# THE ROLE OF DIFFERENT PRE-TREATMENTS IN ANAEROBIC BIODEGRADATION OF PLASTICS AND UPYCLING TO BIOENERGY USING MICROBIAL FUEL CELLS

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## INTRODUCTION

- There is currently a problem of plastic waste accumulating in the environment, posing threats to wildlife and human health, but it also represents a vast, low-cost carbon resource that could be repurposed for the sustainable production of commodity, chemicals and energy sources (Padilla-Vasquez, 2023).
- The continuing demand for plastic products, the lack of appropriate recycling and the ubiquitous pollution of the environment with plastic waste pose a global challenge.
- Biological systems offer a promising approach by enabling the processing of plastic waste through microbial/enzymatic activity.
- Microbial Fuel Cells (MFC) is a sustainable eco-friendly method of plastic degradation that serves as a substitute for traditional plastic waste treatment. This method can degrade plastics anaerobically with the added advantage of recovering valuable molecules from substrates, produce cleaner energy, zero release of pollutants to the atmosphere and can be used in areas without access to electricity (Wang *et al*., 2024).
- Previous work reported in the literature involved aerobic degradation mainly using pure strains of *Ideonella sakaiensis*, but degradation rates are still low. This is in part due to the high crystallinity of the plastics and the low activity of the enzymes (PETases) produced under aerobic conditions.
- Recent reports using electrochemical 3-electrode systems indicated that different sets of enzymes are expressed by *Ideonella sakaiensis* under anaerobic conditions. In addition to reducing plastic pollution, the plastic fermentation process produces useful feedstock chemicals or electricity in a microbial fuel cell, launching possibilities for future bioenergy technologies (Kalathil, Miller and Reisner, 2022).
- It might therefore be expected that employing a coculture of *Ideonella sakaiensis* and *Shewanella oneidensis* would be able to degrade pre-treated plastics (Polyethylene terephthalate, PET) in an anaerobic (microbial fuel cell environment) and convert degradation products to electricity.

## AIM

To investigate the role of different pre-treatments on anaerobic biodegradation of PET plastics in microbial fuel cell systems

## METHODOLOGY

### 1. a) PRE-TREATMENT METHODS

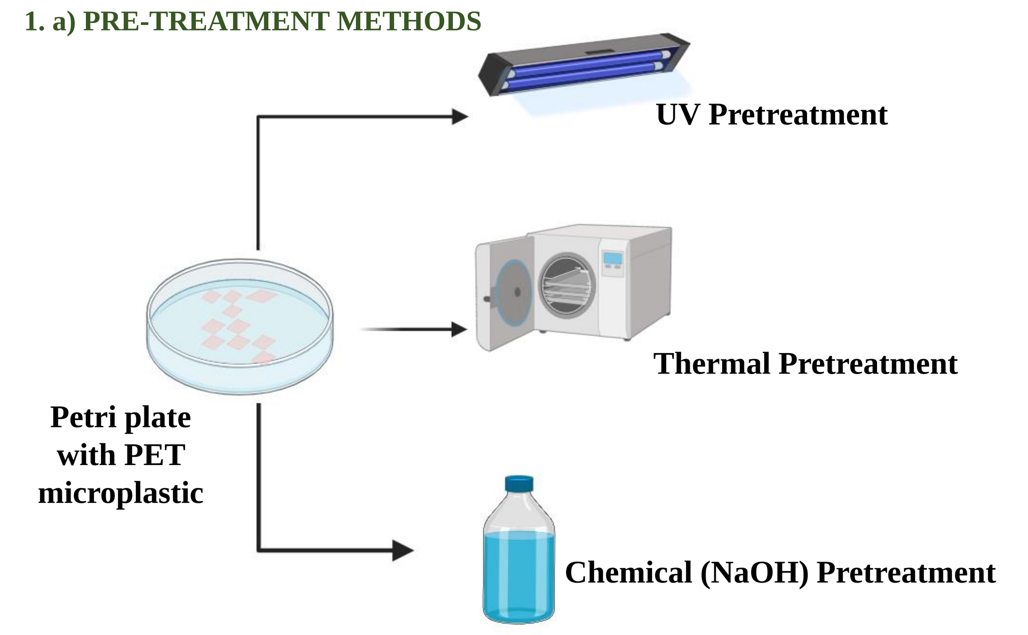


Figure 1a – schematic illustration of various pretreatment techniques applied to Polyethylene Terephthalate (PET)

### 1.b)ANALYTICAL TECHNIQUES USED

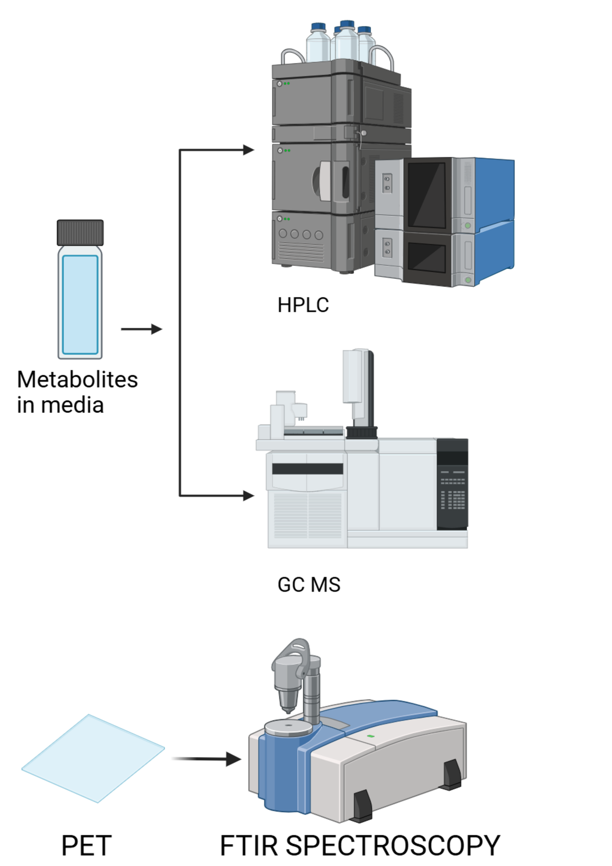


Figure 1b depicts the analysis performed using HPLC and GC-MS to examine the nature of metabolites in the medium, along with FTIR spectroscopy to investigate structural changes in PET.

### 1. c) EXPERIMENTAL DESIGN

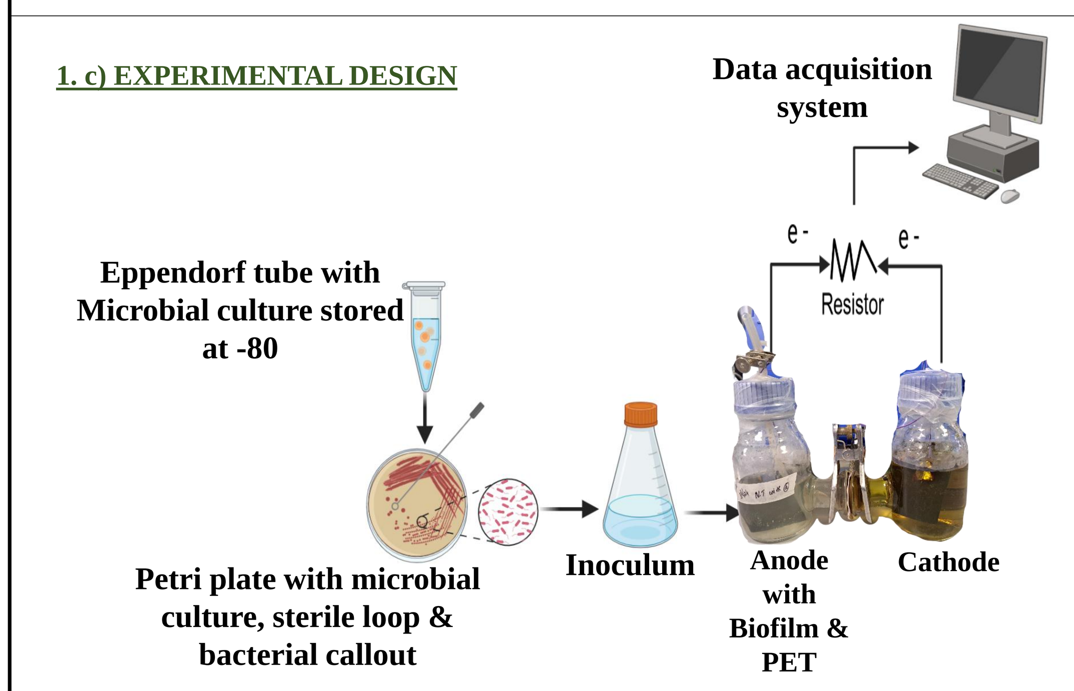


Figure 1c illustrates the entire experimental design, beginning with the cultivation of microbes and leading up to the data acquisition system.

### 1. d) LABORATORY SETUP OF MFC

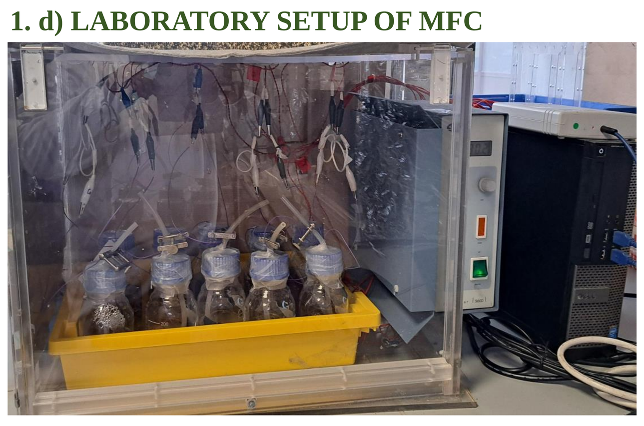

Figure 1d shows the laboratory setup of Microbial Fuel cells in an incubator.

## RESULTS

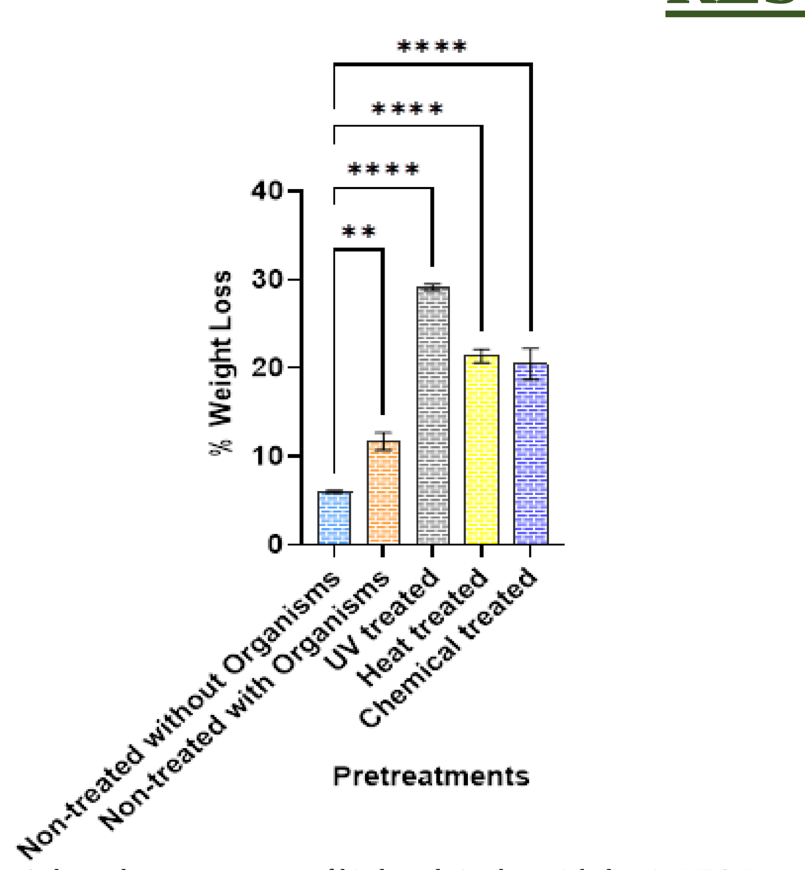


Figure 2 shows the percentage rate of biodegradation by weight loss in MFC. Data was analysed using one-way ANOVA test, n=4, p <0.05 (**), P < 0.0001 (****).

### FTIR SPECTRUM

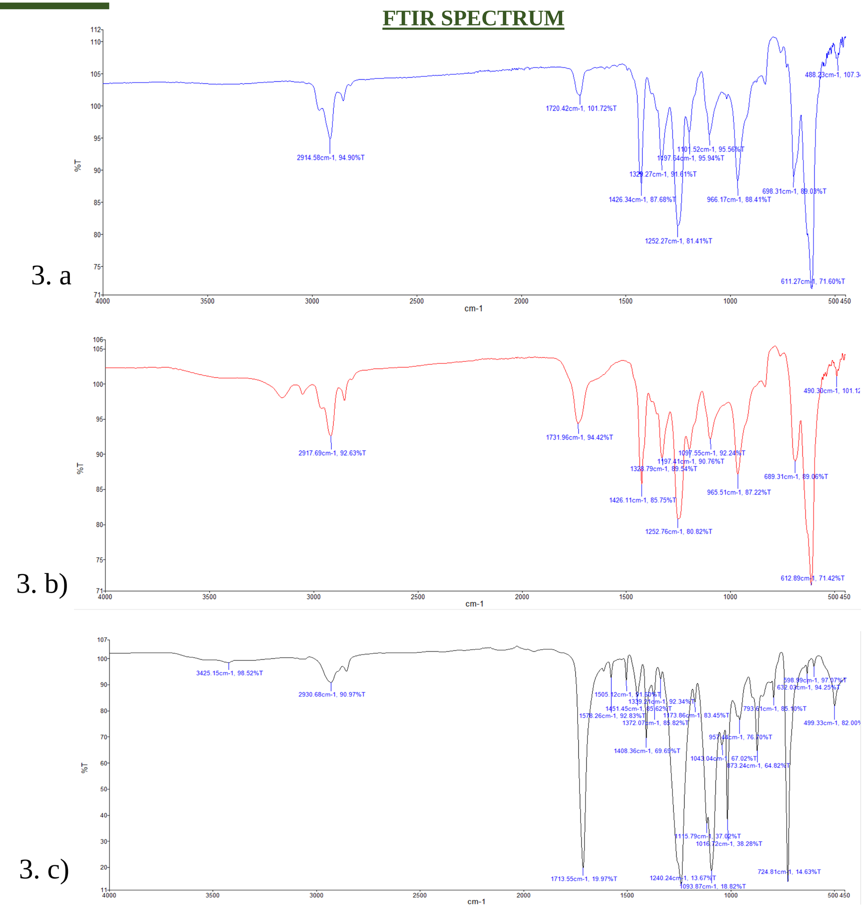


Figure 3a shows the FTIR Spectrum of the control (non-treated) PET used in this study , 3b shows the FTIR spectrum of UV treated (before degradation) PET & 3c shows the FTIR spectrum of UV treated (after degradation) PET.

### CHROMATOGRAM

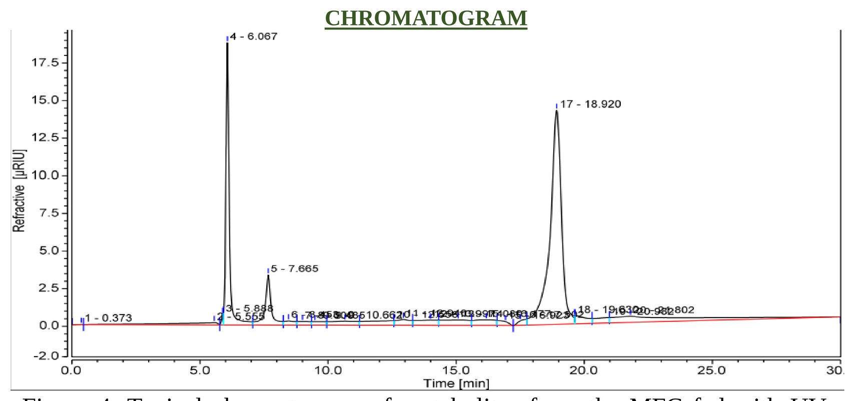


Figure 4. Typical chromatogram of metabolites from the MFC fed with UV-treated PET on day 10. Peak at 18.9 mins retention time coincides with ethanol.

### POWER DENSITY-CURRENT DENSITY

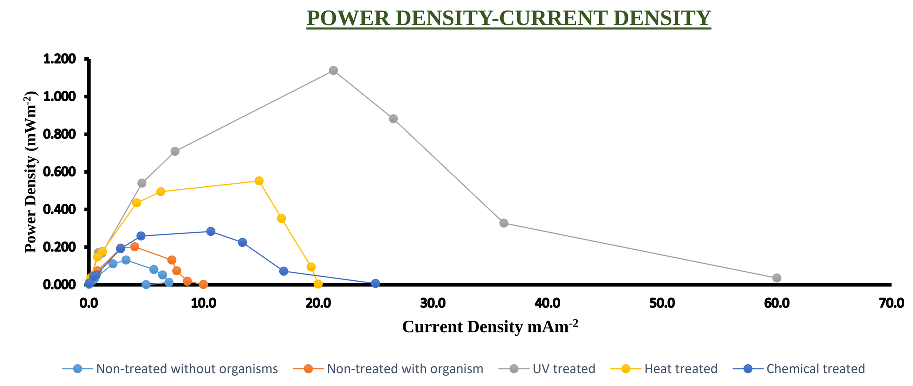


Figure 5 shows the compiled power density-current density graph of all the MFC degradation systems fed with non-treated PET (without organisms), non-treated PET (with organisms), UV treated PET, Heat treated PET & Chemically treated PET.

### VOLTAGE PROFILE

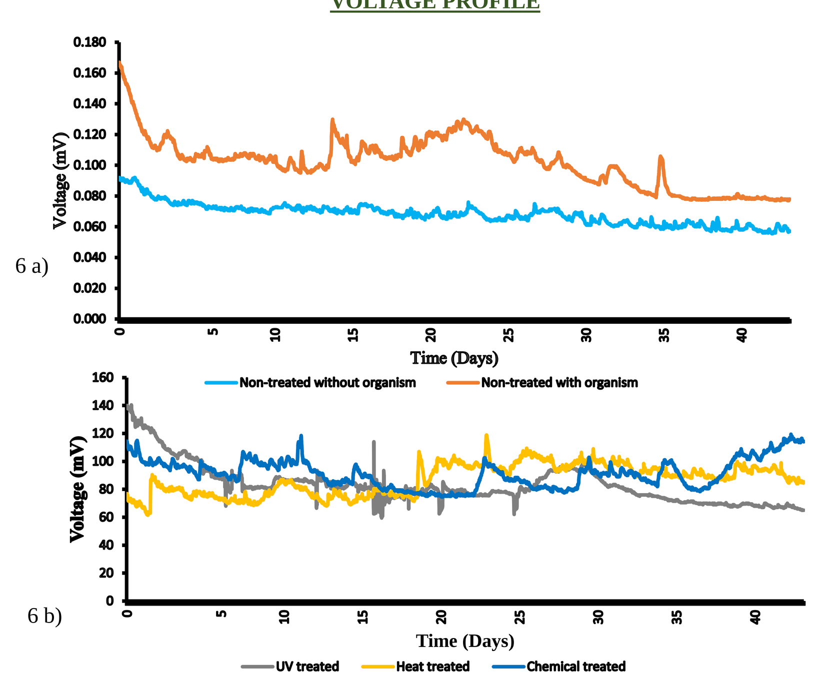


Figure 6a. Voltage-time profile of MFCs fed with non-treated PET without organisms & non-treated PET with organisms & 6b shows the profiles of MFCs fed with of UV-treated, Heat-treated & Chemically treated PETs.

### POLARISATION CURVE

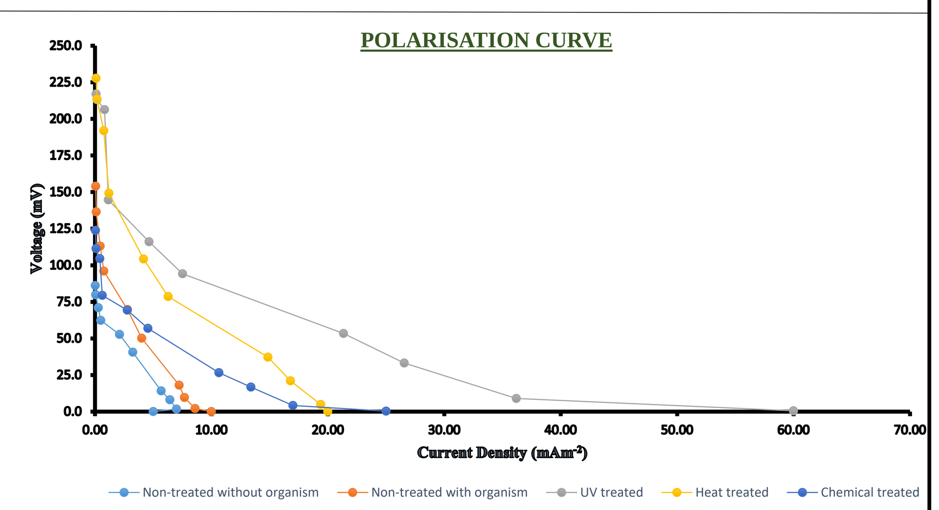


Figure 7 shows the polarisation curves of the MFCs fed with non-treated PET without organisms, non-treated PET with organisms, UV-treated PET, Heat-treated PET and Chemically-treated PET.

## DISCUSSION

- The study was carried out anaerobically employing a microbial coculture in a buffered medium at 30°C. Investigations were conducted on the biodegradation of 60 mg of 4 x 4 mm PET microplastic pieces.
- The rate of biodegradation, the generation of electricity and the production of metabolites in the media were studied. Pretreatment methods including UV, Thermal and Chemicals (NaOH) were examined for their potential to improve polyethylene terephthalate biodegradation and the ensuing production of bioenergy.
- Bioelectrochemical systems with non-treated PETs degraded less compared to the pretreated PETs.
- Electrical power was generated in MFCs in tandem with closed circuit voltages of 65 mV to 141 mV across a 2200 Ohm external resistor and anode electrode size of 25 $cm^2$. MFC with UV-treated PET produced the highest power density of 1.14 $mWm^{-2}$ and a current density of about 21.3 $mAm^{-2}$.
- HPLC detected breakdown products, such as ethanol, whereas FTIR examination revealed surface alterations on the PET. This study highlights the use of UV pretreatment in enhancing the rapid biodegradation of PET microplastics in a microbial fuel cell-oriented anaerobic environment using a microbial coculture with concomitant electricity recovery.

## CONCLUSION

This study has provided an insight on the effects of different PET pre-treatment techniques on PET biodegradation. Biodegradation was observed in all the MFCs with pre-treated PET microplastics of which the UV-treated PET microplastic showed the highest and statistically significant percentage weight loss of 29.2% (18 mg out of 60 mg used) in 40 days. This study highlights the use of UV pre-treatment in enhancing the improved biodegradation of PET microplastics in a microbial fuel cell-oriented anaerobic environment using the microbial coculture and bioenergy recovery.

## REFERENCES

- Kalathil, S., Miller, M. and Reisner, E. (2022). Microbial Fermentation of Polyethylene Terephthalate (PET) Plastic Waste for the Production of Chemicals or Electricity. *Angewandte Chemie* 61(45), p.e202211057. doi:https://doi.org/10.1002/anie.202211057
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- Wang, S., Hadji-Thomas, A., Adekunle, A. and Raghavan, V. (2024). The exploitation of bio-electrochemical system and microplastics removal: Possibilities and perspectives. https://doi.org/10.1016/j.scitotenv.2024.172737. Available at: https://doi.org/10.1016/j.scitotenv.2024.172737.