Incorporating Septage Management into Life Cycle Cost Assessments of Technologies and Strategies for Rural Wastewater Infrastructure

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Introduction

- Septage is a high-strength waste stream, with COD ~20 g/L and may have contaminants including PFAS, pharmaceuticals, and EDCs
- More than 20% of U.S. households rely on decentralized wastewater systems, making effective septage management essential for long-term environmental and economic sustainability
- U.S. wastewater infrastructure receives a D+ ASCE rating, highlighting the need for more resilient and cost-effective wastewater management strategies, particularly in rural areas that rely on decentralized systems
- Rural regions such as the Alabama Black Belt face significant wastewater challenges due to clay-rich soils, low population density, and limited financial resources
- Life Cycle Assessment (LCA) and Life Cycle Cost Analysis (LCCA) are decision-making tools used to evaluate projects from beginning to end, focusing on environmental and economic costs

Problems

- Previous Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) studies primarily evaluate onsite and cluster wastewater treatment systems
- Existing analyses rarely integrate septage collection, transportation, treatment, and disposal/reuse within a single LCA-LCCA framework
- Disposal options are shrinking due to stricter regulations, permitting constraints, and reduced acceptance at municipal WWTPs, increasing costs for rural communities



Figure 1. Dependence on Septage Pumping in Decentralized Wastewater Systems
Source: allsepticandsewer.com

Objectives

- Identify feasible rural septage management pathways including collection, transportation, treatment, and final disposal/reuse
- Develop an integrated LCA-LCCA framework incorporating septage specific lifecycle costs and environmental impacts
- Compare the environmental and economic performance of alternative rural septage management pathways
- Develop sustainable, cost-effective decision-making framework for rural wastewater infrastructure

Methodology

- Review existing septage treatment and management pathways
- Identify feasible septage treatment and disposal pathways
- Develop LCI-LCCI Inventory from literature, regional datasets, and stakeholder surveys
- Establish the baseline assessment framework

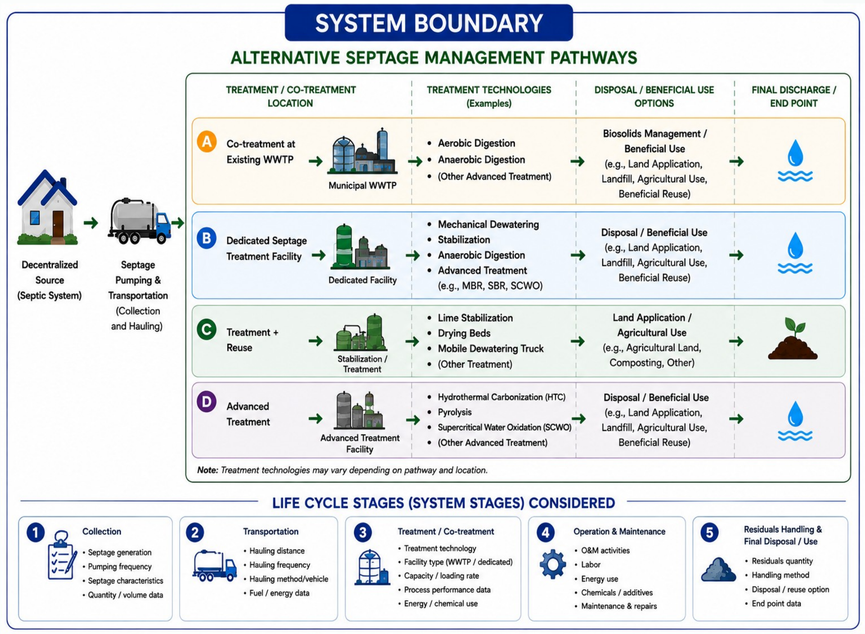


Figure 2. System Boundary

Results

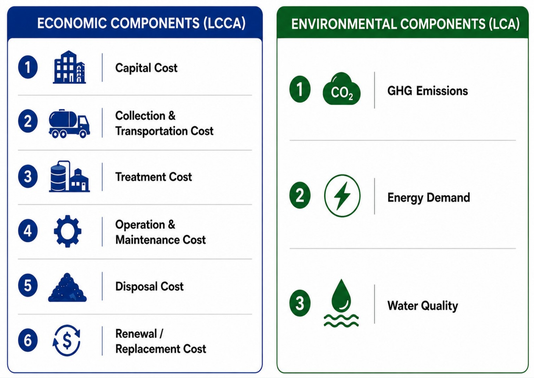


Figure 3. Key LCA & LCCA Components

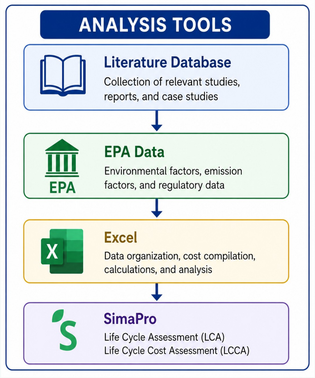


Figure 4. Analysis Tools

- Although more than 170 published lifecycle studies have evaluated wastewater and sludge management technologies, existing research primarily focuses on municipal systems, with limited integration of environmental and economic assessment for hauled septage management pathways

Results

- A comparative LCA of 5 sludge treatment technologies across 18 environmental impact categories found anaerobic digestion ranked best in 11 categories (61%), providing a benchmark for evaluating resource-recovery pathways in septage management
- Existing studies commonly assume fixed hauling distances rather than evaluating transportation as a lifecycle decision variable, leaving the effect of rural hauling distance on septage cost and environmental performance poorly quantified
- Analysis of the Alabama Black Belt identified substantial infrastructure challenges. Representative counties contained 10-20 rural population clusters, with ~ 20-40% requiring standalone decentralized systems, while estimated wastewater infrastructure improvement costs ranged from $2-14 million per county

Next Steps

- Continue stakeholder surveys (septage pumpers and WWTP operators) to finalize region-specific LCI/LCCI datasets
- Conduct integrated LCA-LCCA modeling of identified septage management pathways
- Evaluate hauling distance and treatment configuration through sensitivity and scenario analysis
- Perform sensitivity and uncertainty analyses to assess the robustness of LCA/LCCA results
- Validate the proposed framework using representative case studies from Alabama's Black Belt region

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