice
Neem oil coated urea
Rice straw
Rice–wheat cropping system

ABSTRACT

Rice–wheat cropping systems (RWCS) of the Indo-Gangetic plains (IGP) of India are tillage, water and energy intensive and an important source of greenhouse gas (GHG) emission. Developing agronomic management in RWCS that lead to minimum adverse impact on soil, enhances water use efficiency, reduces GHG emission and are climate resilient is required. The aim of this study was to evaluate different combinations of GHG mitigation technologies for rice and wheat and to find suitable low carbon options for RWCS in the IGP. Seven management systems i.e. conventionally tilled wheat (CTW); zero tilled wheat (ZTW); transplanted puddled rice (TPR); dry direct seeded rice (DSR); intermittent wetting and drying (IWD); application of neem oil coated urea (NOCU); and surface application of rice residue (RR) were experimented in six combination of rotations [CTW-TPR, ZTW-TPR, ZTW-IWD, ZTW-DSR, ZTW + RR-DSR and (ZTW-TPR) + NOCU] for two consecutive years. Among these rotations, ZTW-DSR and ZTW + RR-DSR showed the lowest global warming potential (GWP) and GHG intensity in both the years. Adoption of these systems in the Indian-IGP can reduce GWP of the conventional RWCS (CTW-TPR) by 44–47% without any significant loss in the system yield. This was mainly due to significantly low $CH_4$ emission (82.3–87.2%) in DSR as compared to TPR due to prolonged aerobic condition under DSR. However, frequent wetting and drying in DSR led to higher denitrification emissions of $N_2O$ (60–70%). Significantly higher emissions of $N_2O$ were observed in ZTW treatments (8–11%). NOCU was found effective in reducing $N_2O$ emission from ZTW (17.8–20.5%) leading to lower GWP as compared to CTW. Application of rice residue in ZTW treatment also reduced $N_2O$ emission (11–12.8%). There was no significant effect of different treatments in rice on GHG emission from the succeeding wheat crop; however, ZTW and ZTW + RR were found to enhance $CH_4$ emission from the succeeding rice treatments.


## 1. Introduction

The yield of major staple food crops (wheat, maize, rice and soybean) in many regions of the world is being negatively affected by climate change (IPCC, 2014). On the other hand, agriculture is also one of the major causes for this change. Agriculture, forestry and other land use sectors contribute about a quarter (10–12 Gt $CO_2$ eq. $yr^{-1}$) of net anthropogenic greenhouse gases (GHG) emissions (IPCC, 2014). The intensively cultivated rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) cropping system (RWCS) of the Indo-Gangetic plains (IGP) plays a major role in the food security of south Asia and is a potential source of GHG and vulnerable to climate change. The demand for these two cereals is expected to grow between 2% and 2.5% per annum until 2020, requiring continued efforts to increase productivity while ensuring sustainability (Gupta and Seth, 2007) and low GHG emission. This system has also started to show lower marginal returns, physical and chemical deterioration of the soil and decline in groundwater level in recen past (Chauhan et al., 2012).

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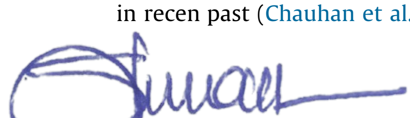

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# Ferrous sulfate as an *in-situ* anodic coagulant for enhanced bioelectricity generation and COD removal from landfill leachate

Smita S. Kumar [a], Vivek Kumar [a, *], Ritesh Kumar [a], Sandeep K. Malyan [c, d], Narsi R. Bishnoi [b]

[a] Centre for Rural Development and Technology, Indian Institute of Technology Delhi, Hauz Khas – 110016, New Delhi, India
[b] Department of Environmental Science and Engineering, Guru Jambheshwar University of Science & Technology, Hisar – 125001, Haryana, India
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Coagulation
Box-Behnken model

ABSTRACT

Landfill Leachate is a heavily contaminated wastewater. MFCs (Microbial Fuel cells) are unique bioreactors, which utilize the catalytic activity of microbes for converting the chemical energy stored in organic-rich streams for bioelectricity production. MFCs represent an auspicious technology to treat landfill leachate and generate bioelectricity. Here, we evaluated the addition of ferrous sulfate as anodic coagulant as well as a media component to enhance the MFC performance. The Box-Behnken Design model of Response surface methodology (RSM) was found suitable for the determination of optimal conditions for the removal of chemical oxygen demand (COD). COD removal of 78.6% was achieved with coagulation alone at pH 8, reaction time of 90 min, and a coagulant dose of 3 g/L. Ferrous sulfate addition to MFC, significantly improved COD removal. 99.6% removal of total COD was achieved from 75% of landfill leachate, at a retention period of four days; whereas, with 100% leachate as anodic feed, 98.7% COD was removed on the third day. The volumetric power density of 6644.6 mW/m$^3$ was achieved without any catalyst using flexible graphite sheets as electrodes. This study revealed that the integration of coagulation with MFC technology enhanced the treatment efficiency as well as power generation for landfill leachate.



## 1. Introduction

Generation of leachate is a noteworthy issue for the sanitary landfills as well as open dump sites and poses a huge threat of contamination to the environment. Leachate can be characterized as a fluid that goes through a landfill and extracts various types of xenobiotic compounds such as alkalinity, dissolved and suspended solids, color, and many other substances that add to biological and chemical oxygen demands (COD) from it [1–3]. In the present scenario, landfill leachate treatment has become a subject of considerable interest. The crucial challenge associated with landfill leachate is its varied quantity and composition. The range of COD of landfill leachate varies a great deal in magnitude and depends on the age of the landfill site and the type of waste dumped to the site ranging from 100 to 70,000 mg/L [4]. Therefore, different values of COD have been reported in recent studies ranging from 1619 mg/L in Quebec province, Canada [5] and 3770 mg/L in Matang Landfill site, Malaysia [6] to 6051 mg/L in Rokitno Landfill site, Lublin Poland, respectively [7].

Based on the chemical constituents and treatment conditions, a wide range of biological, chemical, and physical methods are being employed for landfill leachate treatment [3,8–10]. Owing to the complex chemical nature and large variations in the of landfill leachate, none of the single treatment technologies has been found to be suitable for the treatment of landfill leachate [11]. Hence, a number of recent studies have been directed to deal with the mature landfill leachate and different technologies have been suggested such as co-digestion and pre-treatment with coagulants so as to increase its biodegradability and hence, the removal efficiency [12]. In a recent study, sequencing batch reactor and coagulation were used sequentially for integrated landfill leachate treatment [11]. Microbial fuel cells (MFCs) are anaerobic

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Full Length Article

# Microbial fuel cells as a sustainable platform technology for bioenergy, biosensing, environmental monitoring, and other low power device applications

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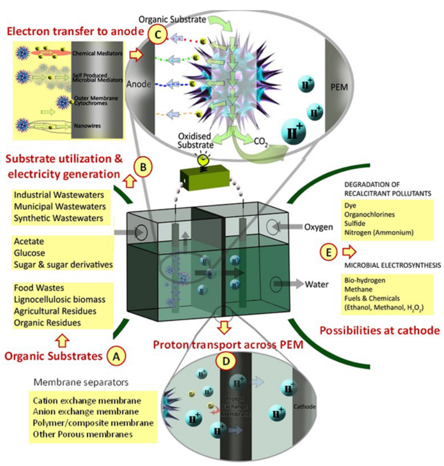
## GRAPHICAL ABSTRACT




*Abbreviations:* MFCs, Microbial Fuel Cells; BOD, Biological Oxygen Demand; SOFCs, Solid Oxide Fuel Cells; mW, milliWatt; LED, Light-Emitting Diode; NADH, Nicotinamide Adenine Dinucleotide; PMFCs, Photographic Microbial Fuel Cells; BMFCs, Benthic Microbial Fuel Cells; WSN, Wireless Sensor Network; BEMAR, Bio-Electrochemically Assisted Microbial Reactor; HER, Hydrogen Evolution Reaction; DO, Dissolved Oxygen; COD, Chemical Oxygen Demand; ANNs, Artificial Neural Networks; GOx, Glucose Oxidase; RGO, Reduced Graphene Oxide; HPLC, High Performance Liquid Chromatography; CG-MS, Gas Chromatography-Mass Spectrometry; LC-MS, Liquid Chromatography-Mass Spectrometry; I, Inhabitation Rate; CY, Columbian Yield; ΔI (μA), Change In current; ΔC(mM), Change in Concentration; A($m^2$), Surface area; IMD, Implantable Medical Devices; HNQ, 2-Hydroxy-1,4-naphthoquinone

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# Mitigation of greenhouse gas intensity by supplementing with *Azolla* and moderating the dose of nitrogen fertilizer

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A B S T R A C T

Integrated use of biological-chemical nitrogen application during rice cultivation is the way forward for sustainable rice production. Experiments were performed to evaluate the effects of *Azolla* (blue green algae) application along with reduced dose of recommended N fertilizer (urea) application on emissions of nitrous oxide ($N_2O$), methane ($CH_4$), global warming potential (GWP) and greenhouse gas intensity (GHGI) in rice. The study consisted of nine treatments on growing three rice cultivars Pusa 1509, Pusa RH-10, and Pusa-44 under recommended fertilizer (120 kg N $ha^{-1}$ by Urea), reduced fertilizer along with *Azolla* application (90 kg N $ha^{-1}$ by urea +50 g $m^{-2}$ *Azolla*), and low fertilizer along with *Azolla* application (60 kg N $ha^{-1}$ by urea +50 g $m^{-2}$ *Azolla*). The lowest cumulative seasonal emissions of $N_2O$, $CH_4$, and GWP were observed in LN1509 (81.55 mg $N_2O$ $m^{-2}$), RN1509 (2.476 g $CH_4$ $m^{-2}$), and RN1509 (110.0 g $CO_2$ eq. $m^{-2}$), respectively. Application of *Azolla* along with the reduced dose of urea did not significantly decrease the yield of rice and the GHGI reduced by 18.41%, 16.88%, and 17.97%, respectively, in Pusa 1509, Pusa RH-10, and Pusa-44 as compared to the recommended fertilizer treatment. The findings of this study suggested that the use of *Azolla* in rice might help in reducing the application of urea fertilizer by 25% in rice without affecting the rice yields. This will be a win-win situation for the farmer who will be saving on the cost of fertilizer and for the policy makers as well by mitigating the greenhouse gas emissions.

## 1. Introduction

Rice (*Oryza sativa* L.) is one of the most important global cereal crops mainly cultivated across Asia (Bhatia et al., 2012a). Continuous standing water throughout the crop growth period is generally practiced for higher rice production (Suryavanshi et al., 2013). However, continued flooding of water in rice creates an anaerobic environment in soil, which results in lowering the soil redox potential (Eh) (Dubey, 2005). Lower Eh increases the population of methanogenic bacteria (Jiang et al., 2019). Methanogens consume the soil organic matter as a carbon source and emit methane ($CH_4$) as a byproduct gas to the atmosphere (Malyan et al., 2016a). According to the latest data published by FAO (2019), the global paddy production in 2017 was around 769 million tonnes and India contributed about 168 million tonnes to the total global production (FAO, 2019). Rice is a cereal crop for more than half of the world population and its demand is increasing as the world population is increasing (Yang et al., 2019; Ranjan and Yadav, 2019). To achieve higher production goals, high yielding rice varieties are cultivated, which require higher amounts of nitrogenous (N) fertilizers as compared to low yielding rice cultivars (Pathak et al., 2014). The amount, type, mode of N fertilizer application for rice significantly affect the emission rate of $CH_4$ and nitrous oxide ($N_2O$) from the rice

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