

Understanding Socio-technical Barriers to Decentralized Wastewater Management in the Rural Alabama's Black Belt

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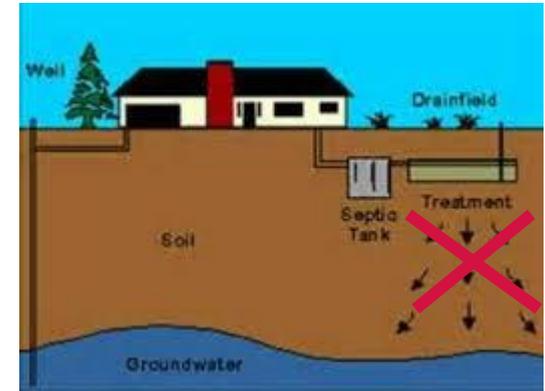
Alabama's Black Belt's Wastewater crisis

- What is Black Belt?
 - Named for its fertile **black soils**
 - Mostly **rural region** with small spread-out residential clusters and low population density
 - Home to many **underserved** communities
 - High **poverty** with average annual income of only \$28,873 (i.e., ~54% of national average)
 - Rich **clay soils** that shrink and swell with moisture, causing **low permeability**



Wastewater problems in Alabama's Black Belt

- Impermeable soils:
 - Do not accept water
 - Typical onsite wastewater systems (septic tanks and drainfields) do not work
- Only 3.33% of the land area in major 11 counties has access to municipal wastewater services¹
- Majority of households use straight pipes discharge, as effective onsite wastewater treatment is not affordable



1: (White & Jones, 2007)

Site visits: Straight pipes and drainfield failures



Regulatory constraints exacerbating wastewater challenges

- Existing ADPH* wastewater discharge option: **Subsurface infiltration** into ground → does not work with clay soils
- Discharge constraints by ADEM**
 - No wastewater **discharge to surface** (treated or untreated)
 - National Pollutant Discharge Elimination System (NPDES) permit is needed
 - Permitting individual homes not doable by ADEM



Source: UXWing (2021)

What do we do to meet Black Belt communities' wastewater needs?

* ADPH: Alabama Department of Public Health

** ADEM: Alabama Department of Environmental Management

Decentralized Wastewater

A potential solution

Customized decentralized wastewater models, including individual and clustered systems

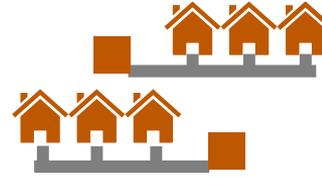
Individual Systems



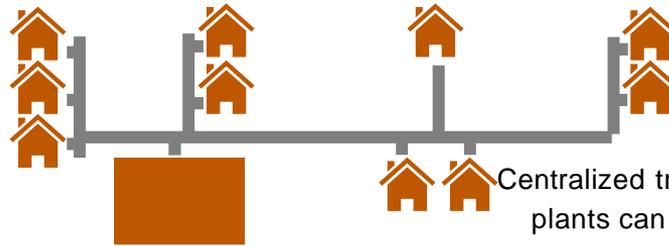
Individual decentralized wastewater treatment systems serve single homes

Clustered Systems

Decentralized wastewater clusters serve multiple households that share a treatment system



Centralized Wastewater Treatment



Centralized treatment plants can serve entire large cities



A combination of individual, clustered, and centralized wastewater systems

Efforts to address Black Belt's wastewater needs

- Implementation of **decentralized clustered** systems
 - Develop **cost-effective** wastewater management technologies (collection, treatment, disposal)
 - Understand **socio-technical challenges** for deploying these technologies
 - Identify long-term **responsible management entities** (e.g., public utility, private managing entity, county-based, multi-county coverage)
- Regulatory modifications (facilitating adequate permits)
- Financing options:
 - Capital investment
 - Operations, maintenance, and management

News Releases: [Headquarters](#) | [Water \(OW\)](#)

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EPA Announces Water Infrastructure Funding for States Through the Bipartisan Infrastructure Law, Calls for Prioritizing Underserved Communities

Source: EPA (2021)

Operation and Maintenance (O&M) of decentralized systems

- Improper management of **decentralized clustered** systems¹
 - Do not provide adequate **treatment level** to protect public health and environment
 - Concerns regarding performance and **reliability**

- Management of such rural decentralized systems is **complex**
 - Wide-spread **poverty** → Limited communities' financial capacity to pay for services
 - Low-population density → Limited number of **rate payers**
 - Impacts long-term **sustainability** of decentralized clustered systems



Source: OECD (2017)

1: (EPA, 2018)

Proper management of decentralized systems

- **Five-level** conceptual decentralized management framework¹
 - Management requirements vary based on treatment systems' complexity and environmental sensitivity
 - Range from programs with least management controls to higher management restrictions
- Need to identify long-term **responsible management entity (RME)*** to provide O&M
 - Major activities performed by RME
 - Management aspects and characteristics (e.g., type, scale, operational requirements)
 - Possible **socio-technical barriers** that may be faced by RMEs



Source: EPA (2003)

* RME: Legal organization with the technical, managerial, and financial capacity to provide O&M

1: (EPA, 2003)

Major activities¹ performed by RME

- Establish **system performance** and monitoring requirements
- Acquire and maintain **operating permits**
- Provide professional **O&M** and acquire required **licensing**
- Inspect **system compliance** status and submit compliance reports
- Define **service charge fees** that ensures financial sustainability
- Provide public education and engagement → **public acceptance**



1: (EPA, 2003, 2005)

Type and scale of RME

- Type^{1,2}
 - **Public** service providers, such municipal utilities (e.g., water, wastewater, electric power, natural gas, solid waste management)
 - **Private** agencies (e.g., electric cooperatives, community development corporations)
 - **Non-profit** corporations

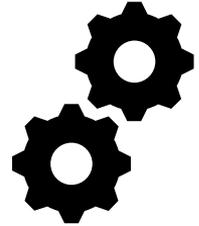
- Scale/jurisdiction¹
 - **Community**-level management (e.g., a small group of homes)
 - **County**-level management (e.g., several clusters within a county)
 - **Regional**-level management (e.g., several clusters across multiple counties)
 - **State**-level management (e.g., several clusters within a state)



1: (EPA, 2005)
2: (RMI, 2004)

System performance and operational requirements

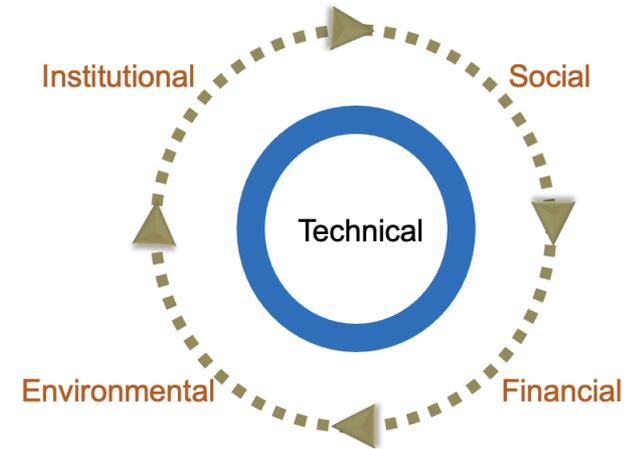
- System **size** (e.g., number of equivalent dwelling units)
- Technical **expertise** and skills (compliance to operating permits)
- **Remote monitoring** and control (operator efficiency and performance tracking)
- Customer **billing** and handling (e.g., link RME service fees with other bills)



1: (EPA, 2003, 2005)

Socio-technical barriers to effective decentralized management

- Prerequisite to identifying adequate RMEs
 - **Objective 1:** Identify **socio-technical barriers**
 - **Objective 2:** Empirically assess impacts of socio-technical barriers on **RMEs' consideration** to provide O&M services
- Highlight policy areas to overcome concerning barriers



What are the impacts of socio-technical barriers on the RMEs' consideration to provide O&M services to rural, decentralized clustered wastewater systems in the Black Belt?

Identification of socio-technical barriers^{1,2,3}

Dimension		Barrier
Technical	Technical expertise	Limited technical assistance/expertise
	Operators' turnover	Difficulty to retain skilled operators
Financial	Financial incentives	Limited financial incentives to manage new systems
	Public funds	Difficulty to obtain funds
	Financial capacity	Communities' limited capacity to pay for O&M services
	Operational cost	Unclear operational cost
Social/Environmental	Environmental awareness	Lack of awareness to consequences of failing systems
	Equity concerns	Concerns of not meeting communities' actual needs
Institutional	Regulatory/liability concerns	Inflexible regulatory codes and liability concerns
	Organizational structures	Lack of organizational structures

1: (EPA, 1997, 2003, 2005)

2: (RMI, 2004)

3: (Mitchell et al., 2008)

Data and methods

Data collection

- Survey questionnaire: 51 questions
 - Entity type (e.g., public, private)
 - Service provided (e.g., water, wastewater)
 - Consideration to provide O&M
 - Current operation of decentralized systems
 - Socio-technical barriers
- Random sampling and snowball sampling
- March – May 2022
- 53 complete responses from 16 states

Binomial logistic (BL) regression

- Dependent variable: **OM Consideration**
- Explanatory variables: Socio-technical barriers; entity- and service-related aspects

$$\ln \frac{p(Y=1)}{p(Y=0)} = \beta_0 + \sum_{i=1}^N X_i \beta_i$$

- Use **odd ratios** to interpret effects of predictors

$$\frac{p(Y=1)}{p(Y=0)} = e^{\beta_0} \prod_{i=1}^N (e^{\beta_i})^{X_i}$$

Regression results of socio-technical barriers ^a

Variable	Odd ratios	2.5%	97.5%	<i>p</i>
Independent variables: Socio-technical barriers				
<i>Operators' turnover</i>	0.0009	7.55 [10 ⁻⁷]	7.31 [10 ⁻²]	0.01**
<i>Financial capacity</i>	368.23	3.41	6.84 [10 ⁵]	0.048**
<i>Regulatory/liability concerns</i>	56.41	2.58	5.48 [10 ³]	0.03**
Control variables: Entity- and service-related aspects				
Entity type	0.004	2.29 [10 ⁻⁵]	9.05 [10 ⁻⁵]	0.006***
State as systems	73.97	2.67	3.61 [10 ⁴]	0.05*
Decentralized service operation	29.09	1.97	2.01 [10 ³]	0.04**

^a BL regression analysis – odd ratios at 95% CI; **p* < 0.1; ***p* < 0.05; ****p* < 0.01.

Model information: Null deviance = 66.51 on 52 degrees of freedom; AIC = 47.30; Number of Fisher Null deviance = 66.51 on 52 degrees of freedom; Residual deviance = r scoring iterations = 8; McFadden's *pseudo-R*² = 0.62.

Impacts of financial capacity on the likelihood to provide O&M

- Black Belt communities' **limited financial capacity** to pay for O&M services
- Respondents concerned by this financial barrier → Impacts RMEs' long-term financial sustainability
- **Federal and state policy** needs to address gaps in these systems' funding
- Funds to **subsidize** the O&M of decentralized clustered wastewater systems
- Currently, most federal wastewater funding programs provide **capital costs** to communities, **not O&M costs**

Impacts of regulatory concerns on the likelihood to provide O&M

- **Surface discharge** of treated effluent is still not permitted
- Ongoing efforts¹ to update such regulations in the Black Belt region
- Respondents may be concerned about their ability to obtain operating permits
- **Alabama's regulators** are encouraged to expedite the new onsite regulations regarding surface discharge of treated effluent
- Facilitate the attainment of required permits → Enable RMEs to provide O&M

1: (CARWW, 2021)

Implications

- Empirical **understanding** to socio-technical barriers' impacts on RMEs' consideration to provide O&M services
- Providing practical and **policy** recommendations to overcome concerning barriers
- RMEs are better enabled to provide adequate O&M services to decentralized systems
- Contributing to addressing wastewater challenges in **rural, underserved communities**

Paths forward

- Gathering additional **survey responses** from public and private entities
- Incorporate the full sample and expand our **BL regression** model (e.g., explore additional control variables)
- Develop practical and policy **recommendations** on how to best address the concerning socio-technical barriers



Please fill this survey

Paths forward: Efforts on Rural Decentralized Systems

- Management scale → How do we establish sustainable **regional** management?
- Financial viability → How do we pay for **O&M costs**?
- Regulatory environment → How do we align **regulatory agenda** with funding programs?
- Collaborations → How to improve **collaboration** and communication across institutional players?
- Intellectual properties → How to replace O&M skills and build **brain talent**?

Paths forward: Efforts on Rural Decentralized Systems

- Building trust → How to build **trust** across stakeholders and increase **community engagement**?
- Natural environment → How natural environment and physical infrastructures **interact**?
- Affordability → How to achieve more **affordable** water and sewer **rates**?
- Data availability → How to address limited **data** on onsite wastewater systems?
- Technology → What technologies to enable adequate **centralized** management?

Acknowledgement

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<https://worldprojects.columbia.edu/transforming-wastewater-infrastructure-united-states>



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