



Child Health Outcomes Associated With Failing Wastewater Management in the Black Belt Region of Alabama

Claudette Poole, MSPH, MD
*University of Alabama at Birmingham
School of Medicine*

Sen Bisakha, PhD
*University of Alabama at Birmingham
School of Public Health*

Amy Hutson Chatham, PhD
*University of Alabama at Birmingham
School of Public Health*

Jillur Rahim, PhD
*University of Alabama at Birmingham
School of Public Health*

Gabriela Oates, PhD
*University of Alabama at Birmingham
School of Medicine*

Abstract Poor rural communities, such as those in the Alabama Black Belt region, face major challenges in managing household wastewater. Our study examined if children in the Alabama Black Belt experience higher rates of health conditions associated with environmental exposure to fecal pathogens. A retrospective cohort study using Alabama Medicaid administrative claims data (2012–2020) compared the prevalence of selected health conditions between rural Alabama counties within and outside the Black Belt region, which is known for its widespread wastewater failures. Children in the Black Belt region had a significantly higher prevalence of anemia (1.6% versus 0.6%, $p = .006$), sepsis (0.6% versus 0.2%, $p < .0001$), and asthma (15.6% versus 10.3%, $p < .0001$), but no significant difference was observed in rates of gastroenteritis, malnutrition, or pneumonia.

Inadequate wastewater management in the Alabama Black Belt might contribute to higher rates of asthma, sepsis, and anemia in children. Our study findings suggest that gastrointestinal disease outcomes alone might be insufficient to evaluate the detrimental health effect of wastewater failures, especially within high-income countries such as the U.S.

Keywords: wastewater management, drinking water, rural child health, Alabama Black Belt region, onsite wastewater systems, health equity

Introduction

Access to safe water and sanitation is essential to public health. Globally, unsafe drinking water and poor sanitation contribute in major ways to adverse child health outcomes, including infant mortality, mortality in children under 5 years of age, malnutrition, stunted growth, and poor school performance

(Headey & Palloni, 2019; Prüss-Ustün et al., 2019; Vally et al., 2019). The WHO/UNICEF Joint Monitoring Program (JMP) for Water Supply, Sanitation, and Hygiene has reported on access to safe drinking water worldwide since 1990. JMP data show that low- and middle-income countries still face substantial access gaps, with approximately 46.6% of the

population remaining underserved (United Nations, n.d.). Unsafe drinking water has been identified as the cause of approximately 36.0% of the 1.4 million annual diarrheal deaths globally (Prüss-Ustün et al., 2019). Lack of access to safe water and sanitation is closely linked to poverty (Capone et al., 2020; Gasteyer & Vaswani, 2004; Meehan et al., 2020), and addressing water and sanitation access is a key goal of the sustainable development efforts of the World Health Organization (WHO).

Access to safe water and sanitation often is underrecognized as a public health concern in high-income countries such as the U.S., driven by the widespread belief in universal access. Official estimates are that 99.2% of the U.S. population has continuous access to potable water, and 88.9% of people in the U.S. have access to sanitation services (Our World in Data, 2023). Yet JMP national-scale data and data collection methods mask local-scale inequities in high-income countries, especially in rural, low-income, and minority communities.

Historically in the U.S., the federal government invested substantially in water and wastewater infrastructure, eradicating waterborne diseases such as cholera that were the leading cause of death a century ago. This investment in infrastructure has not been sustained, and communities that were excluded initially have limited means to address their unmet community needs. It is estimated that at least 2 million people in the U.S. do not have access to water and sanitation infrastructure, which disproportionately affects poor rural communities (Gasteyer & Vaswani,

FIGURE 1

Alabama County Map Indicating Black Belt and Comparator Counties



2004; Maxcy-Brown et al., 2021; Mueller & Gasteyer, 2021; Roller, et al., 2019).

There have been limited efforts to quantify these access gaps and measure the impact on public health nationally. Recent work of Dig Deep and the U.S. Water Alliance has made substantial strides in defining the issue by

analyzing quantitative data available at the national level (Roller et al., 2019). Beyond waterborne disease outbreak data collected by the Centers for Disease Control and Prevention (CDC), few studies have been conducted to define and describe the public health effect of contaminated water. Collier

et al. (2021) sought to determine the burden of infectious waterborne disease in the U.S., utilizing surveillance and administrative data from 2000 to 2015, including both gastroenteritis and respiratory pathogens. They estimated that 7.15 million waterborne illnesses occur annually, resulting in 601,000 emergency department visits, 118,000 hospitalizations, and 6,630 deaths.

Lee et al. (2023) published a systematic review to quantify the disease burden associated with contaminated drinking water in high-income countries. They identified and analyzed 24 studies reporting estimates for gastrointestinal illness attributable to microbial contaminants, giving a population-weighted average burden of gastrointestinal illness risk attributed to drinking water of 3,529 annual cases per 100,000 people. They identified only 10 studies evaluating exposures beyond infectious agents; these limited studies had a primary focus on the cancer risk associated with chemical contaminants. The pooled population-weighted average of excess cancer cases attributable to drinking water across these 10 studies was 1.8 annual cancer cases per 100,000 people, which exceeds the WHO-recommended normative targets (Lee et al., 2023).

The Special Rapporteurs of the United Nations (independent human rights experts appointed by the Human Rights Council to monitor, report, and advise on specific thematic issues or country situations globally) specifically noted the plight of African American communities in rural southern Alabama in 2011 and 2018. These observations were made during their U.S. tours related to the human right to safe drinking water and sanitation in light of extreme poverty (Alston, 2018; de Albuquerque, 2013).

The Alabama Black Belt, a region named for the dark color of the soil, refers to an area of southern Alabama that is predominantly rural and has experienced decades of economic decline and outmigration (Wimberley, 2010; Winemiller, 2025). Throughout the region, limited centralized sewer treatment facilities serve small towns; however, most households require individual onsite wastewater systems. The high clay soil in the area causes regular septic systems to malfunction, necessitating the installation of prohibitively expensive engineered systems (He, Dougherty, Shaw, et al., 2011; He, Dougherty, Zellmer, & Martin,

TABLE 1

Characteristics of Selected Black Belt Counties and Comparator Counties in Alabama

Characteristic	Black Belt Counties (n = 9) Mean % (SD)	Comparator Counties (n = 5) Mean % (SD)	Mean Difference	
			95% CI	p-Value
Total population number (2020) ^a	130,668	207,254	—	—
African American population (2020) ^a	65.0 (±12.30)	18.3 (±11.90)	[31.80, 61.30]	.0001
Population living below the federal poverty limit (2020) ^a	24.3 (±4.34)	16.3 (±0.83)	[3.75, 12.44]	.0016
Children below the federal poverty limit (2020) ^a	36.5 (±6.75)	24.5 (±2.27)	[5.22, 19.00]	.0024
Rural–Urban Commuting Area (RUCA) codes score across all counties (2019) ^b	6.1 (±2.52)	4.8 (±1.64)	[-1.44, 4.07]	.3203
Households with at least one of four housing problems, such as overcrowding, high housing costs, lack of kitchen facilities, or lack of plumbing facilities (2019) ^c	15.8 (±3.23)	11.8 (±2.17)	[0.43, 7.53]	.0311
Life expectancy (years) (2019) ^c	69.9 (±2.02)	71.6 (±0.89)	[-3.55, 0.26]	.0854
Infant mortality rate (infant deaths per 1,000 live births) (2019) ^c	6.3 (±7.442)	9.0 (±5.615)	[-11.10, 5.64]	.4907
Low birth weight (2019) ^c	13.8 (±1.41)	10.0 (±1.73)	[1.81, 5.52]	.0010
Number of primary care physicians per person (2019) ^c	3,488 (±2,560)	3,154 (±2,347)	[-2,69, 3,15]	.8145
Air pollution particulate matter (2019) ^c	9.1 (±0.13)	8.7 (±0.61)	[-0.06, 0.84]	.0800
Adults who smoke (2019) ^c	25.4 (±1.74)	24.4 (±1.14)	[-0.86, 2.95]	.2548

^aU.S. Census Bureau, 2020.
^bEconomic Research Service, 2025.
^cUniversity of Wisconsin Population Health Institute, 2022.
Note. CI = confidence interval.

2011). As a consequence, many households resort to unpermitted systems, the extreme of which are “straight pipes” where household plumbing—including sewage—is discharged untreated onto the ground surface adjacent to the home (Elliott et al., 2017).

National and international attention on Alabama escalated after 2017, when a study reported the presence of human hookworm in area residents (McKenna et al., 2017). These findings catalyzed a U.S. Department of Justice investigation into racially discriminatory practices by the Alabama Health Department. The resulting investigations of health outcomes related to inadequate sanitation in the Black Belt region have focused on hookworm primarily. A large-scale prevalence study conducted in the region from 2019 to 2022, however, found no cases of hookworm or other soil-transmitted helminths (Poole et al., 2023).

Furthermore, a large number of households in the region report living in unsewered homes where untreated sewage is discharged to the nearby ground and private

wells are used (Poole et al., 2024). Moreover, an analysis of a subset of children in this region revealed that one third tested positive for a fecal pathogen, with the consumption of well water identified as the associated risk factor (Capone et al., 2023).

Given the environmental exposure to fecal pathogens in the region, we sought to evaluate their adverse effects on child health outcomes. We hypothesized that the prevalence of adverse health conditions potentially linked to environmental exposure to fecal pathogens would be higher in children residing in the Alabama Black Belt (southern Alabama) than in children in northern Alabama.

Methods

We conducted a retrospective cohort study using Alabama Medicaid administrative claims data from 2012 to 2020. We included pediatric Medicaid enrollees <19 years of age from selected counties, identified by ZIP Code, who had at least one approved Medicaid claim for gastroenteritis, malnutri-

tion, anemia, sepsis, pneumonia, or asthma as determined by ICD-9 and ICD-10 codes. Children with unapproved Medicaid claims were excluded from our study. Diseases/conditions were selected for analysis based on the literature linking these conditions to environmental fecal exposure. Counties were chosen using data from the U.S. Department of Agriculture’s Natural Resources Conservation Service, which maps Alabama’s soil conditions (Mitchell, 2018); U.S. Census Bureau (2018); the Alabama Department of Public Health on Health Professional Shortage Areas (2025); the *Educator’s Guide for the Alabama Possible Barriers to Prosperity Data Sheet* (Hitchcock et al., 2025); and the 2022 *County Health Rankings and Roadmaps* by the University of Wisconsin Population Health Institute (2026).

The Black Belt counties where household wastewater failures are widespread include Choctaw, Dallas, Greene, Hale, Lowndes, Marengo, Perry, Sumter, and Wilcox. Five counties in the northern region of the state of Alabama were selected for comparison:

TABLE 2

Prevalence of Health Outcomes Between the Black Belt Counties and Comparator Counties in Alabama

Health Outcome	Unit	Black Belt Counties (<i>n</i> = 9)	Comparator Counties (<i>n</i> = 5)	Mean Difference	
				95% CI	<i>p</i> -Value
Children enrolled in Medicaid (2012–2020)	Number	225,000	288,000	–	–
Enrollees with at least one claim	Percentage	89.6	89.6	–	–
Gastroenteritis prevalence	Average number of claims/year	3,521	4,559	[-5.83, 1.57]	.2394
	Mean % (<i>SD</i>)	14.0 (±3.62)	16.1 (±3.78)		
Malnutrition prevalence	Average number of claims/year	24	35	[-0.07, 0.02]	.2837
	Mean % (<i>SD</i>)	0.1 (±0.03)	0.1 (±0.05)		
Anemia prevalence	Average number of claims/year	387	171	[0.35, 1.78]	.0060
	Mean % (<i>SD</i>)	1.6 (±1.00)	0.6 (±0.17)		
Sepsis prevalence	Average number of claims/year	141	47	[0.29, 0.60]	.0001
	Mean % (<i>SD</i>)	0.6 (±0.21)	0.2 (±0.07)		
Pneumonia prevalence	Average number of claims/year	400	391	[-0.12, 0.81]	.1320
	Mean % (<i>SD</i>)	1.7 (±0.44)	1.3 (±0.48)		
Asthma prevalence mean	Average number of claims/year	3,621	2,935	[3.70, 6.70]	.0001
	Mean % (<i>SD</i>)	15.6 (±1.82)	10.3 (±0.65)		

Note. CI = confidence interval.

Chambers, Etowah, Fayette, Lawrence, and Randolph (Figure 1).

To calculate prevalence, we determined the number of children with at least one approved claim for each condition, using the total number of children with Medicaid claims as the denominator. If a child had multiple claims for the same condition in 1 year, only one claim was counted. We then calculated the average number of claims per condition per year and assessed statistical significance using a two-tailed unpaired *t*-test. A *p*-value of ≤.05 determined a measure of significance.

Results

The characteristics of the regions are presented in Table 1. Demographically, the Black Belt counties have a substantially higher percentage of African American residents (65.0%) compared with the comparator counties (18.3%), with a difference ranging from 31.8% to 61.3% (*p* <.0001). The Black Belt region also faces

higher poverty rates, with 24.3% of the total population living below the federal poverty line, versus 16.3% in the comparator counties (*p* =.0016). Furthermore, 36.5% of children in the Black Belt live below the poverty line, significantly more than the 24.5% in the comparator counties (*p* =.0024). Additionally, housing challenges are more prevalent in the Black Belt, where 15.8% of households experience at least one of four housing issues (i.e., overcrowding, high housing costs, lack of kitchen, or lack of plumbing facilities), compared with 11.8% in the comparator counties (*p* =.0311).

General health-related comparisons between the Black Belt and comparator counties revealed similar numbers of primary care physicians per person (*p* =.8145), smoking rates among adults (25.4% versus 24.4%, *p* =.2548), and air pollution levels (*p* =.08). Life expectancy was also similar (69.9 years versus 71.6 years, *p* =.0854), as were infant mortality rates (6.3 versus 9.0 per 1,000 live

births, *p* =.4907); however, the Black Belt shows a higher percentage of low-birth-weight infants, at 13.8% compared with 10% in the comparator counties (*p* =.001).

The comparison of the prevalence of health conditions is presented in Table 2. Regarding health conditions among children, the number of Medicaid enrollees was similar across both regions. For gastroenteritis, the average number of claims per year was slightly lower in the Black Belt, at 14.0% compared with 16.1% in the comparator counties, but this difference was not statistically significant (*p* =.2394). Malnutrition claims were minimal in both regions, and pneumonia claims were similar between the two areas, with no significant difference (*p* =.132).

The Black Belt does have a higher prevalence of cases of anemia (1.6% versus 0.6%, *p* =.006), sepsis (0.6% versus 0.2%, *p* <.0001), and asthma (15.6% versus 10.3%, *p* <.0001), with these differences being statistically significant.

Discussion

Our study aimed to assess if environmental exposure to fecal pathogens, resulting from wastewater failures in the Black Belt, was associated with higher rates of adverse health conditions in children in that region. Asthma and gastroenteritis claims accounted for approximately one third of all claims in the Black Belt, compared with one quarter in the comparator counties. Although we expected higher rates of gastroenteritis, the data showed no significant difference between the two regions. This lack of a difference could be due to families in the Black Belt region facing higher barriers to healthcare access and being less likely to seek medical care for milder illnesses such as gastroenteritis, the symptoms of which often resolve on their own.

In contrast, conditions such as asthma, pneumonia, and sepsis, which require medical intervention, were more prevalent in the Black Belt region. Asthma rates were nearly 50% higher in children in this region, while sepsis rates were 3 times higher. Exposure to fecal pathogens from untreated sewage could contribute to these findings. Studies have shown that endotoxins, which are present in human and animal feces, can trigger asthma and exacerbate respiratory symptoms (Thorne, 2021; Thorne et al., 2015). Children in the Black

Belt region could be exposed to these environmental irritants due to widespread wastewater failures, which in turn could contribute to the higher asthma rates observed in the region.

Moreover, anemia has been associated with chronic intestinal infections and was also observed to be more common in the Black Belt region. This finding aligns with previous studies showing a higher prevalence among African Americans (Williams et al., 2024).

Limitations

Relying solely on Medicaid claims is not an accurate method for measuring disease prevalence because it misses conditions that do not result in healthcare visits or are covered by other types of insurance. We acknowledge that several confounders might have influenced our findings, which we did not account for. The concept of environmental fecal exposure was based on reported differences in household wastewater management by geography and poverty levels, wastewater failures documented in the literature, and findings from prior research; however, direct environmental measurements were not taken. Therefore, we cannot definitively say that the differences in disease prevalence were caused by environmental fecal exposure, and it is more probable that multiple factors were involved.

Conclusion

Understanding the health impact of environmental exposures is essential for prioritizing interventions. In low- and middle-income countries, improvements in wastewater infrastructure have substantially reduced environmental fecal contamination, leading to a decline in infant and childhood mortality from gastrointestinal diseases. In places such as the U.S., however, simply assessing gastrointestinal disease outcomes is likely to be insufficient to fully grasp the effect on child health due to inadequacies in wastewater infrastructure. Our study shows that child health outcomes are worse for children living in the rural region of the Black Belt in southern Alabama. Poverty associated with substandard housing is most likely the main factor, but the role of wastewater failures in adverse effects on health conditions such as asthma warrants further research. 🌸

Corresponding Author: Claudette Poole, MSPH, MD, Associate Professor of Pediatric Infectious Diseases, University of Alabama at Birmingham School of Medicine, 1600 6th Avenue South, CHB 308, Birmingham, AL 35233. Email: claudettepoole@uabmc.edu

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