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Review Article

Simultaneous Biodegradation of Spent Oil and Bioenergy Generation in Single Chambered MFCS: A Mini Review

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ABSTRACT

Due to the huge demand for energy and restricted equipment, we are facing an ongoing global energy crisis. Renewable sources of power have yet to be properly used, and energy sources that are not renewable are constantly running up. The search for alternate energy generation routes is desperately needed. A feasible replacement is the application of microbial fuel cell (MFC) technology, which harnesses the chemical energy of organic material into electrical energy employing microorganisms. A number of studies have confirmed the latest findings on MFC, indicating that various kinds of microbes can be adapted to exploit a broad spectrum of carbon sources, including wastes. As a consequence, the microbe-mediated transformation of wastes utilizing innovative bioremediation approaches, including MFC, for the production of electricity has been viewed as a beneficial and environmentally sound methodology. Combining an assortment of inorganic as well as organic substrates, MFCs utilize microbes and organic material in order to generate power using bacterial metabolism. MFCs are revolutionary bioreactors that use microorganisms to bio-catalyze various kinds of wastes (food, residential, agricultural, and food production sectors) while converting chemical energies into electrical electricity. MFC is a promising methodology with benefits like straightforward waste recyclability, byproduct utilization of various sources, and regulated, healthy, green energy generation. Additionally, there seems to have quite the amount of discussion in the usage of MFCs presently since scientific advances in electrode emergence and the deployment of compatible distinct rural and urban wastes.

Keywords: Microbial fuel cell, Electrical energy, Bioremediation, Organic substrates, Microbe-mediated transformation, Bacterial metabolism

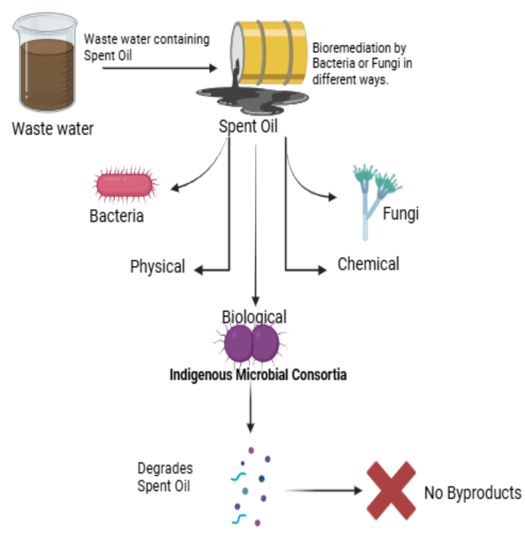

Figure: Graphical Abstract

INTRODUCTION

A prominent environmental problem is spent engine oil (SEO). Heavy metals and carcinogenic polycyclic aromatic hydrocarbons are abundant within it. Polynuclear hydrocarbons that are aromatic and heavy metals have reached elevated toxicity levels and represent an elevated likelihood of cancer in mammals. SEO provides an immense monthly influence on pollution [1]. In spite of its mainstays being vehicles and manufacturing enterprises, SEO damages more than petroleum. Hydrocarbon additives are incorporated in SEO as well as fuels and heavy metals[2]. Crude oil pollution and SEO pollution are two distinct conditions. The negative impact on the environment wrought by crude oil contaminants deserves an excessive amount of attention worldwide by researchers [3, 4]. Petroleum wastewater is being researched thoroughly as a feed substrate to feed the anode chamber, which is found in MFCs [5, 6]. Water-emulsified SEO represents an important danger to the aquatic environment and is exceptionally challenging to remove. This microbial fuel cell (MFC) is a renewable bioelectricity source and a pollutant remediation strategy. Like any chemical fuel cell, MFC generally has a salt bridge or cation exchange membrane linking both anode and cathode chambers, respectively [7]. Wastewater is bioremediation through microbial cells in the anode chamber that additionally transforms chemical energy into bioelectricity. Most of the time, particles may be cleared by the microbial process of oxidation or reduction at the electrodes or terminal. As a means to remove pollutants, MFC makes use of the following mechanisms: (i) oxidation of pollutants (food waste, agricultural waste) at the anode; (ii) adhesion of pollutants on biofilms; (iii) the influence of the electrical field on the chemical formulation of pollutants; along with (iv) proton transfer towards the cathode (reduction), which modifies the pH of the catholyte.[8] Employing microbes in bioremediation is an excellent technique. However, there can be nothing of any significance in the biomass as is produced following cleaning up.

The expression "petroleum hydrocarbons" (PHs) encompasses an extensive group of chemical particles that are the primary components of crude oil, diesel, and petrol. [9, 10] PHs can be organized into four different groups: (i) aliphatics, which consist of alkanes, alkenes, and alkynes; (ii) cycloaliphatics, and these comprise cycloalkanes; (iii) aromatics, which at first include monoaromatics and polycyclic aromatic hydrocarbons (PAHs); and (iv) other components, and this involve asphaltenes, waxes, tar, and resins. PHs were previously confirmed to be carcinogenic [11,12]. By virtue of their physical and chemical features, these impervious components have a widespread distribution in soil, water, and the surroundings. PHs are susceptible to the capacity to bioaccumulate in living tissues due to specific properties such the lipophilicity and electrophysiological stability, that may result in deleterious and enduring consequences [13,14]. These hardly recyclable substances can be detected in the environment through an abundance of sources. The biggest problem is related to emissions and spills, involving the release of petroleum-based substances such as petrol, fuel from diesel engines, and lubricants, along with others [15]. Furthermore, PH pollution can be caused by human-related activities such as coal mining, transportation, storage, onshore and offshore petroleum field operations, and municipal and industrial runoffs. These PHs were officially categorized as priority pollutants of ecosystems by the American Environmental Protection Agency (USEPA) [16]. As an outcome, any PH pollutants pose an emergency for both direct, such as breathing in their emissions) and indirect (for example, spotting these compounds in water bodies) relationship [17].

A number of methods, including biodegradation, membrane processes, electrocoagulation, adsorption, and sophisticated oxidation procedures (AOPs), have been employed in the present moment for hydrocarbon remediation [18-20]. However, each of these techniques offers imperfections.

The method of biodegradation is exceedingly slow pace and requires extensive reaction times—days, maybe. Massive facilities for treatment are consequently essential. Membranes suffer from elevated usage of energy and fouling concerns while functioning on a huge scale [21]. Because of the saturated activated carbon's demand for interval regeneration and its vulnerability to interference from other harmful substances, adsorption on activated carbon, a phase change technological advance, is challenging and pricey [22]. AOPs can additionally be costly and challenging to set up and manage. They are primarily intended for low-pollution conditions. A significant quantity of sludge is generated by electrocoagulation, rendering it unhealthy and unrecoverable. Electrocoagulation does not constitute an appropriate option because of the significant investment and operating expenditures for industrial scaling up [23].

Especially compared to the preceding provided approaches, bioelectrochemical systems (BESs) have established promising niches in the last decade. The BES refers to the employing of microbial electrochemical technologies (MET), in which organic compounds undergo breaking apart and electrons get generated by microorganisms behaving to be catalysts [24]. Electricity and other chemical substances containing extra significance can be generated via the electrons [25]. The BESs possess a range of applications involving MFC, microbial electrolysis units (MEC), microbial desalination devices (MDC), and microbial electrosynthesis devices (MES). BES functions in relatively mild and simple conditions compared to many conventional strategies. With extremely unhealthy wastewater to contaminated soil and sediment, it successfully tackled a wide variety of persistent harmful substances [25]. An additional advantage of BES includes the capacity to be combined with other technologies. For instance, it can be employed in combination with membranes, adsorption, electrochemical cells, established wetlands, AOPs, and others [26]. In addition, BES's electrochemical arrangement effectively modulates the electrons emitted throughout microbial metabolism [27].

MFC is a system that removes contaminated media, such as soil, sediments, or wastewater, while also producing energy sustainably from biodegradable elements. An ion-exchange membrane (IEM) differentiates the two chambers, which usually have an anodic and a cathodic. Microorganisms devour and oxygenate the substrate (biomass or organic matter) on the anode's appearance, producing protons and electrons in the course of this procedure [28]. The main means of detoxifying a contaminated environment in a BES is microbial or biotic degradation. The anode is a component that accelerates oxidation reactions and functions as an electron acceptor [29]. Degrading bacteria, such as hydrocarbon reduction bacteria (HDB), break down complex organic substances, including PAHs, into smaller molecules initially. At the anode surface, exoelectrogenic bacteria (EB), such as Proteobacteria, then keep breaking down the intermediates. Subsequently, generated electrons may be either indirectly or directly delivered to the anode [30,31]. In addition to reducing an accumulation of intermediate compounds, EB improves the efficiency of extracellular electron transfer, which must happen to complete the biodegradation process.

Microbial fuel cells (MFCs) possess the capability to produce electrical power using lignocellulosic material and low-strength sewage. In addition to renewable biomass, MFCs can produce an electric current employing an extensive spectrum of aqueous or dissolving complex organic materials [30,31]. The electrons that can be either supplied or eliminated via an electrical circuit undergo exchange among microorganisms with electrodes in an MFC. The most common form of bio-electrochemical structures, MFCs, use microorganisms' metabolic activity to convert biomass into energy [31]. MFCs represent the most secure, easiest, and most sustainable option for generating bioenergy [32]. An organic substrate experiences deterioration, resulting in the generation of both protons and electrons. A wide variety of naturally occurring wastes, including sewage sludge, municipal garbage, and domestic wastewater, were used in previous research [33]. Such carbohydrates frequently serve as fuel within the anode chamber. Food waste can be utilized as the biological substrate in MFCs for making electric power, as shown by a number of papers [34,35]. The manufacture of environmentally friendly electricity and the biological breakdown of harmful substances using the administration of MFCs utilizing food waste is receiving a lot of media scrutiny already. This is the result of huge quantities of food which is discarded.

The construction and functionality of MFCs:

Due of numerous applications associated with this environmentally friendly technology, MFCs have grown into an increasingly adaptable renewable energy source. Electricity can be produced in microbial fuel cells employing any organic material that biodegrades (both simplest and most complicated molecules) from various agricultural and agro-related wastes and wastes generated byproducts [35]. The potential of microorganisms to capitalize on every kind of waste material as fuel for operations provides an ideal method to generate sustainable bioelectricity through different biomass. [36] MFCs are bio-electrochemical devices containing a broad spectrum of structural configurations, including single and double chambers and additional systems containing or not containing a proton exchange membrane (PEM) [37].

Coupled with other beneficial features such as powerful cation conductivity, and low internal resistance, and being able to be used for a prolonged amount of time without compromising with the MFC, PEMs were selectively accessible to protons [38]. Consequently, in double-chambered MFCs, PEM has been recognized as the most widely used membrane separator [39]. Depending on the distinctive features of construction required to perform various kinds of utilities, these biochemical devices mostly consist of a chamber or chambers, electrodes, and substrates. Dual-chamber microbial fuel cells consist of those which consist of cathodic and anodic sections that a salt bridge has separated or PEM [40,41]. The anodic chamber continues to operate in an anaerobic state, while the cathodic chamber can hold either anaerobic or aerobic states. Nevertheless, solitary-chambered MFCs contain the anode and cathode in a single chamber[42, 43].

The approach combines electrical reactions and microbe metabolism, which helps manage waste accumulation and generate power at exactly the same time [43]. Electro-active bacteria, occasionally referred to as electrolytes, contain molecular machinery that enables them to carry electrons to a potential electron-accepting substance without requesting any kind of assistance [44]. In the anode chamber, they function as biocatalysts, reducing organic matter (waste substrate) and transforming chemical energy through the oxidation of organic and inorganic particles into ATP via a variety of sequential operations [45]. The bacteria that ingest organic waste to produce electricity are commonly referred to as the MFCs' giants [46,47]. Electrons and protons are generated primarily an outcome of the bio-potential that accumulates throughout the microbial breakdown of organic particles [47]. In the MFC system, both protons and electrons combine in the cathodic chamber, delivering electrons to the anodic surface whilst simultaneously adjusting oxygen concentrations dissolved in water levels [48]. Using an oxidation reaction, exo-electrogenic bacteria metabolize biological substances in the anode chamber, decreasing an electron acceptor and boosting the cathode chamber's redox possibility [49]. Electricity gets generated because electrons transfer from the anode to the cathode through a difference in redox potentials [50].

MFC having a single chamber

A single-chamber MFC system offers an affordable configuration and doesn't require a PEM and a cathode chamber[51]. The first single-chambered MFC was made up of a rubber-stopped container with an anode in the middle, a window-mounted cathode with an internal proton-permeable porcelain sheet, and sewage sludge working as a biocatalyst for generating the greatest voltage density [52]. It has been determined that temperature exerts an enormous effect on the creation of electricity and the breakdown of organic substrates in MFC operation [53]. Many researchers attempted to utilize microfiltration membranes (MFM) to improve the current generated by the single-chambered MFC [54]. While compared with each other, MFCs with MFM to devices with PEM as a separator showed that the voltage accomplished in the former type was 29% more [55] (Figure 1).

The examination of the MFM and the single-chambered MFC using PEM showed that the MFM produces a significant improvement in internal resistance, coulombic efficiency, and power generation [56]. Table 1 shows the efficiency of single chamber MFC by using different substrates, anode materials, cathode materials, MFC type, microorganisms, and current/voltage output.

The Types of Electrodes:

Among the most crucial elements of establishing a scalable MFC technology is the creation and implementation of electrodes. An electrode is an electrically conductive substance that enables the movement of electricity from an anode to a cathode [61]. Good electrical conductivity, bigger surface area, lowered external resistance, non-corrosiveness, biologic compatibility, chemical stability, and mechanical stability are among the important qualities of an electrode employed in MFC fabrication [62]. MFCs are created employing anode materials such as graphite plates, graphite cloth,

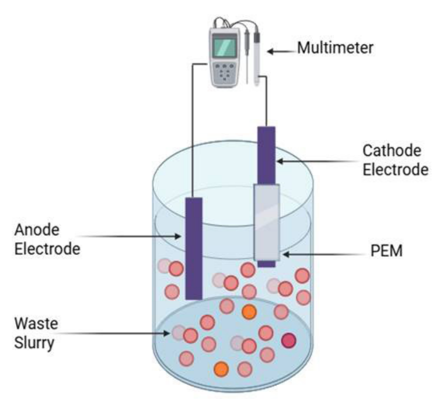

Figure 1: A simple single-chambered MFC

Table 1: Comparative study of performance of SCMFCs utilizing different substrates

No.	*Substrate type*	*Anode material*	*Cathode material*	*MFC type / Inoculum*	*Microorganisms*	*Current / Voltage Output*
1	Beer brewery waste water	Carbon fiber	Air-cathode	Single chamber	Mixed culture	0.18 mA/m2[57]
2	Meat processing waste	Carbon paper	Carbon paper	Single chamber • Domestic waste water	Mixed culture	0.115 mA/cm2[57]
3	Wine waste water	Graphite fiber brushes	Carbon cloth + PTFE + coated with Pt. catalyst	Single chamber MFC reactors	Mixed culture	278 mW/m2[57]
4	Cheese whey waste	Carbon cloth sheets	Carbon cloth sheet modified by addition of gas diffusion layer on air side	• Single chamber • Anaerobic Mesophillic Sludge	Mixed culture	50mV[58]
5	Kitchen waste	Carbon cloth sheets	Carbon cloth sheet modified by addition of gas diffusion layer on air side	Single chamber • Anaerobic Mesophillic Sludge	Mixed culture	40 mV[58]
6	BSA	Non-wet proofed toray carbon paper	Wet proof toray carbon paper	Single chamber • Domestic wastewater + BSA (300 mg/L)	Mixed culture	354 ± 10 mW/ m2[59]
7	Arabitol	Carbon cloth	Carbon cloth	Single chamber • Mixed bacterial culture	Mixed culture	2030 mW/m2[60]
8	Biodiesel waste water	Carbon brush	Carbon cloth	Single chamber • Domestic waste water	Mixed culture	2110 Mw/ m2[60]
9	Biodiesel waste water	Carbon brush	Carbon cloth	Single chamber • Domestic waste water	Mixed culture	2110 Mw/ m2[60]

rods, glassy carbon, felt, grains, paper from carbon, carbon foam, platinum example, polypyrrole nanotube, and platinum black [63]. Pt black, graphite, glassy carbon, carbon felt, carbon paper in carbon shape, Pt, the carbon fabric, or circulated vitreous carbon are the substances used as the cathodes [64]. The reduction of biofilm formation of electrogenic bacteria on the electrode surface constitutes one of the major achievements in anode electrodes [65]. The most important component in MFC design that impacts both cost and performance is the electrode material. The conducting component that conveys electrons from the anode to the cathode, therefore establishing an advantageous flow of electrons, is identified as an electrode [66]. As shall be described below, the most effective electrode material must include several kinds of significant attributes [67].

Performance analysis of the electrodes with respect to their surface area

The production of electricity and output in MFCs are significantly affected by the electrode surface area [68]. A bigger electrode surface area enhances the electrode kinetics in the MFC system, and that, in return, provides different reaction sites since electrode impedance is directly connected with ohmic losses [69]. More electrode surface makes sense for MFC design since it helps to stimulate biofilm formation, and the more surface area, the bigger the bacterial accumulation [70].

Conductivity for electricity

After traversing the anode, the electrons generated by microbes throughout the development of biofilm would keep moving through a circuit that is not internal. Higher electrical conductivity implies the electrode material is less vulnerable to electron flow [71,72].

Robustness and sustainability

The electrode material's roughness on the surface could enhance durability and contribute to fouling, which decreases MFC efficiency [73]. The MFC electrode material should be sturdy and durable in environments that are alkaline as well as acidic [74]. Apart from appearing economically priced, the most suitable electrode material should have outstanding electrophysiological capabilities (electron transfer), mechanical stability, a high current density, and a substantial surface area [75,76]. The anodic electrode materials in MFCs need to be compatible with the bacteria so that they not only function as conductors but also encourage the development of bacterial biofilms over time [77]. The area and smoothness of the electrode materials are crucial in the generation of electricity [78]. Bacterial buildup of biofilm on the edges of electrodes is enabled through larger surface areas with an especially rough surface. Nanoparticle-based carbon materials are appropriate substrates for electrodes for MFCs, considering they have many desirable features, including a large surface area, enhanced transportation of electrons, and molecular adsorption [79]. Enhancing MFC performance for wastewater treatment and electricity production has shown promising findings when conductors have been modified with nanomaterials, including iron oxide and gold nanoparticles or pre-treatment procedures like autoclave sterilization and sonication [80].

Electrodes composed of carbon

Since carbon exists in an abundance of dimensions, shapes, and coverage areas—all of which are important for MFC design - it is one of the most widely used and effective electrode materials[81]. Carbon-based substances, which include carbon fiber, carbon paper, carbon felt, and carbon nanotube-based composites, have been the object of numerous research efforts with the aim of increasing power output partly because of their high electrical conductivity, specific surface area, biocompatibility, chemical stability, and affordable housing [82].

- *Carbon-derived material*

Given its beneficial characteristics, which include commercial availability, conductivity, stability, and comparably affordable price as compared to other carbon-based electrode components, carbon cloth has been among the electrode materials selected for researchers [83]. Long fibers of carbon synthesized by the thermal degradation of acrylic compose the carbon cloth. A component of individual threads is joined together to create a bundle, and this bundle is ultimately woven to construct carbon fiber [84].

- *The carbon felt*

The mat-like structure of carbon felt is used as an electrode material, and its efficiency is increased by electro-deposition with other materials. Numerous studies have been conducted on the use of cathodic electro-deposition to apply RuO_2-based nanoparticle films to the carbon-felt surface [85,86].

- *The metal graphite*

Graphite's outstanding electrochemical properties, including biocompatibility, were recently revealed using the application of microscopy with scanning electrons (SEM). Furthermore, an immense quantity of an antibiotic-resistant clonal colony (*E. coli*) is observed attaching to the top layer of a graphite electrode [87]. The electrical energy produced by the graphite-felt electrodes is approximately three times more powerful than that of graphite rods alone [88].

Moderators

Typically, the chemical substances employed for enhancing MFC performance have the designation mediators [89]. There are, in fact, two different kinds of microbial fuel cells: these with and others without a mediator. The performance of the MFC system has been enhanced in multiple experiments by incorporating mediators such potassium ferry cyanide, neutral red, anthraquinone, thionine, disulfonic acid, azure, and cobalt sepulchrate. Microorganisms, in such instances, completely deteriorate organic substrates and transfer a portion of the electrons to electrodes [90]. The turnover rate in relation to the electrode should be carried into account while determining mediators. Whenever contracting MFCs, the mediator that encourages a high rate of electron turnover should be adopted [91,92].

Components employed in MFC

As it functions as a nourishment delivery and supplement and is necessary for the evolution of organisms, the substrate is an important component within each natural cycle. Arguably, the most significant organic components influencing the electricity generated in MFCs have been proposed to involve the substrate [93,94]. When it comes to manufacturing power, an extensive list of materials with a high carbohydrate content is needed, which may include either simple substances or exacerbated arrangements. The development of MFCs frequently relies on simple organic substrates containing acids such as alcohols (ethanol), inorganic compounds (sulfate), succinate, propionate, malate, acetate, butyrate, and succinate [94], [95]. Additionally, complex substrates include cellulose, starch, molasses, chitin starch, and wastewater from swine farms, the meat packaging field.It is being proven that these organic sources significantly impact the electrical density overall output of the MFC [96].

The Pterolium Based Wastes

Solids, carbohydrates, lipids, and nitrogen constitute oil waste [97], [98]. Whenever sedimentary microbial fuel cells with the anaerobic breakdown method were examined for the breakdown of petroleum hydrocarbons, the former technique proved approximately ten times more effective than the other method [99]. The greatest electricity density of 2240 mW/m^2 has been established with studies of soybean oil wastewater in single-chamber MFCs with 50 L working volume [100]. In the higher working volume, graphite felt served as the anode and carbon cloth as the cathode. Utilizing graphite material as the anode and stainless steel as the cathode, an optimal elimination of COD efficiency of 96% and Coulombic removal effectiveness of 33.6% have been reported in the lower working volume [101], [102]. In contrast with soybean oil, palm oil created a lower Coulombic performance of 24% and vegetable oil produced a lesser COD elimination rate of 70 and 86%, accordingly, in a two-chamber MFC [103]. A study done [104] applying the vegetable oil effluent revealed a COD removal efficiency equivalent to the study of Abbasi *et al.* [105]. Using wastewater at the refineries of petroleum, a single-chamber MFC functioning in batch mode yielded a 48% COD removal efficiency[106], whereas functioning in continuous mode supplied an increased COD removal and power density [107]. When compared to a conventional MFC, which employs oil sewage and generates 80 mW/m^2, a constructed wetland reactor with a microbial fuel cell reactor utilizes a MnO2-modified cathode produced with comparable COD removal but a higher power density of 102 mW/m^2. An 80% COD removal efficiency and 45 mW/m^2 power density have been obtained utilizing mineral oil wastewater in a single-chamber air-cathode MFC [108].

Domestic Grey Water Remediation by using MFCs for Reuse purposes:

Employing MFC technology, wastewater from homes can be converted into electricity. The average COD levels in residence wastewater are around 410 mg/L, and the high equates in municipal or household waste can negatively impact the complete outcome [109]. The MFCs that have been produced employing kitchen trash as the substrate additionally proved themself to be an efficient means to recycle organic waste, manufacture green electricity, and ensure an environmentally sound environment [110]. Using plastic containers having a 1000 mL capacity and an 800 mL operating volume, a lab-scale two-chamber MFC was developed. Rods of graphite, that possess a greater area of surface (31.1 cm^2), have been used as electrodes [111]. By maintaining the anode compartment anaerobic, the chambers are linked together by a PVC and a PEM, allowing enables the straightforward movement of a proton among both cathode and anode chambers. In order to preserve aerobic conditions, the cathode region remains open to the environment. About 68 μA of current and 889 mV of voltage have been generated within the MFC system [112].

Commonly Employed Microbial Consortiums in MFCs for Bioremediation

Due to their capacity to shuttle electrons from the cell's outer membrane to the anode and catalyze reduced electron acceptors by collecting electrons from the cathode surface, microorganisms remain essential to the normal functioning of MFCs [113]. Biofilm is a designation for the extremely thin film of bacterial proliferation because microbes correlated with MFC form on the electrodes [114]. The area in which biofilms being formed mature exerts a direct bearing on the breakdown of the complicated biological substrates in MFC and determines the microorganisms' capability of producing electrons. A number of bacterial species have been characterised as electrogenic bacteria or exo-electrogens, including *Shewanella* sp., *Propionibacterium freudenreichii*, *Lactococcus lactis*, *Geobacter* sp., *Cupriavidus basilensis*, *Pseudomonas* sp., *Rhodoferax* sp., etc [115].

The extensive variety of processes that regulate the electrons as the different responses of specific organisms in a mixed microbial culture may both be determined utilizing pure cultures. Among the pure cultures implemented in the generation of bioelectricity are the yeast *Saccharomyces cerevisiae*, *Escherichia coli*, *Desulfovibrio desulfuricans*, and *Klebsiella pneumoneae* [116], whereas mixed cultures are more productive than pure strains, studies have demonstrated that pure microbial cultures have high electron transmission efficiency. Still, their application is constrained by low growth rates in a highly specific substrate, low energy transfer rates, and the potential for unwanted contamination [117]. A single Combination culture is appropriate for generating bioelectricity owing to the mutually beneficial interaction among microbes, the way they interact with materials, and their capacity to reuse electrons. Individuals with various cultures can adapt to various circumstances and each species has the capacity to carry out a particular duty that helps other species in the same way, leading to enhanced performance [118]. MFCs utilize either pure or blended cultures to cleanse wastewater from homes and produce strength. The cytochromes (pili) within the outer membrane function as a nanowire, permitting direct electron dissemination from the biofilms. For the first time, *Saccharomyces cerevisiae* had been used as electrogenic bacteria in MFC to produce electricity [119]. The life expectancy of MFCs is usually directly impacted by both microbial activity and substrates or nutrients available in the setup. Based on the available statistics, regular MFCs may persist somewhere between months to years, even though various reports additionally reveal that they are capable of lasting only a few weeks [120].

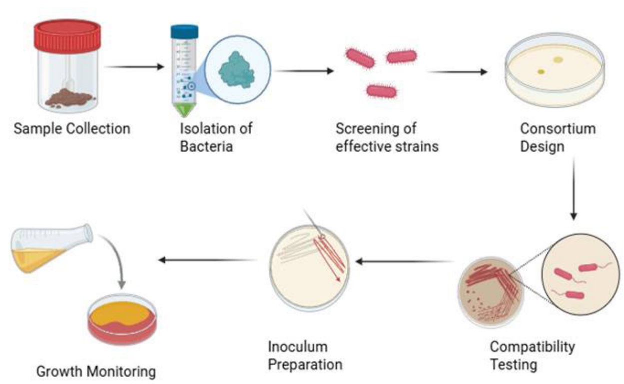

Figure 2: Schematic illustration of the bacterial growth cycle

Future Applications of MFCs

Another encouraging, innovative, sustainable technology that may assist the upcoming generation in addressing the energy crisis is microbial fuel cell technology [121]. Due to excessive electrical utilization, current methods for producing electricity depend entirely on other natural energy sources and are progressively running without resources. MFC usage and applications have grown progressively more common as a multi-system for waste management and energy recovery at the precise same time [122].

CONCLUSION

MFCs are encouraging technology that utilizes organic waste and other domestic or industrial waste for producing electricity. With minimized emissions and air pollution, it operates as a green technology for generating electricity from biodegradable rubbish. MFC technology could be employed as a reliable means for disposing of rubbish, and it would contribute to reducing the problems that waste accumulation produces for the environment and human health. The specific kind of bacterial population employed and the substrates in the medium, as well as the electrodes, all constitute significant considerations in the optimizing method that results in increasing energy production employing MFC technology. As it turns out, this procedure does not generate any poisonous substances and is environmentally sustainable. As a result, MFC technology has an enormous amount of potential for contributing to the solving of the upcoming energy challenge alongside effective waste management, something that sets it apart.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest with anyone.

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