A Preliminary Life Cycle Assessment of the Pilot-Scale Staged Anaerobic Fluidized Bed-Membrane Bioreactor (SAF-MBR) System

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Introduction

Currently in the United States, aerobic wastewater treatment utilizes about 3-4% of the nation's total energy usage[1]. Both the aeration for secondary treatment and the transport and disposal of biosolids are major constituents of this energy-intensive process. Researchers have recently begun looking into anaerobic treatment as a replacement since it produces less biosolids and converts organic material into methane gas which can then be used as a renewable energy source[2]. Researchers at Stanford University have constructed a pilot-scale version of the Staged Anaerobic Fluidized Bed-Membrane Bioreactor (SAF-MBR), and it has been operational for about a year. However, there lacks a comprehensive evaluation of the emissions associated with the SAF-MBR, and whether it could produce a net-positive energy balance. **Therefore, a preliminary life cycle assessment was conducted for the SAF-MBR to evaluate the overall environmental impacts throughout its construction and use phase.**

Methods

- A life cycle assessment (LCA) is a compilation and evaluation of a product and assess the environmental impacts throughout its life cycle
- Figure 1 shows the system boundary for the LCA and identifies the inputs, outputs, and processes
- Functional unit of 1 m^3 of treated wastewater used to standardize the components and data from the one-year operational period
- Theoretical sludge handling was incorporated to simulate a full-scale wastewater treatment process
    - 5 g of polymer per kg of VSS for thickening and dewatering
    - Assumed landfilling of dry solids
- Theoretical methane production was taken from the primary COD and soluble COD removal data
- Components were placed in the LCA Software *SimaPro8* and environmental impacts were recorded

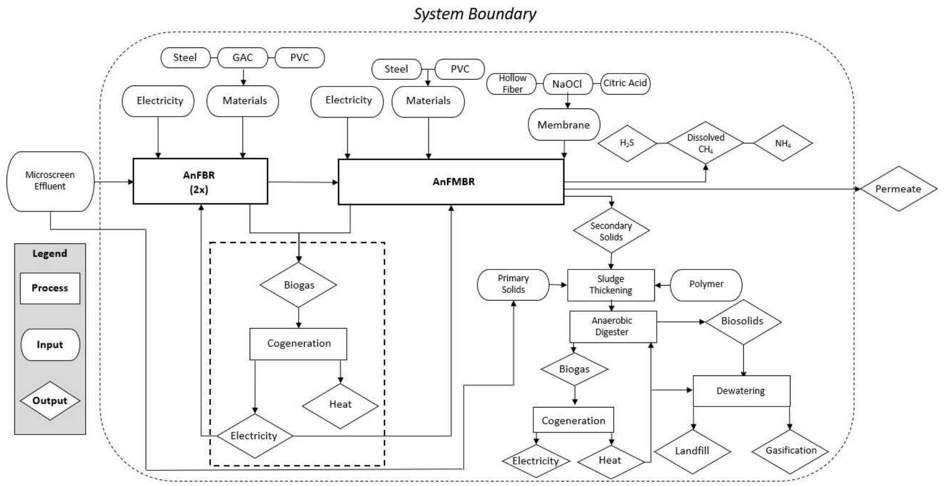

Figure 1. System Boundary for scaled-up SAF-MBR system

Scenarios

Scenario 1: One-year operational period based on data provided by CR2C. Only solid waste disposal was investigated for the LCA and not SAF-MBR disposal.

Scenario 2: Forty-year operational period with construction emission ≅ 0. Membrane replacement after 5 years and increased membrane cleaning in the years prior to replacement.

Scenario 3: Forty-year operational period with the inclusion of a methane air stripper with 99% dissolved methane efficiency. Increased usage of bleach for air stripper cleaning

Results

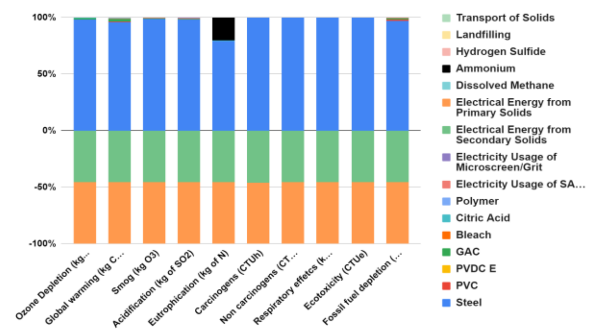

Figure 2a: One-year impact category emissions as a percentage of inputs

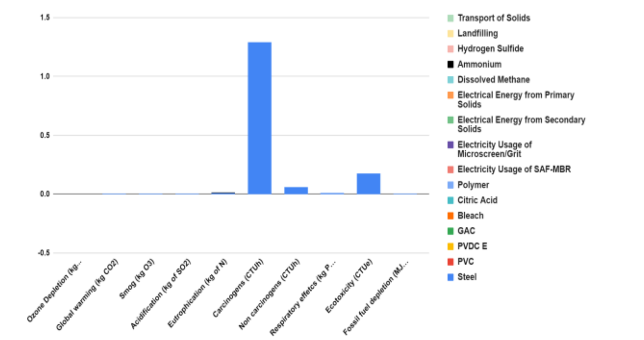

Figure 2b: One-year normalization impact category emissions

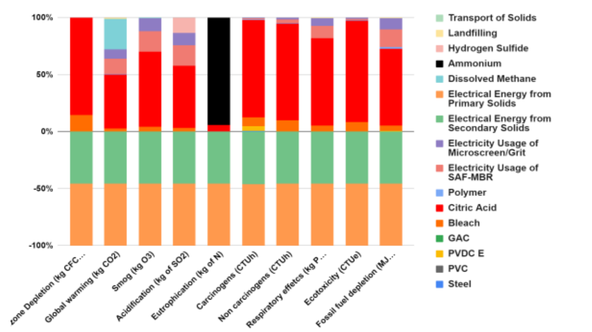

Figure 3a: Forty-year impact category emissions as a percentage of inputs

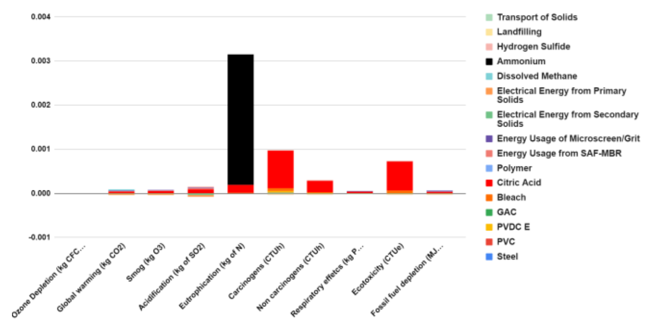

Figure 3b: Forty-year normalization impact category emissions

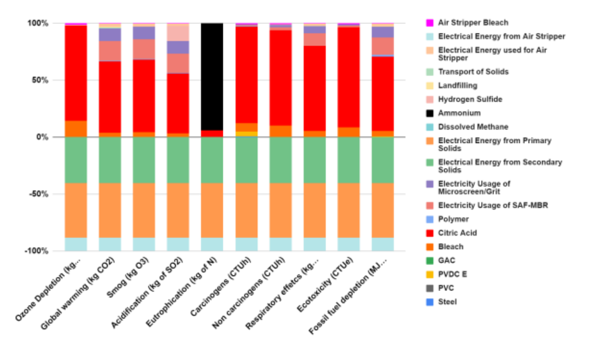

Figure 4a: Forty-year with air stripper impact category emissions as a percentage of inputs

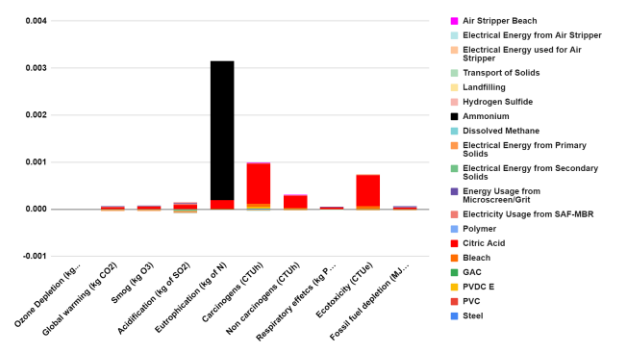

Figure 4b: Forty-year with air stripper normalization impact category emissions

Major Findings and Future Work

- Inclusion of air stripper decreased the greenhouse gas emissions by about 55%
- Net-positive energy balance through methane production from the SAF-MBR
- Energy production could mitigate the energy usage emissions
- Ammonium proved to be more detrimental than dissolved methane
- Citric acid utilized for membrane cleaning has large emissions associated with it

- Adding denitrification as a downstream step to decrease ammonium in effluent as a scenario
- Finding replacements to citric acid for membrane cleaning
- Conducting sensitivity analysis for other scenarios to explore the most environmentally friendly combination
- Using standard deviation of CR2C data to create emission range and error
- Using past literature on aerobic treatment to draw comparisons to anaerobic treatment

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