Integration of Waste Valorization with Energy Generation through Bioelectrochemical Systems (BES): A Sustainable Solution

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Climate mitigation is a critical factor in preventing catastrophic global warming in the future. Improper treatment of waste generated by various industries has led to extensive land, water, and soil pollution. Industrial wastes can be classified as recyclable, biodegradable, and non-biodegradable, among others. In parallel, urban wastewater generation has increased significantly due to rapid urbanization. According to the NITI Aayog report titled "Urban Wastewater Scenario in India" (2022), approximately 72,368 million litres per day (MLD) of wastewater were generated in the preceding year. The report further revealed that only about 44% of this wastewater is treated, along with the associated sewage sludge.

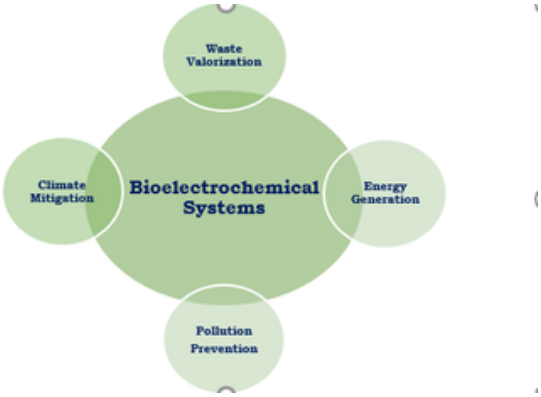

Figure 1. Importance of Bioelectrochemical Systems

Wastewater, sewage sludge, and municipal solid waste are rich resources for the production of bioenergy and platform chemicals. In countries such as India, a large fraction of these wastes is disposed of in landfills, leading to severe environmental contamination and the direct release of greenhouse gases (GHGs) into the atmosphere. Existing conventional wastewater treatment plants and biogas production facilities are inadequate to manage the rapidly increasing volumes of liquid and solid wastes. Bioelectrochemical systems (BES) integrate traditional biological reactors with electrode-based setups, enabling multifunctional applications within a single system. However, despite their significant potential, BES technologies are still at a nascent stage of commercial development.

Bioelectrochemical systems consist of anodic and cathodic electrodes housed within a reactor chamber, with or without a membrane separator, depending on the intended application.

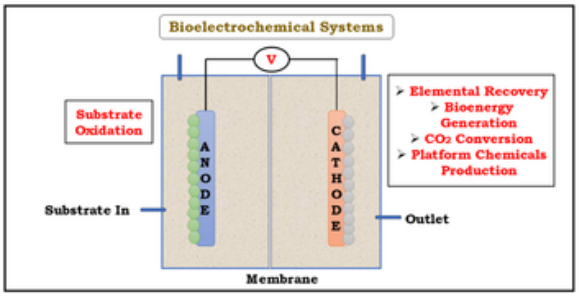

Figure 2. The Multifunctional BES

Advanced bioelectrochemical systems are employed in:

- Advanced wastewater treatment, including the removal of heavy metals, nutrients, toxic elements, and the treatment of industrial leachates.
- Energy generation, such as biomethane and biohydrogen production from municipal solid waste and sewage sludge.
- Platform chemical production for applications in fuels, solvents, and pharmaceutical industries.

Figure 3. Lab scale Upflow Bioelectrochimical System Reactor (BES)

The above bench scale BES reactor (present in the Combinatorial Lab, MSME department) is used for waste valorization with simultaneous biohydrogen production.

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