SYNOPSIS

Introduction

Energy is a critical input for the functioning of today's society and economy. The world highly demands for sufficient and uninterrupted supply of energy which is unlikely to satisfy through conventional fossil fuel sources. Therefore, alternative and renewable energy sources should be explored to gain sustainability. It is anticipated that in the next 20 years the average per capita supply of clean water will decrease by one-third due to rapid growth of population especially in arid and semi-arid countries. Industrial effluents consisting of organic matter and other pollutants are also being discharged into waste streams without proper treatment. This can lead to adverse ecological problems and water crisis in the near future. In the recent years, efforts are being diverted towards energy recovery and water treatment, simultaneously. Improvements may be required on the existing methods and also efforts should be made to develop new technologies for energy recovery from wastewater. Therefore, the modern outlook is to produce energy and value-added products using negative valued waste which is gaining prominence. Global challenges on energy, water and climate are presented schematically in Figure 1.

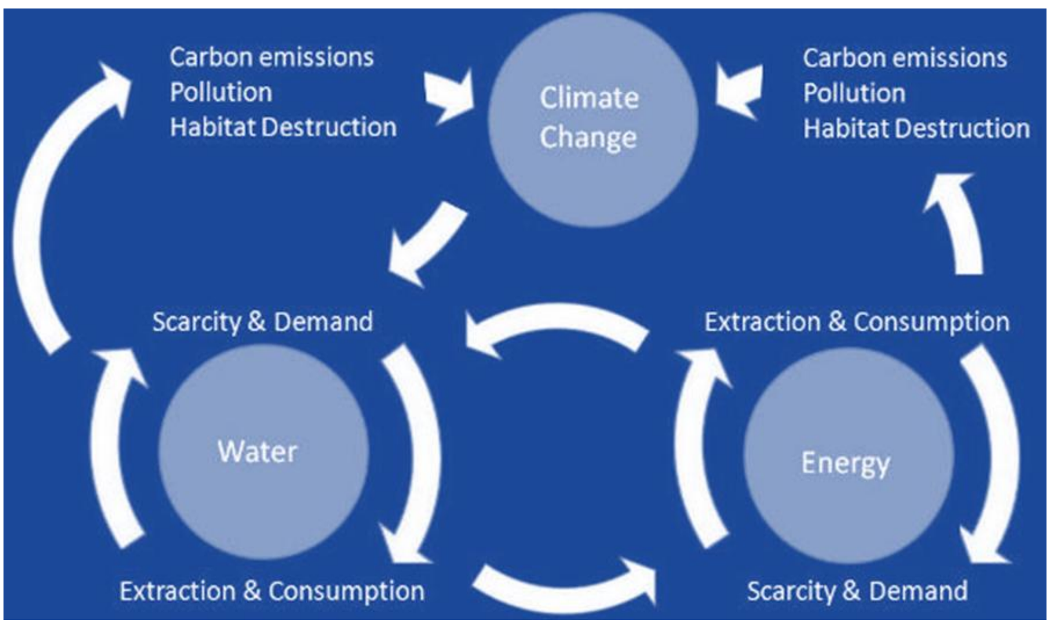

Fig.1: Schematic view of Energy, Water and Climate as nexus for global challenges.

Statement of problem

Keeping in view of the global energy and water crisis, one such product that can fulfill this requirement is bio-hydrogen. Hydrogen as a renewable energy from wastewater addresses today's two most imperative concerns: energy security and climate change. Dark fermentation is an eco-friendly biological process, which has received significant interest in the recent decade owing to the fact that H_2 can be generated continuously. In this way, production costs of biologically mediated H_2 can compete cost-effectively with other conventional methods. Yet, augmenting rate and yield are the two critical confronts for sustainable biological H_2 production. Another green option is bioelectricity generation. The concept of converting chemical energy to electrical energy using microorganisms or their enzyme systems is referred as bioelectrogenesis and the system used is microbial fuel cell (MFC). Based on the application requirement, MFC has been modified into a microbial electrochemical system (MES) which is product specific. Yet, it is mandatory to consider the sustainable energy yields before commercialization. The most significant barrier for the exploitation of MES lies on inherent sensitivity to energy losses (viz., ohmic, activation and mass transfer losses), which become dominant during scale-up.

In response to the challenges of finding solutions and process understanding, different strategies have been adopted to harness microbial energy and value-added products through biological and bioelectro-fermentative routes. The thesis has five chapters: **Chapter 1** presents a general introduction and review of literature covering different topics of the thesis; **Chapter 2** presents acidogenic biohydrogen production and influence of inorganic salts on insitu buffering capacity; **Chapters 3** presents bioelectrogenisis for harnessing maximum power and relative influence of overpotentials over process performance; **Chapter 4** deals with bioelectrofermentation for biohydrogen production under applied potentials and microbial desalination along with power generation; **Chapter 5** comprises the summary of research and future scope of this study.

Summary of Research

Chapter1: Introduction and Review

Microbial catalyzed hydrogen (H_2) production by acidogenic fermentation process is considered as one of the promising alternatives for sustainable renewable energy as it exhibits eco-friendly merits. The process is viable from practical point of view and can be operated under ambient conditions. It has been attracting increasing attention due to its applicability to different types of wastewaters and high specific productivity. However, H_2 storage and safety issues are the critical concerns prior to use of H_2 as a fuel. Instead, microbial fuel cell (MFC) yields bioelectricity as direct source of energy through fermentative process. However, MFCs are challenging to construct and to operate with maximum efficacy. Moreover, during MFC operation, there exists a possibility to integrate diverse components (biological, physical and chemical) which provides an opportunity to trigger multiple reactions cohesively termed as bio-electrochemical reactions occurring as a result of substrate metabolic activity.

Chapter 2: An attempt was made to evaluate acidogenic behavior of anaerobic biocatalyst for H_2 production from different primary substrates. The study emphasizes on the function of substrate-linked dehydrogenases in H_2 production. Experiments were designed to enumerate variation in biohydrogen (H_2) production pattern with formate and glucose as carbon source under acidogenic mixed microenvironment. H_2 production results were validated with modified Gompertz model. Further, evaluation of H_2 production efficiency was carried out by optimization of process parameters viz., type and nature of inoculum, initial pH and organic content. For this, a systematic protocol was designed to enumerate the variation in bio-hydrogen production under different pH and organic loads. In another study, an attempt was made to regulate the buffer capacity by addition of inorganic salts of hydroxide, bicarbonate and phosphate.

Chapter 3: The study investigates the prolonged effect of external resistance on MFC performance in terms of metabolic energy distribution. Load optimization was carried out to determine the maximum power point (MPP). Bio-electrochemical voltammetric responses were recorded and electron flux kinetics was calculated to interpret the redox activity of the biocatalyst involved in electron transfer. An attempt was also made to evaluate the overpotential and resistances resulting in electron losses and low power output. In this study, different cells are configured by varying the electrode material, surface area and catholyte. A comparative assessment was made to understand the variations in electrogenic activity and cell potentials.

Chapter 4: A microbial electrolysis cell (MEC) was designed and operated for the recovery of residual biohydrogen from acidogenic effluents by applying different applied potentials.

Synergistic effect of biocathode in H_2 production and buffer capacity regulation during MEC operation was studied. In another study, relative functioning of microbial electrochemical systems (MES) for simultaneous wastewater treatment, desalination and resource recovery were investigated. Two MES were designed having abiotic cathode and biocathode, which were investigated with synthetic feed and saline water as proxy of typical real-field wastewater. Comparative anodic and cathodic efficiencies were assessed for both the MES operated in open circuit and closed circuitry.

Chapter 5: Summary and Future Scope

The main source of our current energy need is petroleum refinery, which has grave impact over energy-environment nexus. Therefore, the futuristic scope for the production of bioenergy and biomaterials has significant potential to meet the ever-increasing demand. In this perspective, a biorefinery concept visualizes negative-valued waste as a potential renewable feedstock. Different biorefinery models are hypothesized that will pave new avenues for the development of green bio-based society. The model-flow mimics the closed loop approach wherein waste as resource is valorized through a cascade of various biotechnology processes to yield circular economy. Biorefinery offers a sustainable option to utilize waste to produce a gamut of marketable bioproducts and bioenergy by replacing petro-chemical refinery.