NC STATE UNIVERSITY
Department of Chemical and Biomolecular Engineering

Analysis of Emerging Wastewater Management Systems

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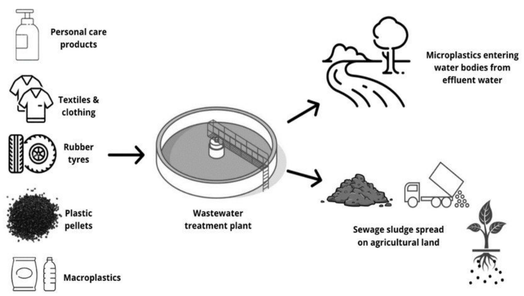
AECOM

Project Overview

- Municipal wastewater treatment plants produce sludge and biosolids which have been historically land applied or landfilled.
- Current methods of sludge management do not effectively address urbanization trends and concerns over emerging contaminants (VOCs, PFAS, and microplastics).
- Costs for beneficial use and disposal are increasing.

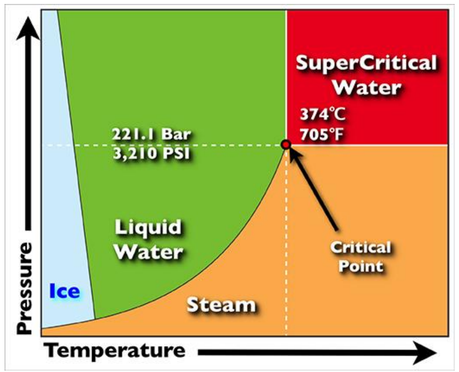


Objective: This project involves comparing two sludge processing technologies, drying/gasification and supercritical water oxidation (SWCO), at a processing capacity of 25 dry tons per day.

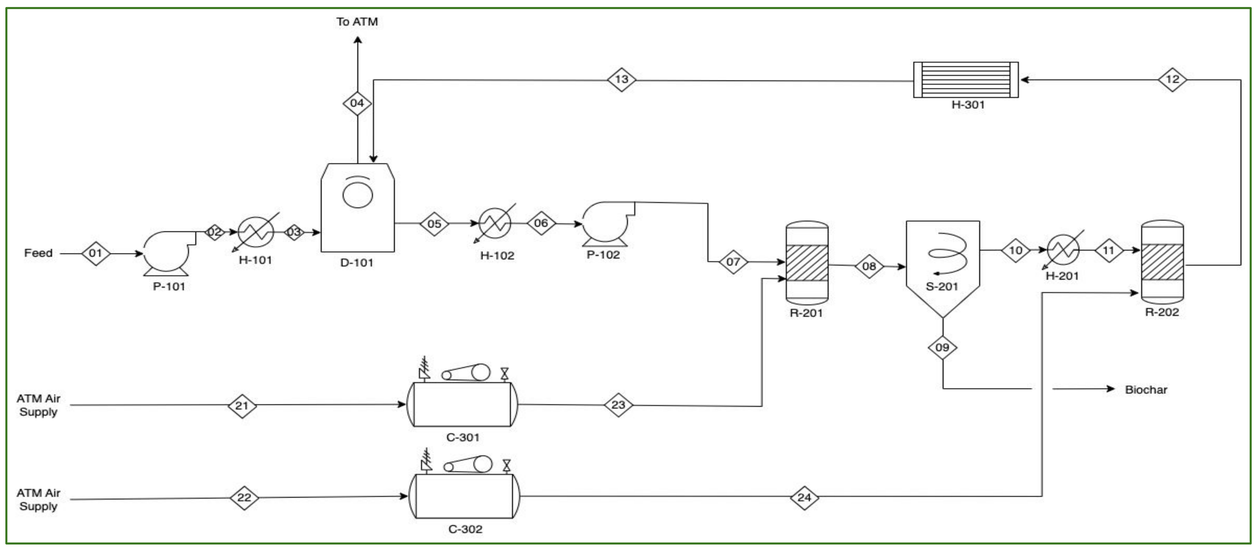
Technical Background

- **Gasification** is a thermal decomposition process that produces synthesis gas (syngas) and biochar
  - Operates at temperatures between 1,100 - 1,800 ℉
  - Involves incomplete oxidation
- **Supercritical Water Oxidation (SCWO)** induces a polarity shift of water which dissolves organic waste
  - Operates above supercritical point of water: 1202 ℉ and 3350.6 psia
  - Involves deposition of solids

Feed Mixture: 40:60 primary to secondary sludge ratio, and dewaterd to 20 wt% solids



Drying/Gasification

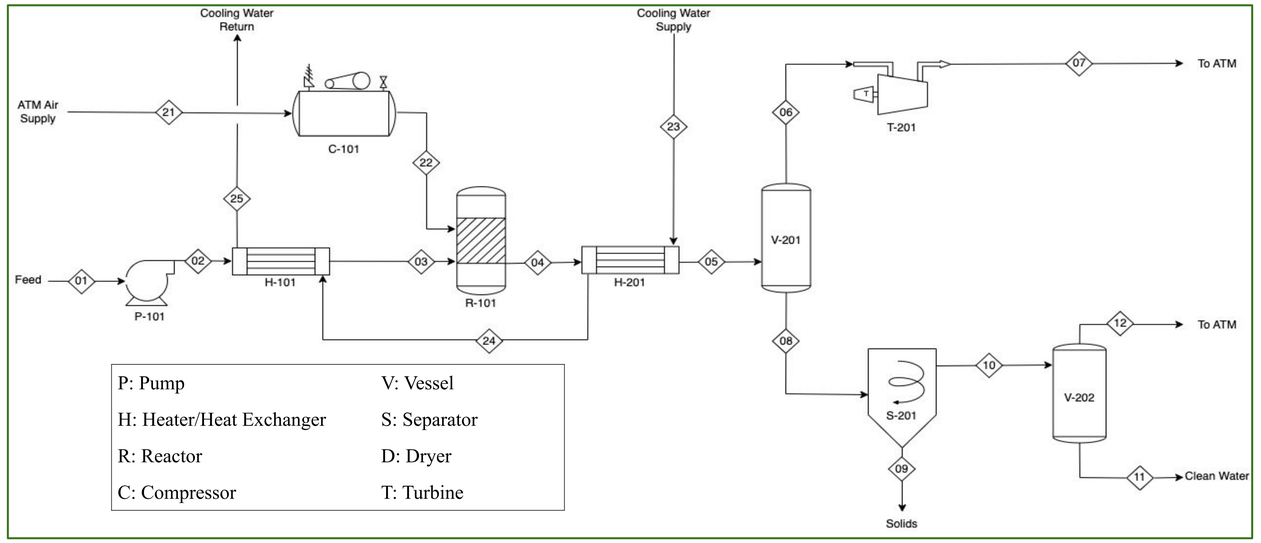


Process Design
- Reactor Type: Fluidized Bed (CSTR)
- Reactor Volume: 1,600.67 ft^3
- MOC: Refractory metal
- Air Requirement: 0.703 lbs air/ lb of feed
- Main Separation Method: Cyclone

Advantages/Disadvantages
- Requires feed preheating
- Agricultural benefits of biochar
- Energy recovery: accounts for >75% of energy required by dryer

Process Outputs
- 15,557 tons of syngas/year
- 1,350 tons of biochar/year

Supercritical Water Oxidation



Process Design
- Reactor Design: Tubular (PFR)
- Reactor Volume: 1,886.51 ft^3
- MOC: Inconel 625
- Air Requirement: 2.20 lbs air/ lb of feed
- Main Separation Method: Hydrocyclone

Advantages/Disadvantages
- Produces clean water
- Short residence time
- No preheating of feed required
- High energy input

Process Outputs
- 93,650 tons of clean water/year
- 31,100 tons of CO_2/year
- 105 tons of salts/year
- 212,200 kWh of electricity/year

Economic Analysis

	Gasification	SWCO
Fixed Capital Cost of Equipment	$52,079,610.00	$45,800,000
Cost of Operations Labor	$2,939,608.00	$779,896.00

Safety, Health, and Environment

- **Safety:** Extreme operating temperatures and pressures
  - Refractory metal and inconel are used to construct reactors
  - Increased insulation on heat exchangers
- **Health and Environment:** Released contaminants and pollution
  - 90-99% PFAS destruction
  - Thermal oxidation as fuel for gas treatment

Recommendations/Results

- SWCO is the most feasible option for large scale processing due to its shorter residence time, production of clean water, and electricity generation
- Limitations within project scope are largely due to the lack of data pertaining to reaction kinetics and particle size distribution (PSD)
- Studies to characterize sludge feed and determine kinetic behavior of small-scale reactor systems would be needed to further research

Image References: Milojevic, N., & Cydzik-Kwiatkowska, A. (2021). Agricultural use of sewage sludge as a threat of microplastic (MP) spread in the environment and the role of governance. Energies, 14, 6293. https://doi.org/10.3390/en14196293, Dembek, M., & Bocian, S. (2019). Pure water as a mobile phase in liquid chromatography techniques. TrAC Trends in Analytical Chemistry, 123, 115793. https://doi.org/10.1016/j.trac.2019.115793

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