Advancing Sustainable Bioethanol Production from Organic Waste by Integrating Life Cycle Modeling

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Abstract

Introduction: The study aims to assess the environmental and economic impacts associated with bioethanol production from the Organic Fraction of Municipal Solid Waste (OFMSW). This study employs a life cycle assessment (LCA) model technique to comprehensively assess the several stages and methods of bioethanol manufacturing from OFMSW. The aim is to gain insights into the sustainability and viability of this bioethanol production method and provide insights that can support the design and establishment of a bioethanol production plant. The city of Lahore generates around 71,000 kg of OFMSW each year, but there is no facility to convert this waste into bioethanol.

Materials and Methods: An attributional LCA was performed to conduct this life cycle impact assessment using the ReCiPe (H) model. It was determined that approximately 154 kg of bioethanol can be produced from every 1 ton of organic waste. Based on the functional unit (1 ton), the findings show that bioethanol synthesis from the mixed waste of organic sources is more environmentally sustainable than current landfilling methods.

Results and Discussions: It has lower impacts on climate change 3.05E-05 kg CO_2 eq, photochemical ozone formation is 132 kg NOx eq, human toxicity 13.6 kg 1,4 DB eq, eutrophication potential, ozone depletion potential, and acidification potential is 10.9 kg P eq, 0.0111 kg CFC-11 eq, -5.39E-03 kg SO_2 eq, respectively. Scenario modelling was carried out to evaluate the use of photovoltaic solar cells for electricity supply. The results revealed a significant decrease in the generation of fine particulate matter, reducing it from 67.8 kg to 0.766 kg PM2.5 equivalent, compared to conventional grid electricity. Hotspot identification was conducted to determine the specific impact categories affected. The economic analysis revealed that the potential to generate bioethanol is $528,329.631 in annual revenue.

Conclusion: Using bioethanol made from OFMSW as an alternative fuel is both environmentally and economically viable. It also helps to decrease landfill waste. This strategy aligns with the values of the circular economy and contributes to achieving the most famous United Nations Sustainable Development Goals.

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