Sustainable Energy Authority of Ireland

National Energy Research, Development & Demonstration Funding Programme

FINAL REPORT TEMPLATE

SECTION 1: PROJECT DETAILS – FOR PUBLICATION

Project Title	ADED: Integration of anaerobic digestion (AD) and electrodialysis (ED) for methane yield promotion and ammonium in-situ recovery
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	Name	**Organisation**
Project Partner(s)		
Collaborators		

Project Summary (max 500 words)
In its landmark Climate Action and Low Carbon Development (Amendment) Bill 2021, Ireland has set up its targets of net-zero emissions by 2050 and 51% reductions in emissions by 2030. Anaerobic digestion (AD), which converts organic matter in organic wastes (animal manure, agricultural by-products, organic wastes, etc.) to biogas, provides a clean route to produce renewable bioenergy, sustainably manage organic wastes and reduce greenhouse gas emissions, thus playing a critical role in the sustainable and climate-neutral bioeconomy. Adoption and application of AD in Ireland can be improved by addressing two challenges: one is methane production inhibition by high ammonium (NH_4^+) concentrations and the other is digestate disposal. This project aimed to develop a novel AD technology for a high methane production efficiency by in-situ NH_4^+ recovery through electrodialysis technology (ED). The newly developed technology, which integrates ED into AD, was named as ADED. With four work packages, we investigated the feasibility of ADED technology for in-situ recovery of NH_4^+ and improvement of methane yields and carried out life cycle impact assessment. Two different influent NH_4^+-N concentrations were investigated, 5,000 mg/L and 10,000 mg/L. Compared to the control AD reactor (conventional AD), ADED promoted CH_4 production. When the influent NH_4^+-N was 5,000 mg/L, the CH_4 yield of the ADED was enhanced by 1.43 times compared to conventional AD. When the influent NH_4^+-N was 10,000 mg/L, the ADED reactor showed a high CH_4 production rate, but the control reactor was not stable and failed. Life cycle impact assessment results revealed that ADED technology would offer a more

environmentally friendly alternative to conventional AD. All these results indicate that ADED technology has a potential to control NH_4^+ inhibition in the AD process.

Keywords (min 3 and max 10)	Ammonium recovery; anaerobic digestion; bioenergy; carbon-neutral economy; electrodialysis; life cycle assessment; methane;

NB – Both Section 1 and Section 2 of this Final Report will be made publicly available in a Final Technical Report uploaded online to the National Energy Research Database.

In the following Section, please provide a clear overview of your project, including details of the key findings, outcomes and recommendations. The section headings below are provided as a guide, please update or add to these as best suits your project.

By submitting this project report to SEAI, you confirm you are happy for Section 1 and Section 2 of this report to be made publicly available. If you wish to request edits to this section in advance of publication, please contact SEAI at EnergyResearch@seai.ie.

SECTION 2: FINAL TECHNICAL REPORT – FOR PUBLICATION (max 10 pages)

2.1 Executive Summary

This project developed a novel approach to enhance anaerobic digestion (AD) performance for biowastes using an electrodialysis-integrated AD (ADED) technology. The ADED technology successfully mitigates ammonia inhibition, a common issue in AD processes, especially when producing biogas from high-ammonia substrates. By integrating ED with AD, the ADED system can effectively reduce NH_4^+-N concentrations in the digesters and improves methane yields. In this study, the digesters were operated under varying NH_4^+-N concentrations and the results demonstrated the ADED's capability to maintain NH_4^+ levels below 2,000 mg/L with competitive energy consumption and significantly higher methane yields compared to conventional AD reactors. The life cycle impact assessment results indicate that ADED would be an environmentally sustainable alternative, and particularly beneficial in managing high ammonia concentration wastes. This technology not only can enhance methane yields but also recover valuable nutrients, positioning it as a promising solution for sustainable waste management and bioenergy production.

2.2 Introduction to Project

The ADED project was a pioneering research initiative undertaken by the University of Galway. This project, set within the context of Ireland's ambitious climate targets and the growing global demand for sustainable energy solutions, aimed to produce bioenergy from organic wastes with simultaneous recovery of organic fertilisers.

Anaerobic digestion (AD) is a well-established process for converting organic waste materials into biogas, a renewable energy source. However, one of the main challenges in AD is the inhibition of methane production due to high concentrations of NH_4^+. This project introduced electrodialysis (ED) as a novel solution to this challenge. By integrating ED into the AD process, the project could enhance methane yields due to reduced NH_4^+ inhibition and recover ammonium efficiently in-situ.

2.3 Project Objectives

The ADED project's primary aim was to develop a novel technology that can update the current AD technology with a higher methane yield and NH_4^+ recovery. The specific research objectives of this project were:

1. Establishing the proposed ADED system in a laboratory setting.
2. Investigating the efficiency of the ADED process.
3. Conducting a techno-economic analysis of the system.

2.4 Summary of Key Findings/Outcomes

- **Innovation 1: Electrodialysis integration into AD (ADED) in-situ efficiently recovered NH_4^+ from digestate.**

The experimental results demonstrate that ED is a viable option for integration with AD. It effectively recovered NH_4^+ from digestate. This ADED technology would be a novel approach for in-situ recovery of NH_4^+ from digestate.

- **Innovation 2: ADED promoted methane yields by releasing NH_4^+ inhibition.**

  Compared to the control AD reactor, which was operated in a conventional mode, ADED promoted CH_4 production. When the influent NH_4^+-N was 5,000 mg/L, the CH_4 yield of the ADED was enhanced by 1.43 times compared to conventional AD. When the influent NH_4^+-N was 10,000 mg/L, the ADED reactor showed a high CH_4 production rate in comparison with the control reactor, which was not stable and failed.

- **Innovation 3: ADED technology can offer a more environmentally friendly alternative to conventional AD.**

  Life cycle impact assessment results demonstrate that ADED technology offers a more environmentally friendly option to the conventional AD by notably reducing the global warming potential, acidification potential, fossil fuel depletion, and eutrophication potential, particularly in high ammonia concentrations.

2.5 Project Impact

Impact on Irish Energy Sector & Policy Alignment:
The ADED project, an innovative integration of AD and ED, directly contributes to the Irish Energy Sector's transition towards a more sustainable and carbon-neutral economy. By enhancing the methane yield and enabling efficient ammonium recovery, this project aligns with Ireland's Climate Action and Low Carbon Development (Amendment) Bill 2021. It supports national goals of net-zero emissions by 2050 and a 51% reduction in emissions by 2030. Furthermore, it resonates with SEAI's remit, fostering biogas production efficiency and advancing renewable energy sectors within Ireland, which benefits the energy security of Ireland.

Societal Impact:
The approach of this project offers a dual advantage – sustainable management of organic wastes and the generation of renewable bioenergy. This directly benefits communities by providing a clean energy source and addressing waste management challenges. Additionally, by recovering ammonium as fertilizer, this project contributes to organic farming, enhancing local food production and reducing dependency on imported chemical fertilizers.

Economic Impact:
The economic value of this project lies in its potential to increase the profitability of the biogas industry. By improving methane yields and digesters' loading rates, ADED technology promises higher energy outputs from the same input materials. This efficiency gain translates into cost savings and increased competitiveness for renewable energy producers. The by-product, ammonium, as a marketable fertilizer, adds an additional revenue stream, enhancing the overall economic viability of the AD process.

Technological Impact:
This project represents a significant advancement in AD technology. By addressing the challenge of methane production inhibition due to high ammonium concentration, the output of this project provides a new approach for the broader application of AD technology, especially for high-nitrogen waste streams. The integration of AD and ED is a novel approach, demonstrating a feasible strategy for enhancing bioenergy production while simultaneously recovering valuable resources.

Wider Contextual Value:
In the global context, this project exemplifies a model for sustainable waste management and energy production. It contributes to international efforts in combating climate change by providing a replicable, scalable solution for renewable energy generation. The project also aids in resource recovery, aligning with global sustainable development goals and circular economy principles.

2.6 Recommendations

The results of the ADED project clearly indicate that this technology can effectively alleviate ammonia inhibition, especially for high-ammonia nitrogen wastewater, such as dairy wastewater and slaughterhouse wastes. Typically, these wastewaters and wastes are challenging to AD process.

2.7 Conclusions and Next Steps

This project investigated the feasibility of ADED technology for in-situ recovery of NH_4^+ and improvement of the methane yield of AD systems. With NH_4^+ recovery by ED, the methane yield was enhanced, particularly when the digestate had a high NH_4^+ concentration. LCIA reveals that ADED technology would offer a more environmentally friendly alternative to conventional AD. All these results show that ADED technology has a great potential to be used.

As this study was in the proof-of concept stage, the scaling-up of this research should be carried out in future.