Next Generation Fuel

Lecture Series on

Next Generation Fuel (NexGen Fuel)

November 2021

Distinguished Speaker

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Indian Institute of Technology, Kharagpur

AICTE-INAE Distinguished Visiting Professor

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Organized by

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Dr. Debabrata Das pursued his doctoral studies from Indian Institute of Technology (IIT) Delhi and post-doctoral research work at University of Utah (UU), USA. Presently, he is a **INAE-AICTE Distinguished Visiting Professor** of SRM Institute of Science and Technology, Chennai and Heritage Institute of Technology, Kolkata. In addition, he is the **Scientific Advisor** of M/s. Dhampur Sugar Mills Ltd., New Delhi. He was also associated as **MNRE Renewable Energy Chair Professor** for three years and **Professor** for 32 years at IIT Kharagpur. He is actively involved in the research of hydrogen biotechnology for a period of more than twenty years. His commendable contributions towards development of a commercially competitive and environmentally benign bioprocess for the biohydrogen production from organic wastes using both mesophilic and thermophilic microorganisms.

He has more than **170** research publications in the peer reviewed journals and contributed more than **38** chapters in the books published by International publishers. He has been awarded with 2 international patents and applied for 4 more. He has been awarded as Fellow of Indian National Academy of Engineering (2015) and Fellow of International Association of Hydrogen Energy (2016). He has been honored with a number of prestigious awards and facilitation by many international and national society. A few of them are Akira Mitsui award of International Association of Hydrogen Energy at WHEC 2008 at Brisbane, Australia followed by Malaviya Memorial Award 3013 of Biological Research Society of India at Jawaharlal Nehru University, New Delhi.

Schedule of Lecture:

Session 1	Date	Time
Lecture 1: Zero carbon fuel	10.11.2021	3:15 pm -4:30pm
Lecture 2: Algal Biorefinery: An integrated approach	11.11.2021	3:15 pm -4:30pm
Lecture 3: Paper based microbial fuel cell	12.11.2021	3:15 pm -4:30pm

Session 2	Date	Time
Lecture 4: Stoichiometry of bioprocesses	19.11.2021	3:15 pm -4:30pm
Lecture 5: Material and energy analysis of bioprocesses	20.11.2021	3:15 pm -4:30pm
Lecture 6: Sterility of the biochemical industries	21.11.2021	3:15 pm -4:30pm

Abstracts of Lectures

Lectures of Session-I

1. Zero carbon fuel

Abstract: Hydrogen is considered as a zero carbon fuel because when it burns produces water only. Hydrogen is the fuel of the future mainly due to its highest heating value, recyclability and nonpolluting nature. Biological hydrogen production processes are found to be more environment friendly and less energy intensive as compared to thermochemical and electrochemical processes. They are mostly controlled by either photosynthetic or fermentative organisms. The microorganisms and biochemical pathways involved in hydrogen generation processes are playing important role. Several developmental works have been already carried out. Immobilized system is found suitable for the continuous hydrogen production. Fermentative hydrogen production processes have some edge over the other biological processes. Several pilot plants have been successfully demonstrated throughout the world to find out the viability of the biohydrogen production processes.

2. Algal Biorefinery: An integrated approach

Abstract: The emissions of greenhouse gases are responsible for the increase of earth's temperature thus leading to the global warming. The reservoirs of fossil fuels are shrinking rapidly and might be available for one more century only. An urgent necessity for future fuel has gained interest in recent times. Future fuel should be renewable in nature, carbon neutral and easily accessible. Atmospheric carbon dioxide has been captured by photo-

autotrophic life to produce algal biomass. Terrestrial phototrophic organisms such as plants, trees, herbs and shrubs are advanced organisms and efficiently capture CO_2 as their biomass. They are also an integral part of the food web of the ecosystem. The terrestrial photoautotrophic biomass could be used as feedstock for fuels and biochemical products but it can supply a fraction of the total energy need. Moreover, destruction of natural habitats associated with terrestrial photoautotrophic biomass could pose a serious environmental and ecological threat. On comparison with terrestrial photoautotrophic organisms, aquatic photoautotrophs are less developed. But they have huge potential as feedstock for fuel and biochemical products. The faster growth rate, non-stringent nutritional demand and ease of cultivation are the salient features of algal biomass production. They can capture atmospheric CO_2 and can convert them to biomass. Use of such biomass could offset the dependency on conventional fossil fuels. Cultivation of algae could counter the debate regarding “food vs fuel” as it doesn’t require fertile land or any other seasonal requirements. Many technologies have been developed to realize the potential of algae. A biorefinery integrates biomass conversion processes and equipment to produce fuels, power, heat, and value-added chemicals from biomass. For realizing the commercial potential of algae, a biorefinery concept has been envisioned that could help to extract maximum benefits out of algal biomass. A refinery concept promotes harvesting of multiple products from the feedstock so as to make the process economically attractive. The bioremediation ability of algae for the removal of heavy metals could be mitigated through algae cultivation. Moreover, wastewater can also be used for algal cultivation thereby helping in overall reduction in chemical oxygen demand. Thus an effective wastewater management concomitant with energy production could be achieved via algal cultivation.

3. Paper based Microbial fuel cell

Abstract: The Microbial fuel cells (MFC) is considered as a renewable natural power source derived from organic wastes and sewage treatment. Bioelectricity is usually produced through MFC in oxygen-deficient environment where a series of microorganisms convert the complex wastes to electrons via liquefaction through a cascade of enzymes in a bioelectrochemical process. MFC-based technology has a dual purpose: power generation and wastewater treatment. Several applications of MFC are bioremediation (sediment MFC), desalination (microbial desalination cell), CO_2 sequestration (microbial carbon capture cells), hydrogen production (microbial electrolysis cell), synthesis of chemicals (microbial electrosynthesis), biosensors (microfluidic MFC), etc. The main advantage of micro-scale portable MFCs such as paper based MFC is short start up time as compared to conventional MFCs. Anyhow, the major disadvantage of micro-scale portable MFCs is the requirement of syringe pumps or other flow distribution systems in many of the concerned techniques makes them impractical to be used in remote locations to drive devices. Paper platforms, on the other hand, eliminate the need for any external pumping devices by allowing fluid transport through capillary action. Further, paper based platforms are bio-compatible and retain liquids for a long period of time in their active forms. Paper based fuel cells can be employed in implantable bioelectronic devices and wearable electronics and can also be integrated with sensors having low power requirements.

Lectures of Session-II

4. Stoichiometry of the bioprocesses

Abstract: Stoichiometry plays very important role for the material and energy analysis of both chemical and biochemical processes. Stoichiometry of the of the bioprocesses are not only include the study of quantitative relationships between the amounts of reactants used and the amounts of products formed in a biochemical reaction or mutual relationships and internal limitations within the biochemical system but also the validity of the experimental result and heat evolved in the aerobic fermentation processes. In case of the stoichiometry of the bioprocess, it is necessary to have some preliminary idea on the substrates utilization and products formed. Fermentation processes are mostly governed by mostly two types of microorganisms: aerobes and anaerobes. Thermodynamic efficiency of these processes are different. Stoichiometry of the Baker's yeast fermentation process has been discussed as a case study.

5. Material and energy analysis of bioprocesses

Abstract: Bioprocesses are considered as a low carbon and water footprint. The carbon footprint measures the amount of greenhouse gases produced, measured carbon dioxide equivalents (in tonnes). The water footprint measures water use (in cubic metres per year) in a biochemical industry. Material analysis helps to find out quantitative information of the process which is very much required for the material balance of the biochemical processes. Bioprocesses are considered as a less energy intensive as compared to chemical process. On

the other hand, bioenergy plays very important roles as alternative source of energy because the fossil fuels have limited reserve In addition, they are environmentally friendly and sustainable. Gross energy requirement of the process and net utilizable energy product determines suitability of the process with respect to the energy generation either in gaseous or liquid forms.

6. Sterility of the biochemical industries

Abstract: In the fermentation industry one important aspect is sterility because in most cases one desired microorganism should be allowed to grow in a controlled environment. There are three major sources of contamination: Air; Water; and Fermentation vessel. Fermentation processes are broadly classified as aerobic and anaerobic. Most bioproducts are produced through the aerobic fermentation processes where dissolve oxygen (DO) is required for cell growth and metabolism, e.g. penicillin, streptomycin, citric acid etc. However, anaerobic fermentation processes are also used for a few biochemical industries, e.g. ethanol, butanol, methane, hydrogen etc. These processes are operated in the absence of oxygen. Several sterilization processes play important roles such as air -, medium -, and bioprocess sterilization.