Biobot Analytics

The Effect of Septic Systems on Wastewater-Based Epidemiology

WHITE PAPER

Key Points

- **Households with septic systems are more economically advantaged than households on public sewers.** Septic users have higher median household income, higher educational attainment, and greater food security.
- Wastewater surveillance in rural areas likely oversamples economically disadvantaged populations. This is a desirable feature because economic stability is an important social determinant of health and because economically disadvantaged populations may be underrepresented in public health surveillance systems that rely on interactions with healthcare.
- People living in homes that use septic systems can still contribute to public wastewater when they use restrooms in public buildings, like workplaces, schools, restaurants, libraries, and shopping malls.
- **Septic systems need not be a barrier to wastewater surveillance programs nationwide.**

Introduction

Wastewater surveillance is a powerful tool for monitoring Covid-19, other infectious diseases, and substance use. This type of surveillance has the potential to improve health equity by providing population-level representation of everyone who contributes to a wastewater sample. Thus, wastewater surveillance can complement traditional public health surveillance systems, such as case counts and hospitalization rates, which rely on healthcare resourcing and access to healthcare.

For a wastewater surveillance program to be equitable, it should sample wastewater from sites that equitably represent the broader population, including an appropriate mix of rural and urban communities (Medina 2022). Like other public health services, wastewater surveillance is more resource-efficient in urban areas. Rural populations are generally less dense and served by smaller wastewater treatment facilities (CRS 2016), so wastewater surveillance programs must devote more resources to cover the same number of people, compared to urban areas. Thus, special attention is required to ensure that wastewater surveillance programs adequately cover rural communities (Keshaviah 2022).

Even when a community is included in a wastewater surveillance program, that community may not be monitored evenly. Many homes, especially in rural areas, are not connected to a public sewer system and instead use septic systems or other waste management systems. This raises the concern that wastewater collected from municipal wastewater treatment plants will not evenly cover a community's population because septic users are excluded (Holm 2022).

Here, we consider two hypotheses: first, that people who live in households with septic systems are not "covered" by wastewater surveillance programs; second, that the exclusion of people with septic systems introduces an undesirable bias into the results of wastewater surveillance.

Even if a house uses a septic system, its members can still contribute to public wastewater

Most pathogens and substance use biomarkers are excreted in stool and urine (Crank 2022, Santiago 2022, Daughton 2001), so any use of a restroom can potentially capture excreta from infected people. Even tooth-brushing or face washing might deposit saliva-

borne pathogens like SARS-CoV-2 into wastewater. Thus, anyone who uses restrooms in public buildings, such as workplaces, schools, restaurants, libraries, and shopping malls, can contribute to public wastewater, regardless of whether their home is attached to a public sewer.

It might seem unlikely that public restrooms are used for defecation, but there are multiple lines of evidence supporting frequent use of these spaces. First, wastewater surveillance in office spaces routinely provides sufficient fecal material for analysis (Olesen 2021). Second, the scientific literature on bowel habits suggests that many people may not be regular enough to reliably defecate only in their own homes. About half of people report that they "usually" defecate once per day, once per two days, or twice per day; the other half of people report less regular bowel habits (Heaton 1992, Rendtorff 1967). When individual defecations are recorded, about half of the intervals between defecations is 24 hours. The other half of intervals is broadly distributed, with intervals as short as 1 hour and as long as 48 hours about equally common. Thus, many defecations may occur at unpredictable times. Third, less rigorous surveys undertaken by laxative manufacturers and health websites indicate that substantial proportions of the population use restrooms in public buildings (Healthline 2022, MiraLAX 2022).

Some people might rarely or never use the restroom outside their own homes, but this need not be a barrier for wastewater surveillance programs. Like most public health surveillance systems, wastewater surveillance requires only a sample of all individuals. At least some septic users will contribute to public wastewater some of the time, so monitoring public wastewater does not completely exclude septic users.

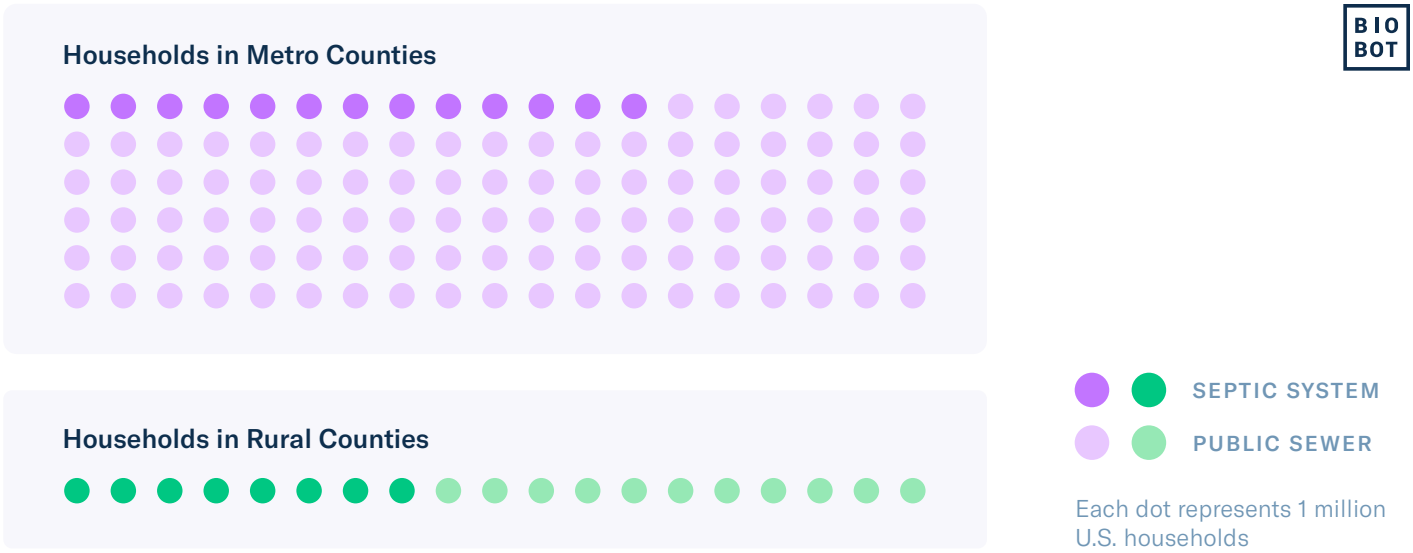
Although monitoring wastewater at treatment plants may be most convenient and cost-effective, further research could also address the possibility of specifically monitoring septage, the material removed from septic tanks that is often treated at wastewater treatment plants (US EPA 1994), or other wastewater treatment systems like lagoons (D'Aoust 2021).

Households in rural counties are less likely to be on public sewers

Even though people who live in homes not attached to public sewers can contribute some material to municipal wastewater, wastewater samples presumably skew toward people who live in households attached to public sewers. To characterize how this skew affects the representativeness of wastewater surveillance programs, we analyzed data from the American Household Survey (AHS), a nationally-representative, biennial survey of households living in houses, apartments, mobile homes, single rooms, or any other location that is occupied as separate living quarters. The survey, conducted by the US Census, includes information about households' sewage systems, income, and demographics (US Census 2021). The public AHS data indicates whether a household is in a rural or metro county and what US Census Division the household is in.

According to the 2019 AHS, 83% of US households dispose of wastewater using public sewers, 16% use septic systems, and <1% have a chemical toilet, outhouse, another type of sewage disposal system, or no sewage disposal system at all. These proportions vary by geographic region. For instance, in the division comprising Alabama, Kentucky, Mississippi, and Tennessee, 28% of households use septic systems. In New England, 26% of households use septic. By contrast, in the Mountain West, 12% of households use septic, and only 9% of households in the Pacific states do.

Nationwide, septic systems are more common among households in rural counties. Nearly half of households in rural counties are on septic systems, compared to about one-tenth of households in metro counties.



Rural households on septic are more economically advantaged than rural households on sewer

In general, rural areas in the US are more likely to be economically disadvantaged (USDA 2022, Hefflin 2011). For example, in the 2019 AHS, households in rural counties had a median household income of $47,000, compared to $63,000 for households in metro counties.

While rural households are more likely to have septic systems, and rural households are more likely to be economically disadvantaged, it does not follow that households with septic systems are economically disadvantaged. In fact, the opposite is the case when stratifying by metro status: within rural counties, septic households are more economically advantaged than sewered households. Within metro counties, the same pattern holds.

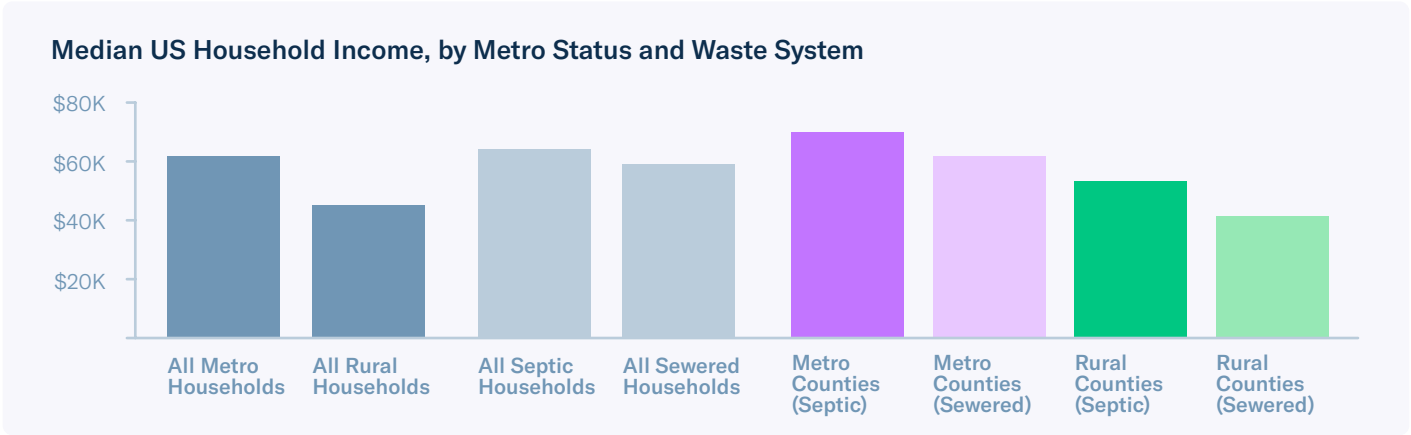
For example, in metro counties, median household incomes are:

- $70,000 among septic households
- $62,000 among sewered households

In rural counties, median household incomes are:

- $53,000 among rural septic households
- $42,000 among rural sewered households

The same pattern in incomes by metro status and sewer system holds across all 9 Census divisions, except for the Pacific region, where too few septic households were surveyed to yield a statistically significant result.



Similar patterns in economic advantage by household type were also recapitulated in education and food security.

	HOUSEHOLDS IN METRO COUNTIES			HOUSEHOLDS IN RURAL COUNTIES		
	Any Waste System	Sewered	Septic	Any Waste System	Sewered	Septic
Number of households	105 million	92 million	13 million	19 million	11 million	8 million
Median household income (nearest thousand)	$63,000	$62,000	$70,000	$47,000	$42,000	$53,000
Householder* has a Bachelor's degree or higher	38%	39%	32%	22%	20%	24%
Household is food secure	87%	86%	91%	86	83%	91%
Householder* is non-Hispanic white	63%	59%	88%	82%	77%	88%

*The dwelling unit's primary owner or renter

Conclusion: Septic systems are not the main barrier to improving rural wastewater surveillance

These results suggest that undersampling septic users desirably focuses wastewater surveillance toward economically disadvantaged populations, which are at greater risk of poor health outcomes and are likely underrepresented in traditional public health surveillance systems that rely on interactions with healthcare (Miller 2021, Ali 2021).

This analysis has important limitations. First, the analysis is county-level because the AHS classifies households as metropolitan on a county-by-county basis. The key result, that septic users are more economically advantaged than sewer users, holds nationwide and also within US Census divisions. There is, however, no guarantee that this broad pattern is recapitulated in every community. Second, the survey did not include information to address other social determinants of health, such as healthcare access, social context, and air and water quality (US CDC 2021, Braveman 2014). Third, these results may not be applicable outside the United States. In particular, wastewater surveillance faces very different challenges among populations that truly have no access to wastewater treatment (Adhikari 2022).

Wastewater surveillance in rural areas faces important challenges. For example, the increased per capita cost of wastewater surveillance in rural areas, although not a limitation unique to wastewater surveillance, does mean

that wastewater surveillance will be more resource-efficient in urban areas (US HHS 2018). If sampling at wastewater treatment facilities is not possible, or would cover too few households to be resource-efficient, then wastewater sampling at commonly-used public buildings, like workplaces, schools, libraries, shopping malls, or churches may provide another option for monitoring a broad slice of the community.

In closing, we note that Maine, a state with a very high proportion of households on septic (US Census 1990), currently has an expansive Covid-19 wastewater surveillance program (Maine CDC 2022). The success of Maine's program, coupled with the analytical findings, suggest that septic systems need not be a barrier to wastewater surveillance programs nationwide.

Prepared By Scott W. Olesen, PhD Cristin Young, PhD Claire Duvallet, PhD

METHODOLOGY

For these analyses, we used the public use file (PUF) from the 2019 AHS (US Census 2021), which contains information on more than 63,000 households. The 2019 AHS included households in 35 core-based statistical areas (CBSAs) and households not in any CBSA ("Standards" 2000). For simplicity and clarity, we refer to households in a CBSA as "metro" and those not in a CBSA as "rural," although this conflates the distinct concepts of metropolitan and urban (Ratcliffe 2016).

AHS measures household food security using 10 questions that address, for example, feeling hunger and the ability to afford food. AHS aggregates these results into a food security score of high, marginal, low, or very low. We use "food secure" to refer to households with high food security.

Key results were recapitulated in regression analyses (linear regressions predicting household income from waste system and controlling for Census division, metro status, householder education, and household race; logistic regressions predicting waste system from income and householder education, controlling for Census division, metro status, and householder race; results not shown).

Results were computed, accounting for the complex survey design, using the survey and srvyr packages in R (Lumley 2022, Freedman Ellis 2022, R Core Team 2022). Code to reproduce these results is available at:

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