INTRODUCTION TO RESEARCH

PROBLEM DESCRIPTION

Ammonia (NH₃) is world’s second most produced chemical and is a vital resource for protein production. NH₃ becomes present in residual (waste) water streams, for example after protein degradation by organisms, and is considered a pollutant for aqueous environments, because it potentially leads to algae blooming.

To this extend, NH₃ must be removed from residual water streams, before the water is discharged. Current methods applied in waste water treatment plants (WWTP), consume significant amount of energy: aeration (to facilitate (de)nitrification) accounts for approximately 50-70% of the total energy usage of a WWTP.¹

PARADIGM SHIFT

When the NH₃ can be recovered as fuel from residual water stream, energy can be produced in stead of used in order to remove NH₃. This might lead to a paradigm shift: from pollutant to power.

¹Environmental Dynamics International (2011). Ammonia (NH₃): The world’s second most produced chemical and a vital resource for protein production. How can we make use of this ammonia to produce energy? IWA Publishing.

SOFC

A Solid Oxide Fuel Cell (SOFC) is a specific type of fuel, made of solid ceramic materials. In a SOFC, H₂ is oxidized by O₂ resulting in a current of electrons, which can be utilized as electrical energy. Additionally, the residual released energy can partially be utilized as thermal energy.

The electrical efficiency of a SOFC is 50%, whereas the total energy efficiency can reach up to 85-90%, in case of thermal energy utilization.²

Because a SOFC operates at temperatures of T = 600 – 800 °C, NH₃ can be cracked internally into H₂, making it possible to use NH₃ directly as a fuel.


NH₃ IN SOFC

Electrical energy production

Cathode reaction

O₂ reduction: \( \frac{1}{2} \text{O}_2 + 2e^- \rightarrow \text{O}^{2-} \)

Anode reactions

NH₃ cracking: \( \text{NH}_3 \rightarrow \frac{1}{2} \text{N}_2 + \frac{3}{2} \text{H}_2 \)

Complete NH₃ cracking at T > 450 °C. In the presence of a nickel catalyst

H₂ oxidation: \( \text{H}_2 + \frac{1}{2} \text{O}_2 \rightarrow \text{H}_2\text{O} + 2e^- \)

Overall reaction

NH₃ oxidation: \( \text{NH}_3 + \frac{3}{4} \text{O}_2 \rightarrow \frac{3}{2} \text{H}_2\text{O} + \frac{1}{2} \text{N}_2 \)

Available elec. energy: 3.7 kWh/kg-NH₃

N2kWh RESEARCH

RESEARCH PLAN

N2kWh RESEARCH

RESEARCH STEPS

Research Track A: Selection of most suitable technique to concentrate NH₃

Research Track B: Selection of most suitable technique to produce gaseous NH₃

Research Track C: Development of a mass and energy balance tool, in order to evaluate various scenarios

Research Track E: Implementation of the system and determine the required pre-treatment for various residual water streams

RESEARCH OBJECTIVE

Development of an energy producing system to remove NH₃ from high N, low C residual (waste) water streams using a SOFC: the energy that is required to produce the fuel should be lower than the energy produced from the fuel.