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Bioelectro Chemical Systems: A Sustainable and Potential Platform for Treating Waste

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Abstract

Rapid urbanization and industrial growth across the globe has increased the generation of solid, liquid and gaseous wastes. This is leading to the contamination of soils, groundwater, surface water and air with hazardous and toxic chemicals. It is predicted from the 'business-as-usual' projections that the solid-waste generation rates will exceed 11 million tonnes per day by 2100, which is three times more than current rate. On the other hand, the increased wastewater production and its direct discharge into rivers is causing major usable water resource crunch. Carbon dioxide from industrial sources is also ultimate waste product which is major contributor to the climate change.

In general, the technologies for disposal of solid, liquid and gaseous waste are less efficient and energy intensive. In the recent years a paradigm shift has taken place towards the outlook of waste disposal and thrust is shifting to use it as a resource for production of energy and commodities. Some of the widely practiced interventions in this direction may be cited as utilization of organic waste and sewerage water for production of methane as a fuel. Although the net energy yields in these conversion processes are generally low but many rapid advancements taking place to overcome these limitations.

Bioelectrochemical systems (BES) are emerging as an exciting platform to convert chemical energy of organic wastes into electricity or hydrogen or value added chemical commodities. In BES, specific group of electro-active bacteria can be used as catalyst. Compared to traditional treatment-focused, energy-intensive environmental technologies, this emerging technology offers a sustainable solution for integrated waste treatment and energy and resource recovery, because it offers a flexible platform for both oxidation and reduction reaction oriented processes. In this way, BES works on interface of fermentation and electrochemistry. The applications of BES into waste treatment domain may include, current generation, efficient bioremediation of a wide range of organic wastes, desalination, color removal, toxicity reduction, gaseous pollutants treatment and synthesis of

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commercially viable chemicals and solvents from CO_2 reduction. This paper discusses the current state of the technology and emerging innovations on BES application with respect to solid waste management, wastewater treatment and CO_2utilization, including the on-going research at IndianOil R&D centre.

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Keywords: Bioremediation, microbial fuel cell (MFC), bio-electrochemical system (BES); Bioremediation, biogas, biomethanation;

1.0 Introduction

The advent of new century has witnessed extensive industrial growth and urbanization resulting in increased generation of solid, liquid and gaseous wastes. Consequently, there is alarming environmental pollution like accumulation of enormous amount of solid waste, contamination of water resources due to manmade emissions and has evidenced a a rise in global warming and has evidenced a rise in global warming. It is predicted from the 'business-as-usual' projections that the solid-waste generation rates will exceed 11 million tonnes per day by 2100, which is three times more than current rate (Hoornweg et al., 2013). On the other hand, the increased wastewater production and its direct discharge into rivers is causing major usable water resource crunch (van Loosdrecht and Brdjanovic, 2014). The waste management is becoming a serious global issue. However, nations are trying to reduce the amount of waste generation and governments also adopting various policies for waste management, and are creating instruments for incentives to various players involved in waste management. But most of the countries are still treating these wastes in a conventional manner as decades ago. Considering all these major issues, innovative technologies are needed to develop for the solid waste management as well as wastewater treatment and CO_2 mitigation.

Commonly used technologies for treating various kinds of waste streams include thermo-chemical digestion and bio-assisted methods. The technologies for solid waste disposal as well as liquid and gaseous waste treatment are, in general energy intensive and adversely effect the environmental integrity of science. Most of these processes release CO_2 into the environment, causing increased global temperatures. Moreover, in the recent years a paradigm shift has taken place in the waste disposal towards conserving the energy stored in the waste organics. This has put forward the necessity of rapid evolution of bioenergy discipline to solve the looming energy crisis as well as to save the planet from the brink of an environmental catastrophe. Biofuels/bioenergy production from waste resources opens windows for an exciting and sustainable alternative to the fossil fuels which can help in the worldwide energy crisis and environmental pollution problems. In this direction, few strategies were developed towards energy recovery from waste organics, such as biomethanation and biohydrogen production. However, the efficiency of these processes in terms of waste recycling and energy recovery is not upto the mark due to the inability in dictating the microbial metabolism, especially with mixed consortia that suits for the waste organics. In this realm, a novel system with selective microbial process towards designated it as bio-electrochemical system (BES)

2.0 Principles and advantages of BES

BES works at the nexus of water/waste and energy, representing a new and promising biological process for energy recovery and generation (Rabaey and Rozendal, 2010). This trans-desciplinary system is based on electro-active microbes that are capable of exchanging electrons with electrodes. BES works on interface of fermentation and electrochemistry as base research areas, although, various other sciences like electrode technology, material sciences, separation technology, engineering also contribute to make the system complete. The applications of BES include, current generation, bioremediation of a wide range of wastes, specific pollutants/xenobiotics removal, desalination, color removal, toxicity reduction, gaseous pollutants treatment, synthesis of commercially viable chemicals and solvents, CO_2 reduction, etc. BES holds a great promise for sustainable production/recovery of energy and chemicals.

BES can be classified into various categories based on their application