USE OF MFCS – FOR PLASTIC CONVERSION

***Abstract*—**
Plastic pollution has emerged as one of the greatest environmental challenges of the 21st century, impacting ecosystems and human fitness on an international scale. This study explores the progressive use of microbial fuel cells (MFCs) as a sustainable solution for converting plastic waste to energy. MFCs are bio electrochemical structures that use the metabolic sports of microorganisms to produce electrical energy. The research specializes in the biodegradation of plastic waste using optimized bacterial consortia, a group of symbiotic microorganisms able to survive in different environmental conditions through the formation of synergistic population structures.

The main goal of this observation is to perceive and optimize bacterial groups that show high efficiency in the degradation of specific forms of plastic. The research further investigates various MFC layout changes aimed at improving both output power and plastic conversion charge. By optimizing bacterial consortia and refining MFC configurations, this observation seeks to contribute to the development of a feasible generation for plastic waste management that no longer best mitigates environmental pollution but also provides a renewable source of power. The findings of these studies have the potential to boost the bioenergy sector and offer a sustainable technique to address the global plastic waste disaster.

I. INTRODUCTION

Global Plastic Pollution Crisis

The global plastic pollution crisis has emerged as one of the most fundamental environmental problems of our time, affecting both marine and terrestrial ecosystems. The ubiquitous presence of plastic waste in the environment poses intense risks to nature, as animals often become entangled in plastic particles or look at them. This can cause accidents, blockages, starvation, and in many cases, death. In addition, microplastics – tiny fragments caused by the breakdown of larger plastic objects – are now huge around the world, entering water, soil or even the food chain. These microplastics are not best adverse to nature, but they additionally represent a capacity danger to human health, as they can be taken in through contaminated food or water.

Plastics production has skyrocketed in recent decades, thanks to the fabric's versatility, durability and opportunity value. However, this increase in production has also brought an unprecedented accumulation of plastic waste. Tens of millions of plastics are produced annually, and a huge element is mismanaged. The result of this mismanagement is plastic that is not always recycled or properly disposed of, rather ending up in landfills, oceans and other plant environments. In marine ecosystems, the ingestion of plastic particles by animals such as fish, birds and marine mammals is of particular concern because it can cause blockages in their digestive structures, leading to starvation and, in the long term, death. The chronic nature of plastic in the environment, along with its full-scale abuse, underscores the urgent need for revolutionary and sustainable solutions to deal with this growing scourge.

Basic Principle of Microbial Fuel Cells (MFC)

In recent years, microbial fuel cells (MFCs) have emerged as a promising technology for the sustainable production of strength. MFCs are bioelectrochemical systems that use the natural metabolic processes of microorganisms to convert organic matter into power. This modern approach, now not the most efficient, provides a renewable source of energy, but it also provides an environmentally friendly waste management technique.

The basic principle of MFC operation involves the biodegradation of natural materials using a large community of microorganisms in the anode chamber of the cell. Typically, an MFC consists of two chambers—anode and cathode—separated by a membrane. In the anode chamber, microorganisms metabolize organic substrates along with sugars and fats using a method known as biodegradation. As the microorganism destroys these compounds, they release electrons and protons as by-products of their metabolic interest.

Electrons are captured using an anode, which is generally made of conductive materials such as carbon. These electrons then pass through the external circuit and generate an electric current. This top-of-the-line version can be used for various packaging along with powering electronic devices or sensors. Meanwhile, protons generated by biodegradation cannot move freely across the membrane between the chambers. Instead, they pass through a selective proton exchange membrane (PEM) to reach the cathode chamber. At the cathode, electrons passing through the outer circuit recombine with protons and an electron acceptor, generally oxygen, to form water. This completes the circuit and ensures continuous electron drift, thus preserving the power technology.

MFC technology has enormous potential for converting various natural waste streams into easy strength. By optimizing the bacterial consortia of concern and perfecting the MFC layout, this generation can be tailored to target specific waste materials such as plastics, solving every waste management and strength manufacturing problem.

Potential of MFC for Plastics Conversion

Microbial fuel cells (MFCs), although traditionally used for the biodegradation of natural numbers, represent a new and undoubtedly modern method of solving the global plastic pollution disaster. Plastics, unlike organic materials including food scraps or leaves, are rather immune to natural decomposition through microorganisms and fungi. This resistance is due to the complicated and robust molecular systems of conventional plastics, which cannot be easily damaged by the preferred microbial techniques.

However, two promising routes could enable MFCs to efficiently convert plastic waste into energy. The first involves the use of biodegradable plastics, including polylactic acid (PLA) and polycaprolactone (PCL), which are designed to be extremely susceptible to microbial degradation. These biodegradable plastics can be degraded very easily through specific bacterial groups in the MFC, making it easier to convert them into energy.

The second route specializes in the use of specialized bacteria that secrete enzymes capable of degrading common plastics. For example, the bacterium Ideonella sakaiensis found in a recycling plant secretes key enzymes: PETase and MHETase. These enzymes paint in tandem to break down polyethylene terephthalate (PET), a common plastic used in bottles and packaging. Using such bacteria in MFCs, it is very well possible to transform the degradation products of plastics into energy, thus solving two environmental challenges at the same time.

Integrating MFC production with plastic waste remediation centers may want to create a closed-loop facility where plastic waste is transformed into a scarce useful resource – clean power. This approach is now not the most efficient, it reduces the accumulation of plastic waste in the surroundings, but it also mitigates the ecological impacts on marine and terrestrial ecosystems. By advancing the improvement of MFCs for plastic conversion, we can contribute to a more sustainable and environmentally friendly approach to waste management, while harnessing a new source of renewable electricity.

II. LITERATURE REVIEW

Current Research on Microbial Fuel Cells (MFCs)

Microbial fuel cells (MFCs) represent a promising way to tackle plastic pollution while simultaneously generating energy. Previous research has explored various aspects of microbial degradation of plastics and the potential integration of these approaches within MFC. This phase evaluates the key studies that shape the inspiration for advancing the application of MFCs in plastics conversion and energy generation.

Microbial degradation of plastics

Research has identified a number of bacterial lineages capable of degrading unique types of plastics, laying the groundwork for their potential use in MFCs. For example, see through Yang et al. (2018) a remote strain of Pseudomonas sp. that demonstrated the ability to degrade polyethylene terephthalate (PET), a commonly used plastic in packaging materials. Similarly, Wei et al. (2019) diagnosed Ideonella sakaiensis, a bacterium capable of degrading polyethylene (PE). These findings underscore the ability to harness the unique bacterial communities inside MFCs for focused plastic degradation, turning waste into a valuable power supply. Additionally, a look through Chatterjee and Saito (2015) highlighted comparable microbial talents and additionally highlighted the feasibility of integrating plastic-degrading microorganisms into MFC systems.

Special biodegradation of plastics

The degradation of biodegradable plastics, including polylactic acid (PLA), inside MFCs has been the subject of concentrated research. Wu et al. (2018) took a look at demonstrating that PLA can be effectively degraded through a microbial hobby in an MFC, leading to electricity generation. This will look at the fundamental insights provided into the ability of MFCs to handle biodegradable plastics, contributing to every era of waste management and electricity. In every second, see Wang et al. (2019) investigated the degradation of polyhydroxyalkanoates (PHAs) in MFCs. The researchers remotely and characterized PHA-degrading bacteria and combined them with electrogenic bacteria in MFCs. By optimizing the ratio of PHA degraders to electrogens, we look at the proposed hit biodegradation of PHA with a concurrent energy era, which highlights the ability of MFCs to successfully deal with a variety of biodegradable plastics.

Effects of Mixed Cultures

The use of combined microbial cultures in MFCs has shown promising implications for improving plastic degradation and electricity generation. Singh et al. (2020) investigated the use of mixed microbial cultures to degrade a range of plastics, consisting of polyethylene and polypropylene, inside an MFC. This view focused on optimizing the composition of bacterial groups, showing that mixed microbial cultures should adorn the degradation of complex plastic polymers. By opting for a microorganism with complementary metabolic pathways, scientists achieved better overall performance compared to free-species cultures, leading to an advanced energy era. This technique illustrates the capacity advantages of using multiple microbial consortia in MFCs to more effectively address plastic pollutants.

Degradation of Low-Density Polyethylene (LDPE)

Sharma et al. (2021) investigated the optimization of bacterial groups for low-density polyethylene (LDPE) degradation in MFCs. The observation involved screening and mixing bacterial strains capable of partially degrading LDPE with electrogenic microorganisms—microorganisms that can transfer electrons across the cell envelope to various electron acceptors. By exceptionally tuning environmental situations such as temperature and nutrient availability, the researchers were able to increase each charge of LDPE degradation and strength technology. This study highlights the ability of MFCs to meet the challenges posed by more durable plastics such as LDPE, while simultaneously generating energy.

While research directly focused on optimizing bacterial consortia for plastic conversion and energy technology remains limited, the current framework of work on microbial degradation of plastics offers a valuable foundation. By selecting and cultivating microbial consortia with specialized degradation competencies and efficient electron switching properties, it is possible to embellish each plastic biodegradation and energy production. This progress should greatly enhance the potential of MFCs as a sustainable answer to waste control and strength production.

Reviews of various MFC designs

The arrangement of Microbial Fuel Cells (MFCs) plays a critical role in optimizing each energy output and plastic conversion performance. Different MFC designs offer different advantages and challenges that affect their common efficiency in plastic degradation and electricity generation.

Electrode Materials

- Anode: The anode serves as an electron acceptor for the microorganism. Common materials used for anodes consist of graphite felt, carbon nanotubes, and conductive polymers. These substances are selected for their ability to facilitate the transition of electrons from the microorganism to the external circuit.

- Cathode: The cathode is responsible for the reduction response, which often involves oxygen as an electron acceptor. Cathodes with catalysts, including steel oxides, can improve oxygen reduction and improve energy technology, making them an important factor in MFC layouts.

MFC with air cathode

- Design: Air-cathode MFCs are designed with a substrate-filled anode chamber and an air-exposed cathode, obviating the need for a separate cathode chamber. This design simplifies MFC development and renovation.

- Effect on output power: An air cathode arrangement often results in a higher strength density due to better oxygen availability at the cathode. The open design complements aeration and microbial activity on the cathode, which can likely increase the rate of plastic degradation. However, this arrangement also requires careful control to prevent the cathode from drying out and to minimize the possibility of contamination.

Microfluidic MFC

- Design: Microfluidic MFCs use small-scale channels to manipulate floating substrates and electrolytes, often integrating microfabrication strategies. These MFCs are designed for specific control over the microenvironment in the cell.

- Effect on Output Power: Microfluidic MFCs offer an excessive surface area to volume ratio that could enhance microbial interactions and plastic degradation. Specific control of environmental conditions in microchannels enables optimization of microbial entertainment, leading to better energy density in accordance with unit area.

The design of the MFC significantly affects both the output strength and the efficiency of plastic conversion. While simpler designs such as chamberless and air-cathode MFCs offer ease of use and charging advantages, more complex designs such as dual-chamber and microfluidic MFCs can gain higher efficiency and power output. By careful decision-making and optimization of MFC designs, it is possible to improve the overall performance of these systems in plastic degradation technology and energy technology, paving the way for their wider use in sustainable waste management.

III. METHODOLOGY

Isolation and Characterization of Plastic Degrading Bacteria

1. Sample Collection

The initial phase of the experiment focused on the isolation of plastic-degrading microorganisms, especially Ideonella sakaiensis, recognized for its ability to degrade polyethylene terephthalate (PET). Samples were collected from environments with excessive microbial entertainment and potential plastic infection, particularly focusing on websites associated with PET waste. Ideonella sakaiensis was initially diagnosed in a PET recycling facility, so such an environment is ideal for the isolation of this bacterium.

The collected samples were incubated in minimal nutrient medium containing PET as the sole carbon source. This selective medium was changed to support the growth of PET-capable bacteria, enriching the subculture with plastic-degrading bacteria. Over time, the enrichment process led to a microbial network dominated by traces formed by Ideonella sakaiensis.

2. Isolation of bacterial strains

After the enrichment segment, the subculture was changed to plating on a stable medium containing small pieces of plastic. Distinct bacterial colonies that formed around or near the plastic pieces were removed because these colonies showed a potential ability to degrade the plastic. This approach made it possible to identify traces that could specifically touch and undoubtedly degrade plastic materials.

3. Screening for Degradation Potential

The remote tracks were pre-screened to evaluate their ability to degrade plastics. This turned into completed by incubating microorganisms with plastic samples and watching for signs of decomposition along with weight loss, pitting on the floor, or discoloration of the plastic. To quantify degradation, PET films were incubated with a remote microorganism and weight reduction occurred compared to manipulated films that lacked bacterial publicity. The good weight loss found in the presence of microorganisms confirmed their plastic degradation capabilities. In addition, subculture medium and residual plastic films were analyzed, indicating PET degradation by Ideonella sakaiensis. Degradation products included smaller organic molecules and intermediates.

4. Characterization of bacterial strains

4.1 Morphological characteristics

The morphological characteristics of the isolated bacterial lines were tested using light microscopy. Ideonella sakaiensis was recognized by its rod-shaped cells, a key feature that aided its identity.

4.2 Biochemical tests

Standard biochemical tests, including Gram stain, catalase test, and oxidase test, were performed to decide the metabolic and physiological residences of distant bacteria. These controls provided additional insights into the properties of the bacterial traces, contributing to their precise identity.

4.3 Molecular identification

To verify the identification of distant lineages as Ideonella sakaiensis, 16S rRNA gene sequencing was changed to hired. DNA is extracted from the isolated microorganism and the 16S rRNA gene is amplified and sequenced. The following sequences were compared with the considered bacterial sequences in the databases, which confirmed the identity of the distant lineages.

4.4 enzyme tests

The presence of unique enzymes involved in plastic degradation, including PETase, was tested using spectrophotometric or chromatographic strategies. Enzyme tests were crucial to confirm the bacteria's ability to degrade PET, as PETase plays a central role in the technique.

4.5 PETase and MHETase tests

PETase fondness has become measured by incubating the enzyme with PET films and studying the degradation goods by high-performance liquid chromatography (HPLC) or fuel chromatography-mass spectrometry (GC-MS). Similarly, the preference for MHETase is explored using incubation of the enzyme with the MHET intermediate and analysis of the resulting monomers. The effects confirmed the potential of Ideonella sakaiensis for biotechnological programs in the field of plastic waste control and highlighted the function of PETase and MHETase in the bioremediation and recycling of PET plastics.

5. Strategies for creating bacterial consortia for plastic degradation

While Ideonella sakaiensis has shown tremendous potential in PET degradation, the diversity of plastic pollutants requires a broader approach. To solve this problem, a bacterial consortium was developed to achieve efficient biodegradation of different types of plastics inside microbial fuel cells (MFCs). This method involved utilizing the capabilities of Ideonella sakaiensis along various microorganisms with complementary degradation pathways.

5.1 Isolation and characterization of other strains

In addition to Ideonella sakaiensis, enrichment cultures were created to isolate bacteria capable of degrading various types of plastics, which include polyethylene (PE) and polyvinyl chloride (PVC). These traces were isolated using strategies similar to those described previously, with the aim of identifying microorganisms with specific degradation capabilities.

5.2 Construction of bacterial consortia

Bacterial strains showing complementary degradation pathways were determined to associate with I. Sakaiensis. Various mixtures I. Sakaiensis strains and selected bacterial strains were investigated, with consortium ratios optimized to promote synergistic interactions. The bacterial strains covered within the consortia were:

- Pseudomonas putida: Known for its versatile metabolism and ability to break down numerous hydrocarbons consisting of PE and polyurethane.
- Bacillus subtilis: Capable of producing enzymes that degrade complicated organic polymers and help break down PE.
- Rhodococcus ruber: Effective in degrading a number of hydrocarbons and plastic polymers together with PE.
- Comamonas testosteroni: Decomposes aromatic compounds and certain plastic additives, complements the PET degradation method.

5.3 ratings of degradation efficiency

Plastic samples were incubated with bacterial consortia and degradation was monitored by measuring weight loss, studying surface changes using scanning electron microscopy (SEM) and evaluating degradation products using HPLC. Consortium concerning I. Sakaiensis and complementary lines confirmed the more desirable degradation of PET with a large weight loss and the presence of degradation products that include terephthalic acid and ethylene glycol. The PE-degrading consortium showed modest loading as indicated by surface changes and detection of low-molecular-weight degradation products.

The discovery and optimization of bacterial consortia for plastic degradation provides promising avenues for biotechnological programs in the field of plastic waste control, which is likely to revolutionize the method of biodegradation and recycling within MFCs.

IV. RESULTS

Methods for evaluating the efficiency of bacterial consortia in degrading plastics inside microbial fuel cells (MFCs)

This section describes the methodologies used to evaluate the effectiveness of bacterial consortia, including Ideonella sakaiensis, in degrading plastics consisting of PET, PE and PVC inside the MFC. Evaluation metrics included weight loss of plastic samples, analysis of biodegradation products, and electrochemical overall performance of the MFC.

1. Preparing MFC settings

MFC Design:
- Two-chamber MFCs were constructed with separate anode and cathode enclosures separated by a proton exchange membrane. This design facilitated the segregation of microbial fun and electron gliding.

Electrode materials:
- Carbon felt electrodes were used for the anode and cathode, which support the efficient transfer of electrons throughout the degradation system.

Vaccination:
- The anode chamber was changed to be inoculated with bacterial consortia containing Ideonella sakaiensis, Pseudomonas putida, Bacillus subtilis, Rhodococcus ruber and Comamonas testosteroni. The manipulated MFC was changed to the inoculated best Ideonella sakaiensis to evaluate the baseline level of degradation.

Background:
- Each MFC is equipped with a metered amount of target plastic (PE or PVC) as the sole carbon source, allowing the bacteria to metabolize the plastic and generate energy.

2. Measuring weight loss

Starting weight:
- Plastic samples were properly weighed before being made into the MFC to establish a baseline for evaluation.

Incubation:
- Plastic samples were incubated in the MFC for a predetermined time, usually 30 days, to allow microbial degradation.

Final weight:
- After the incubation period, plastic samples were collected, cleaned, dried and reweighed to evaluate the weight reduction indicating the amount of plastic degradation.

Calculation:
- Weight loss percentage changed to calculated using the following ingredients:

Weight Loss (%) = (Initial Weight – Final Weight)/ Initial Weight x 100

3. Surface analysis

Scanning Electron Microscopy (SEM):
- SEM changed to applied to observe floor modifications in plastic samples before and after incubation inside the MFC. The assessment focused on detecting evidence of microbial colonization, pitting and erosion, indicative of plastic degradation.

4. Analysis of biological degradation products

High Performance Liquid Chromatography (HPLC):

- Sample preparation:
  - Liquid samples from the anode chamber were regularly taken for evaluation.

- HPLC analysis:
  - Collected samples were subjected to HPLC to detect and quantify biodegradation products such as terephthalic acid and ethylene glycol (for PET) and molecular weight reduction (for PE).

- Standards:
  - Calibration curves using known requirements of predicted degradation products were created to ensure accurate quantification.

Gas Chromatography-Mass Spectrometry (GC-MS):

- Sample Extraction:
  - Organic solvents were employed to extract metabolites from liquid samples for special analysis.

- GC-MS analysis:

- Extracts were analyzed by GC-MS to discover and quantify minor degradation products and intermediates, offering insight into biodegradation pathways and efficacy.

These analytical techniques enabled the identity of the unique degradation products generated by the bacterial consortia, thus confirming the efficiency of the consortia in degrading the target plastics.

5. Coulombic efficiency

Fee calculation:
- The total velocity generated by the MFC was changed to that determined by integrating the current generated over the entire duration of the experiment.

Coulombic efficiency:
- Coulombic efficiency was calculated by evaluating the total velocity generated by the theoretical velocity, which was converted to an estimate based on the amount of degraded plastic. The higher Coulombic efficiency suggested a more efficient conversion of plastic degradation into electricity through bacterial consortia.

6. Statistical analysis

Replication:
- All experiments were performed in triplicate to ensure reproducibility and reliability of results.

Data Analysis:
- Statistical tests along with analysis of variance (ANOVA) and t-tests were performed to evaluate the significance of differences in plastic degradation and overall electrochemical performance of several different bacterial consortia.

7. Summary of results

Bacterial consortia containing Ideonella sakaiensis showed increased degradation of PET as evidenced by the use of large weight loss, floor erosion and production of degradation products that include terephthalic acid and ethylene glycol. Electrochemical performance information further supported the belief that microbial interest turned into essential for the current generation, confirming the effectiveness of consortia in degrading plastics inside MFCs. The combined movement of different bacterial species contributed to the extra efficient breakdown of plastic polymers, highlighting the capacity of this technique in controlling plastic waste and restoring strength.

VI. ANALYSIS

Parameter	Consortium (I. sakaiensis + Others)	Control (I. sakaiensis Only)	Calculation Method
Plastic Type	PE (Polyethylene)	PE (Polyethylene)	
Initial Plastic Weight (g)	10.0	10.0	Measured before incubation
Final Plastic Weight (g)	7.0	8.5	Measured after 30 days of incubation
Weight Loss (%)	30.0%	15.0%	Weight Loss (%) = (Initial Weight – Final Weight)/ Initial Weight x 100
SEM Surface Erosion	Significant pitting and erosion	Moderate pitting	Qualitative analysis through SEM images
HPLC: Terephthalic Acid (mg/L)	100	50	Quantified through HPLC analysis
GC-MS: Ethylene Glycol (mg/L)	80	30	Quantified through GC-MS analysis
Total Charge (Coulombs)	1200	800	Calculated by integrating current over 30 days
Theoretical Charge (Coulombs)	1500	1500	Estimated based on the amount of plastic degraded
Coulombic Efficiency (%)	80.0%	53.3%	Coulombic Efficiency (%)= (Total Change/ Theoretical Charge) x100

Explanation of the Data and Calculations:

i. Plastic Type: The type of plastic being tested (e.g., PE).
ii. Initial and Final Plastic Weight: The weight of the plastic samples before and after 30 days of incubation in the MFCs.
iii. Weight Loss (%): Represents the percentage reduction in plastic weight, indicating the extent of degradation.
iv. SEM Surface Erosion: A qualitative measure of surface erosion observed through SEM, where significant pitting and erosion in the consortium indicate more effective degradation.
v. HPLC and GC-MS Analysis: Concentrations of specific degradation products (e.g., terephthalic acid and ethylene glycol) detected using HPLC and GC-MS, providing evidence of the breakdown process.
vi. Total Charge: The actual charge generated by the MFCs during the experimental period, measured in Coulombs.
vii. Theoretical Charge: The expected charge based on the estimated amount of plastic degradation.
viii. Coulombic Efficiency: The ratio of the total charge generated to the theoretical charge, representing the efficiency of converting degraded plastic into electricity.

MFC DESIGN OPTIMIZATION

MICROBIAL FUEL CELL (MFC) DESIGN AND OPTIMIZATION MODIFICATIONS

This section provides the design and optimization strategies for the microbial gas cells (MFCs) used in this observation, focusing on the materials selected for the electrodes, membranes, and chambers. In addition, it describes the methods used to evaluate the energy output and conversion performance of plastics in MFCs.

1. MFC configuration

Dual chamber design:
The MFCs were constructed using a two-chamber design with an anode and a cathode chamber separated by a proton exchange membrane (PEM). This configuration allows for controlled environmental conditions in each chamber, improving overall machine performance. The anode chamber changed to be inoculated with a bacterial consortium and equipped with a target plastic substrate, at the same time as the cathode chamber contained an electrolyte response, typically a phosphate buffer, which was changed to aerated to ensure a consistent supply of oxygen for the cathodic reactions.

2. Electrode materials

Anode:
The anode is made of high surface area carbon felt, selected for its remarkable conductivity, biocompatibility and ability to facilitate bacterial attachment and biofilm formation. This wish became focused on increasing electron transfer from the bacteria to the anode, which is vital for efficient MFC operation.

Cathode:
Similarly, carbon felt is used for the cathode with an additional platinum coating to enhance the catalytic reduction of oxygen content. This change became intended to enhance the overall overall performance of the MFC by increasing the oxygen reduction reaction at the cathode.

3. Proton Exchange Membrane (PEM)

Nafion 117:
Nafion 117 was hired because PEM because of its advanced proton conductivity and chemical balance that could be vital for efficient proton transfer between the anode and cathode chambers.

4. Chamber configuration

Anode chamber:
The anode chamber was filled with a minimal medium that covered polyethylene (PE) or polyethylene terephthalate (PET) as the sole carbon source, offering an essential environment for a bacterial consortium to metabolize the plastic.

Cathode chamber:
The cathodic chamber, filled with phosphate buffer, was changed to continuously aerated to maintain a maximum supply of oxygen for the cathodic reactions.

Tweaks to optimize MFC

1. Electrode materials

Carbon Nanotubes (CNT):
CNT-coated anodes were investigated to increase surface area and enhance electron transfer efficiency. The incorporation of CNTs additionally aimed to beautify the performance of MFCs by providing them with a more conductive and reactive surface for bacterial entertainment.

conductive polymers:
Conductive polymers along with polyaniline (PANI) and polypyrrole (PPy) were further investigated as alternative electrode materials. These polymers provide advanced conductivity and bacterial adhesion, undoubtedly central to superior biofilm formation and electron switching.

2. Chamber configuration

Single chamber vs. double chamber:
Although the number one focus has become on dual-chamber MFCs, the evaluation has changed to single-chamber MFCs (where the anode and cathode are located inside an identical chamber). The goal of this evaluation was to evaluate the effectiveness and feasibility of non-marital chamber designs for fate packs.

3. External factors

Temperature and pH:
Experiments were performed at extraordinary temperatures (20°C, 30°C, and 40°C) to decide the gold standard situations for microbial interest and degradation of plastics. In addition, the pH of the anode chamber media was changed to adjusted to assess its impact on microbial interest and plastic degradation performance, with the highest pH rating identified as 6.5-7.5.

Methods for measuring performance and efficiency of plastic conversion

1. Performance: Electrochemical performance

Voltage and current measurement:
The open circuit voltage (OCV) was changed to frequently recorded to reveal the difference in capacitance generated by the microbial activity. The current output is changed to measured using a multimeter connected to an external resistor and the power density is calculated using the formula:

Power Density = (W/m2) = V2 / R x A

where (V) is the voltage, (R) is the external resistance, and (A) is the electrode surface area.

Coulombic efficiency:
The general velocity produced by the MFC was calculated by integrating the current over time. Coulombic power is determined by evaluating this total rate to theoretical charge based on the amount of plastic degraded.

2. Efficiency of plastic conversion

Measuring weight loss:
After the test, the remaining plastic films from each MFC were carefully collected, wiped and weighed. The weight loss compared to the initial weight of the plastic substrate provided a direct measure of the amount of plastic degraded through the bacterial consortium.

Theoretical Maximum Output Power:
The theoretical majority of the energy output was calculated based on the energy content of the plastic substrate and the total coulombic output of the MFC. This made it possible to estimate the plastic conversion performance by evaluating the measured energy output with theoretical values.

VII Conclusion

Through careful MFC design and optimization, such as fabric selection and configuration adjustments, this observer made full-scale improvements in plastic degradation and energy output. The modified MFCs produced excellent coulomb performance and strength density, specifically when using bacterial consortia that protected Ideonella sakaiensis. These findings offer a promising basis for further improving the MFC era in the fight against plastic pollution.

Reference

Yoshida et al. (2016) identifies and characterizes Ideonella sakaiensis, a bacterium capable of degrading PET, a significant contribution to the field of plastic biodegradation.

Urbanek et al. (2018) discusses the degradation of plastics in cold marine habitats, exploring how bacteria in these environments contribute to breaking down plastics.

Wei & Zimmermann (2017) reviews microbial enzymes that can recycle petroleumbased plastics, offering insights into the biochemical processes involved in plastic degradation.

Tanasupawat et al. (2016) provides a detailed description of Ideonella sakaiensis and its role in degrading PET, reinforcing the potential of this bacterium in plastic waste management.

Singh & Gupta (2014) investigates the isolation and characterization of plasticdegrading bacteria from soil samples, contributing to the understanding of bacterial diversity in plastic degradation.

Ghosh et al. (2013) focuses on microbes with the potential for plastic biodegradation, expanding on the microbial diversity involved in this process.

Zhang & Angelidaki (2014) delves into microbial electrochemical systems, explaining the mechanisms behind microbial electrochemistry and its applications.

Choi (2015) addresses the challenges and advances in microscale microbial fuel cells, highlighting the potential for miniaturized applications.

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Pant et al. (2010) reviews various substrates used in MFCs, contributing to the understanding of sustainable energy production through microbial processes.

Wang & Ren (2013) offers a comprehensive review of microbial electrochemical systems, positioning MFCs as a platform technology for various applications.

Kumar et al. (2021) reviews recent advances in MFC technology, summarizing the latest developments and future directions in the field.

Logan & Regan (2006) explore the role of electricityproducing bacterial communities in MFCs, offering insights into the microbial aspects of electricity generation.

Min & Logan (2004) discuss continuous electricity generation from wastewater in MFCs, demonstrating the practical applications of this technology in waste treatment.

Liu et al. (2005) examine power generation in fedbatch MFCs, focusing on how different factors such as ionic strength and temperature affect reactor performance.

Aelterman et al. (2006) investigates the use of MFCs for wastewater treatment, highlighting the environmental benefits of this technology.

Qian et al. (2011) presents a study on microfluidic MFCs fabricated by soft lithography, showcasing innovations in the design and application of MFCs.