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An Interdisciplinary Approach to Community-Engaged Research Surrounding Lead in Drinking Water in the Mississippi Delta

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ABSTRACT
Childhood lead poisoning is a problem requiring interdisciplinary attention from toxicology, public health, social sciences, environmental law, and policy. In the U.S., Mississippi was ranked as one of the worst states for lead poisoning with limited childhood screening measures. We conducted community-engaged research by working with leaders in the largely rural Mississippi Delta region from 2016-2019 to collect household water samples and questionnaires and involve their communities in lead poisoning risk awareness and outreach. Drinking water from 213 homes

was collected and analyzed for pH and lead concentrations. Highest lead concentrations were from households served by private wells, and detectable concentrations at or above 0.09 ppb were found in 66.2 percent of all samples. Nine samples exceeded 5 ppb, and these households received certified sink filters. Findings indicated that community-engaged research and outreach could be used to address data gaps relating to lead in drinking water in rural decentralized water systems.

KEYWORDS
Community-engaged research, drinking water, lead, public health, rural water systems

INTRODUCTION

Lead exposure is a serious health concern all over the world. The World Health Organization (WHO) reports that young children are particularly vulnerable to lead poisoning because they absorb four to five times as much ingested as adults from a given source (World Health Organization 2019). In the United States, childhood lead poisoning is a challenging social issue that requires the coordination of public health, housing, and related environmental laws and policies. There is no safe blood level for lead, and the Centers for Disease Control and Prevention (CDC) states that “all sources of lead exposure for children should be controlled or eliminated” (CDC n.d.). Since 1978, when use of lead-based paint was banned in the United States, environmental and health policy has primarily focused on reducing childhood exposure to lead-based paint. Policymakers have focused much less attention on exposure to lead through environmental sources such as water or soil. This is alarming because in up to 30 percent of elevated blood lead levels (EBLLs) cases in children, there is no immediate lead paint hazard (Brown and Margolis 2012).

The Health Impact Project (2017) calculated that the maximum potential future benefits of preventing lead exposure in the U.S. 2018 birth cohort was $84 billion. Furthermore, minimizing drinking water contamination compared to, for example, eradicating lead paint hazards was predicted to impact the largest sample size at the lowest cost (Health Impact Project 2017). Environmental health crises in Flint, Michigan, and Newark, New Jersey raised awareness of the danger that may be present in drinking water when the delivery infrastructure includes lead pipes. Under the federal Safe Drinking Water Act (SDWA), the U.S. Environmental Protection Agency (EPA) has issued regulations addressing lead and copper contamination in drinking water, known as the Lead and Copper Rule (LCR). Under the LCR, the lead action level is exceeded if the concentration of lead in more than 10 percent of tap water samples is greater than 0.015 mg/L (15 ppb) (EPA 2010).

Mississippi communities face public health threats from lead exposure. Little is known about the contribution of lead pipes and water treatment to lead poisoning in the state. A 2014 HealthGrove analysis ranked Mississippi as one of the top 20 (#18) worst states for lead poisoning (Morin 2016). Each year more than 200 Mississippi children are diagnosed with lead poisoning (elevated blood lead levels (EBLL) $\geq$ 5 μg/dL) (Mississippi Department of Health 2018). Actual numbers of EBLL cases are likely much higher because the percentage of children screened in Mississippi averages ~18 percent and has declined in recent years to ~16 percent (Mississippi Department of Health 2018). African-American children and children of low-income families are at greater risk of lead exposure due to economic, housing (living in older or poorly maintained housing), and health disparities. As such, research on lead hazards has significant racial and environmental justice components (Neuwirth 2018; Olson and Fedinick 2016; Renner 2010; Whitehead and Buchanan 2019).

Furthermore, Mississippi is unique in the U.S. because of the highly decentralized nature of its public water systems (PWS) (University of Wisconsin Center for Cooperatives 2010) and its largely rural population. Approximately 51 percent of the state's population lived in a rural place in 2010 according to U.S. Census Bureau definitions (U.S. Census Bureau 2010), and 55 percent of the population was living in non-metropolitan counties as classified by U.S. Department of Agriculture (USDA 2013). Pursuant to the LCR, PWS must collect a certain number of tap water samples on a set schedule based on system size (population served). The minimum number of samples required to be collected is quite small, just 10 samples for systems serving 101-500 individuals and 20 samples for systems serving 501-3,300 individuals. Given the extreme decentralization of water associations, PWS in the Delta region tend to serve small populations (less than 1,500 on average) and so a vast majority of households are underrepresented in LCR sampling.

Additionally, the SDWA does not regulate private wells or systems serving fewer than 25 individuals. As many as 45 million people in the United States drink water that is not subject to SDWA regulations (Brown and Margolis 2012) . Older homes on private wells with soft water of low pH may have higher levels of lead contamination due to the lack of corrosion controls (Pieper et al. 2018, 2019).

To take effective action to address lead in drinking water as an exposure route, academic researchers, policymakers, case workers, and community members need to be informed with data regarding the concentrations and distribution of lead contamination in our communities. Community-engaged research, education, and outreach efforts can provide a more comprehensive picture of the lead contamination risks within PWS service areas and properties served by private wells. Our goal was to use drinking water lead concentrations collected via community-engaged research to inform better monitoring, outreach, and education efforts. Based on the combination of expectations from the literature and knowledge about the characteristics of the communities involved in this project, we expected there to be better participation in collection events when collaborating with public health initiatives. Additionally, we expected higher lead concentrations for older housing, housing in areas with older housing in general, and housing served by private wells.

METHODS

Community Partnerships

Our team's research involving collaborations between the University of Mississippi and community organizations (described below) has allowed us to prioritize our work in communities in the Mississippi Delta region in the northwest part of the state, a predominantly rural and high poverty region facing health challenges (Duncan 1999; Green, Greever-Rice, and Glass 2015; Green 2014; Haggard, Cafer, and Green 2017). In the face of major disparities in the predominately African American communities of the region, the Community Health Centers (CHCs) (Lefkowitz 2007) model has facilitated community-focused initiatives to improve health and wellbeing (Kerstetter, Green, and Phillips 2014). Specifically, the project team leveraged existing collaborations with two programs underway in the Mississippi Delta – the New Pathways to Health and Opportunity Initiative and the Right! from the Start Initiative. New Pathways is focused on health education, workforce development, and civic engagement with youth (6th through 12th grade) and their parents, college students, and healthcare practitioners. Right! from the Start, a collaboration of the Women and Children Health Initiative and the Community Foundation of Northwest Mississippi, focuses on outreach and education on poor birth outcomes and the importance of breastfeeding. Both of these initiatives involve partnerships with CHCs, specifically Aaron E. Henry Community Health Services Center, Inc. and Delta Health Centers, in various ways. Additionally, we engaged with a hospital affiliated wellness center – James

C. Kennedy Wellness Center – along with churches, an Extension private well program, and community events.

Housing Survey

A survey instrument and informed consent form were developed and IRB-approved to assess housing and sociodemographic characteristics. The survey asked participants to list both their residential address and address where results should be mailed. Housing, health, and sociodemographic data were collected. These neighborhood/community conditions based on participants' responses were connected with publicly accessible secondary data sources (mainly American Community Survey at the census tract level and PWS sampling data from the Mississippi Department of Health, Drinking Water Watch). Utilizing the aggregated spatial data, analytic capabilities, and mapping resources, characteristics of the places where lead concentrations were the highest were identified.

Community Engagement Events

The team organized events using eight different community engagement strategies consisting of outreach, engagement, and recruitment (Table 1). Depending on the recruitment method, information was shared about the public health risks associated with lead-contaminated drinking water through formal group presentations, one-on-one interactions, or "train-the-trainer" activities. All participants received a general overview of the problem of lead contamination in drinking water, including water quality, environmental law, environmental toxicology, and health effect information. Participants were asked to complete the household survey and received training on how to collect their sample.

Participants collected one-liter samples of cold tap water in high density polyethylene (HDPE) bottles provided by the team. Consistent with EPA protocols (EPA 2010) for LCR lead and copper tap samples, participants collected "first draw" samples after six hours or more holding time in household plumbing. Samples were stored by project partners for no more than two weeks before collection by the team. The research described in this study was approved by the University of Mississippi Institutional Review Board (Protocol #17x-025). Water samples were returned at various local collection points determined in collaboration with the community organization partners.

Table 1: Community Engagement Approaches including Number of Residents Engaged and Bottle Return Rates

Approach	# bottles passed out	# bottles and questionnaires returned	% returned
Healthcare Workforce Training	88	68	77%
Church Partnership	42	42	100%
Wellness Center Cooking Class	10	6	60%
Extension Event for Well Owners	38	19	51%
Train-the-Trainer Event	12	12	100%
Health Center Career Fair	22	20	91%
Community Health Center Clinics Patient Recruitment	81	39	48%
Festival	9	7	78%
Total	302	213	71%

Lead Concentrations

Upon receiving the samples (within two weeks of collection), the pH of the samples was measured before undergoing standard acid preservation (preserved to pH < 2 using 3 mL of 50 percent 7.8 M HNO_3). Water samples were analyzed in School of Pharmacy and Chemistry laboratories in compliance with EPA Method 200.8 inductively coupled plasma-mass spectrometer (ICP-MS) (Creed, Brockhoff, and Martin 1994) to quantify the total recoverable lead in drinking water. To ensure scientific rigor and reproducibility, all samples were analyzed in duplicate and at least 10 percent of the samples were injected twice for ICP-MS quality control. Blanks were included to ensure no carryover every ~10 samples. The detection limits between runs ranged from 0.04 to 0.09 ppb using a six-point standard curve. Samples were analyzed blind to sample collection location.

Participant Follow-up

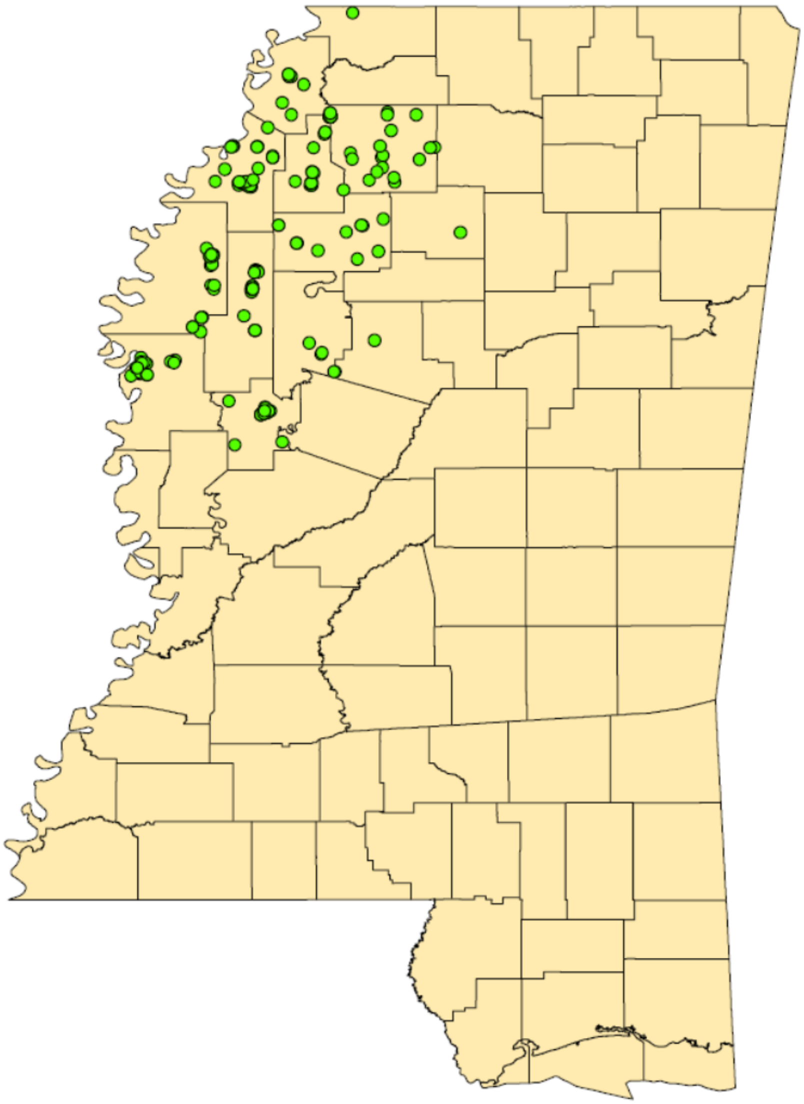
All project participants were mailed individual letters sharing the water testing results from their homes and additional educational materials about how to minimize lead exposure. Examples of these materials are provided as Supplemental Figures 1-3. Because the LCR action level of 15 ppb is not a health-based standard, the Project Team selected the Food and Drug Administration (FDA) standard for lead in bottled water, ≥5 ppb, as its level of concern and recommended the use of filters certified to NSF/ANSI Standard 53 in homes testing above 5 ppb. Participants with concentrations of lead ≥5 ppb received a Brita Complete Faucet Mount System with their test results.

Our work identified an issue surrounding communication of household lead drinking water concentration results back to the residents. There were many returned envelopes that could not be delivered (n=24) because of lack of mail receptacles, insufficient or incorrect address, or vacancy. In an attempt to maintain confidentiality, no names were collected from the participants.

RESULTS

Seven counties were the initial focus for this project (Bolivar, Coahoma, Panola, Leflore, Quitman, Sunflower, and Tallahatchie), but community participation resulted in samples from 13 counties (Figure 1). The project team organized 11 collection events distributing 302 bottles and surveys to participants. Of the distributed bottles, 215 were returned (71.2 percent; Table 1), but two did not have associated questionnaires. The youth-focused healthcare workforce training program reached the highest number of residents (n=88) compared to the lowest from a tent at a festival (n=9). The church partnership and the train-the-trainer health practitioner events both resulted in the highest bottle return rate (100 percent). Table 2 details general demographic characteristics of the participating households and their housing units. Only participants who returned both a bottle and a survey were included (n=213). Table 3 shows the poverty and age of housing indicators for the represented counties.

Figure 1: Map of Lead and Drinking Water Sampling in the Delta and Border Delta Region of Mississippi (n=213*)



*Note: Dots represent participating households returning both a questionnaire and water sample. Locations with more than one household (such as apartment complexes) are represented with a single dot.

Table 2: Lead and Drinking Water Project Household Resident Characteristics (Households with Questionnaires and Water Samples, n=213)

Characteristics		f	%
People in household (n=213)	One	44	20.7
	Two	48	22.5
	Three to four	80	37.6
	Five or more	41	19.2
Children in household < 5 years of age (n=193)		28	14.5
Children in household born in past 12 months (n=202)		3	6.0
Age of people in household (n=193)	Average (years)	37.9	
	Min. to Max.	0.2 to 97.0	
Racial composition of household (n=191)	White	23	12.1
	Black/African American	166	86.9
	Asian	1	0.5
	Multi-racial	1	0.5
Hispanic/Latino/a (n=191)		2	1.0
Housing tenure (n=206)	Renters	60	29.1
	Owners	136	66.0
	Other arrangement	10	4.9
Housing type (n=210)	House	163	77.6
	Mobile home	23	11.0
	Apartment/town house	24	11.4
Resident reported knowing when housing was built (n=205)		111	54.1
Built 1985 or earlier (n=111)		55	49.5
Pipes ever replaced (n=201)	Yes	34	16.9
	Unsure	77	38.3
	No	90	44.8
Source of water (n=202)	Public system	180	89.1
	Well	22	10.9
Use filter for drinking water (n=213)		64	30.0
Use filter for ice (n=213)		66	31.0

*Note: Values fluctuate because of refusals.

Table 3: Lead and Drinking Water Project County Characteristics (Mississippi Delta and Border Delta)

Lead Project Participant Counties	Percent Families Below Poverty	[±90% MoE]	Median Year Housing Structures Built	[±90% MoE]
Bolivar	32.6	[2.9]	1975	[2]
Carroll	10.3	[4.7]	1987	[3]
Coahoma	30.7	[3.4]	1970	[2]
DeSoto	7.2	[0.7]	1995	[1]
Humphreys	36.7	[5.3]	1975	[2]
Leflore	36.0	[3.3]	1974	[2]
Panola	17.9	[3.4]	1986	[2]
Quitman	28.2	[5.3]	1974	[2]
Sunflower	29.7	[2.9]	1975	[2]
Tallahatchie	19.1	[4.3]	1976	[2]
Tunica	23.2	[6.3]	1993	[2]
Washington	29.1	[2.3]	1971	[2]
Yalobusha	17.3	[4.5]	1980	[2]

Note: Lead and Drinking Water Project data reported in this article were collected from 2016 through 2018. Poverty and housing data from American Community Survey 2016 five-year estimates are used for consistency.

All of the samples were below the 15 ppb LCR action level, but nearly two-thirds of the samples had some level of detectable lead (Table 4). Forty-one samples (19.2 percent) had concentrations at 1 ppb or higher. The pH range was 5.84 – 9.13 with the mean 7.74 and median 7.82. Upon visual inspection, there was a slight negative relationship identified between water pH and lead concentration: more acidic water had higher concentrations of detectable lead. Still, there were notable lead readings for water with pH between 7 and 8.5 (Figure 2A).

The majority of the participants were on PWS (n=184) and their average lead concentration was 0.61 ppb. In contrast, the 19 private well samples in the study had higher lead concentrations in their water (2.90 ± 1.04 ppb average/standard error). Overall, lead concentrations ranged from nondetectable to 14.32 ppb, with a mean of 0.86 ppb, and a median of 0.23 ppb.

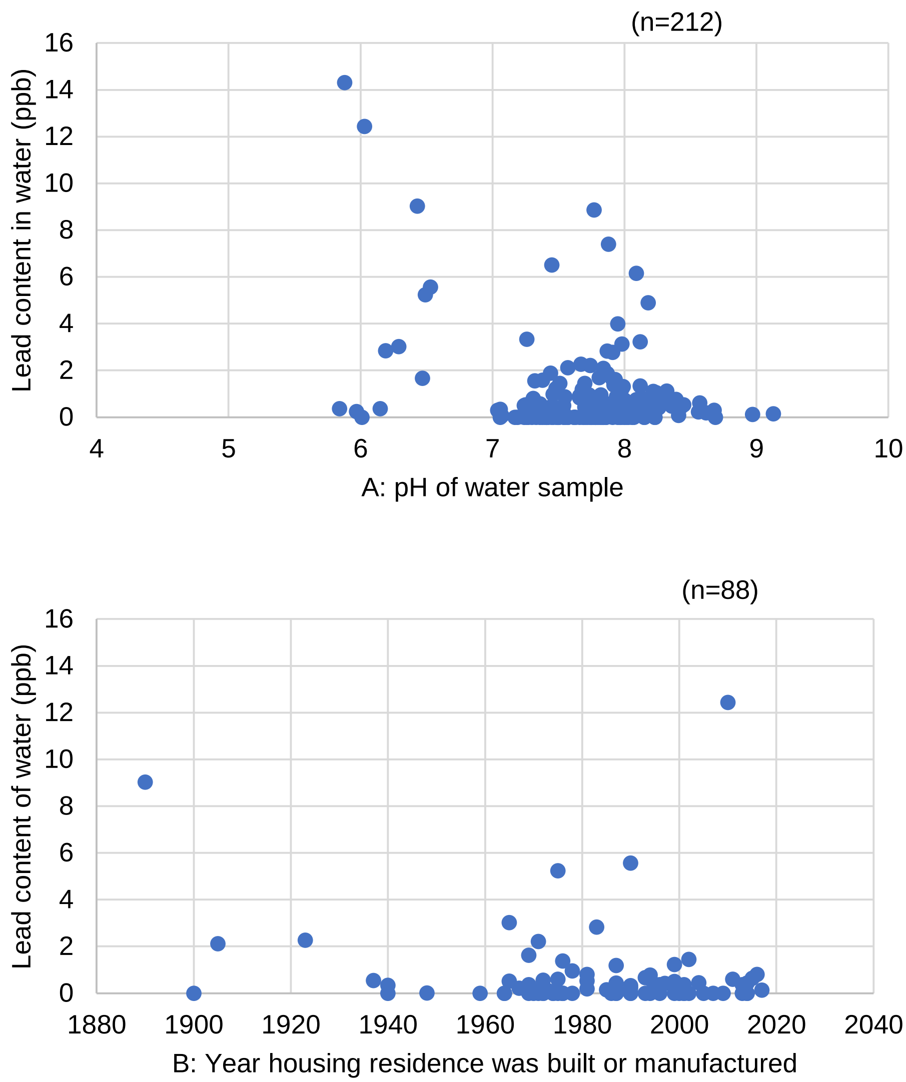
Table 4: Lead and Drinking Water Project Testing Results (Households Returning both Questionnaires and Water Samples, n=213)

Characteristics	Statistics	
	pH (n=212)	Lead (ppb) (n=213)
Mean	7.74	0.86
Median	7.82	0.30
Standard deviation	0.52	1.87
Minimum	5.84	n.d.
Maximum	9.13	14.32
Any detectable lead*	66.7% (141/213) 19.2% (41/213) at 1 ppb or higher	
Pearson's correlation between pH and lead level	-0.35	

*Note: Table shows data for participants returning both a water sample and questionnaire. For all water samples (regardless of survey) 141 had detectable lead from 215 total (66.0%).

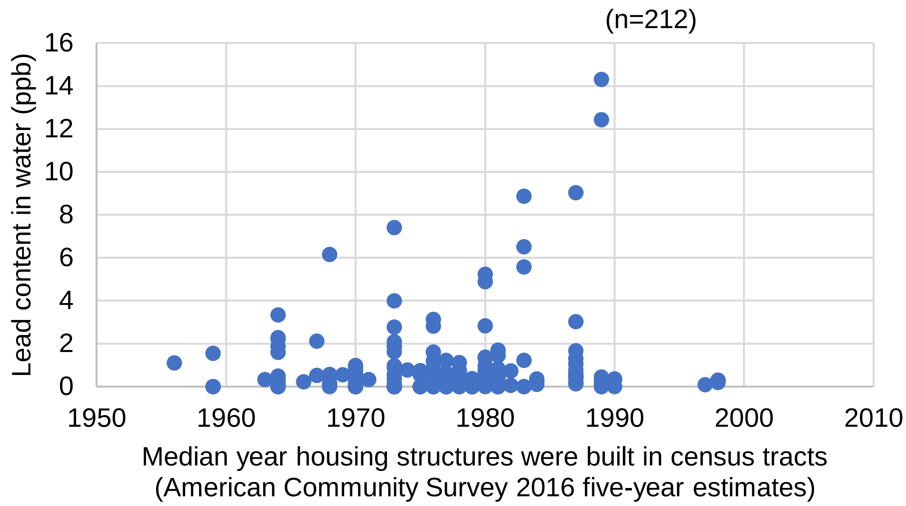
Age of housing is considered a risk factor for potential lead exposure, given that the use of lead in plumbing materials was permitted until 1986. Figure 2B shows the association between the year that housing structures were built and the lead content of water. It is important to recognize that many of the survey respondents were not sure when their housing was built, leading to a lower "n" value for these analyses. In both cases (i.e. specific year and category of 1985 or earlier versus 1986 or later), houses built earlier were more likely to have higher lead content. However, one of the higher concentrations (over 12 ppb) was in a newer housing unit. On average the lead concentrations in water samples from homes built in 1985 or earlier (n=55; 1.06 ppb) was not statistically different than from homes built after 1985 (n=60; 0.94 ppb). To compensate for participants not knowing when their housing was built (n=101), and to address older infrastructures at the neighborhood level, the relationship between the median year that housing was built within the census tract and lead concentrations in the participants' water samples was analyzed. When analyzed this way, there was a positive association (Figure 3) where some of the highest lead levels were in census tracts with median housing built during the years 1985-1990.

Figure 2: Lead Concentration in Water Compared to pH (A) and Year Residence was Built (B)



Note: Sample size is lower in B because some residents did not know/report date built.

Figure 3: Lead Concentration in Water Compared to Median Year Residences Built in Census Tracts



DISCUSSION

Many studies of EBLL have focused on urban cohorts, but the risk factors for rural children are different (Aelion and Davis 2019), and drinking water may be an underappreciated source of lead. Demographic and lead concentration data in both water and children less than 5 years old from seven rural Mississippi Delta counties highlight the urgent need to better understand the extent of drinking water lead contamination to detect and prevent exposure in rural Mississippi communities (Table 5). Furthermore, a systematic review (Pfadenhauer et al. 2016) revealed that evidence based health impacts of interventions to reduce lead in drinking water and in turn BLLs is very limited, and there is a strong need for these studies. That said, it was tentatively concluded (Pfadenhauer et al. 2016) that approaches that combined both educational and environmental interventions (e.g. flushing, filters, etc.), as we have done here, could lead to a more meaningful impact on the public's knowledge of the risks associated with lead exposure and ways in which their exposure could be reduced.

This project engaged multiple community partners and over 200 individuals to collect and analyze residential drinking water samples in the Mississippi Delta. By working with community partners, we were able to leverage pre-existing relationships with community leaders, to help build a strong foundation for the project outreach and researcher-participant trust. An important strength of this project is that it not only engaged community organizations in the research, but also individual families, students, and members of the community to learn more about the dangers of lead and strategies for reducing exposure.

The sample size of this study is limited (n=213), and our ongoing work is designed to expand testing and outreach. However, it is important to note that for some of the PWS in our research area, our sampling efforts far exceeded the regulatory mandate dictated by the EPA LCR. For example, the church event evaluated 38 samples from Belzoni which exceeded the 2018 PWS testing (n=15). Results were consistent with the Belzoni PWS study wherein 90^{th} percentile lead concentrations were reported at 3 ppb compared to our result of 2.7 ppb. Furthermore, in the same county (Humphreys), we measured four additional samples, each from a different PWS, highlighting the difficulty in drawing county level conclusions. Similarly, in Coahoma County 22 samples were tested from Clarksdale Public Utilities, while 17 other samples were from 8 other PWS. Community engagement provided the foundation for sampling more households than would otherwise have been the case under the existing regulatory framework. Our study demonstrates the need for increased community engagement to achieve representative sampling in rural service areas, especially those with smaller water systems and significant private well usage.

Consistent with our expectations, events with more public health focused engagement had higher sample return rates. For example, the event led by community health providers had enthusiastic engagement and a 100 percent bottle return rate. We had initially hypothesized that events in association with health centers (e.g. client recruitment and wellness class) would result in greater participation because these residents were already engaged in their health. However, both numbers of residents reached and percent return were relatively lower via these engagement routes. The client recruitment and wellness class routes saw a 48 percent and 60 percent return, respectively. Anecdotal evidence based on our interactions with collaborators during the course of the project suggests that the discrepancy could have been due to a lack of engagement or encouragement provided by the organizer at these events.

However, the program that reached the most residents was a healthcare focused workforce training program that engaged both students and their parents (77 percent bottle return, n=68). Because this programming included an experienced organizer and a routine schedule, high bottle return resulted. Another successful approach (100 percent

Table 5: Characteristics of Representative Mississippi Delta Populations and Public Water Systems including LCR Exceedances and EBLLs

County	No. of PWS	Minimum Population Served/PWS	Maximum Population Served/PWS	Total Population	LCR Sample Size Range	Systems with LCR Exceedances (>15 ppb) in past 5 years, Pb conc. and sampling date	EBLLs (>5) 2012-2016
Bolivar	28	110	15,000	31,333	1 - 34		8
Coahoma	18	231	17,962	22,628	5 - 30		31
Leflore	16	45	16,000	28,919	5 - 30	Delta Mobile Home Park & Apt. - 18.6 (2016)	112
Panola	27	25	9,971	34,164	5 - 23	Enon-Locke Curtis Water Assn - 47 (2014)	12
						Hide-a-way Hills Water Company - 17 (2016)	
Quitman	14	80	2,446	7,349	5 - 20	City of Marks - 20.7 (2014)	1
						Darling Water Association - 19 (2014)	
						Town of Crowder - 29.3 (2017)	
Sunflower	14	190	10,683	26,407	5 - 30	MS State Penitentiary - 18.2 (2017)	22
						Sunflower Water Association - 23.4 (2017)	
Tallahatchie	16	39	3,299	13,987	3 - 22	East Charleston Water Association - 16.8 (2017)	13

Source: U.S. Census Bureau, Annual Population and Housing Estimates, v 2017 and MS Department of Health Drinking Water Watch.

bottle return, n=42) was working with a church congregation. For this event, a trusted community member with experience organizing for public health initiatives was provided a small stipend to help deploy and recollect the bottles. Overall the bottle and survey return rate using our various engagement approaches was >70 percent. In comparison, a project in New Hampshire with similar goals but using less direct community engagement approaches, including crowdsourcing, kiosk pick up and drop off locations, a social media campaign, and a cash prize contest, reported a return rate of only 18 percent (Jakositz et al. 2020).

Our project investigated whether community-engaged research strategies could be used to collect data to identify communities that were at higher risk for lead exposure. Focus communities' housing stock tended to be older (Table 2), where the median year that housing structures were built ranged from 1970 to 1995, and 56.5 percent of housing was built prior to 1980. Poverty and older housing stocks contribute to the potential for lead in drinking water both because lead was allowed in older homes' pipes, and because a lower tax-base limits the feasibility for the community to undertake large public works projects such as upgrades to drinking water treatment and infrastructure.

Overall, our data provided mixed results concerning the expectation that older homes would definitively have higher drinking water concentrations. For the participant data, the association was in the direction expected, but it was weak and not statistically significant. This could be attributed to a portion of the participants not knowing when their housing was built. Furthermore, when considered at the census tract level some of the areas with more recent median year of builds had higher lead concentrations. The latter could be partially explained by the larger geographic area covered by census tracts in rural areas relative to those in urban areas with higher population density (U.S. Census Bureau 2019). Additionally, it is important to note that even newer builds often rely on older public infrastructures. The New Hampshire crowdsourcing study also found that some of the newest homes had the highest drinking water lead concentrations (Jakositz et al. 2020).

Participants were asked to collect "first draw" samples that would have been stagnant in their home's pipes for at least six hours. This is consistent with PWS sampling protocols mandated by the LCR. However, recent studies have documented that there are scenarios, especially when there are lead service lines and deficient corrosion control, where the first draw sample does not represent the highest lead concentration (Katner et al. 2018; Pieper et al. 2019). First draw samples were deemed sufficient to achieve the community engagement objectives of our study that were focused on identifying the presence of lead risks, rather than assessing changes in lead concentrations that might have resulted with additional flushing.

Because an acidic pH is known to cause lead to leach into drinking water from pipes, solder, or service lines (Lei et al. 2018; Kim et al. 2011), we also analyzed the relationship between pH and lead concentration. The results from this analysis showed that households with more acidic pHs were more likely to have lead in their water. However, it is important not to rely solely on pH measurement as a predictor of lead concentrations because it is not the only contributing factor. Several samples with detectable lead did not have an acidic pH. While identifying areas with consistently acidic pHs could be a useful tool for prioritizing potential at risk areas for further research, it does not target all areas or households that could be at risk for lead exposure.

In this study the most notable risk factor for lead in drinking water was getting one’s water from a private well. Additionally, the average pH of water from the cohort of private well-owners was 6.9 (range 5.88 – 8.36) compared to the overall study water pH mean of 7.74. Years ago, the U.S. EPA assessed rural water quality and recognized that homes in the southern U.S. were at higher risk for potential lead contamination (Francis et al. 1984). This regional susceptibility was further supported more recently through the use of a lead solubility potential model of groundwater (Jurgens, Parkhurst, and Belitz 2019). The combination of groundwater more likely to leach lead and the low likelihood that households on private wells implement corrosion control measures contributes to higher drinking water lead concentrations from private wells (Pieper et al. 2015). Private well water quality assurance is not currently under regulatory authority in the U.S., thus strategies to improve water quality from wells are being proposed (Gibson and Pieper 2017).

Collectively, our data and trends identified areas as higher-risk when there were older homes or households who rely on well water. Officials who enforce the SDWA and the LCR can use these data to identify at-risk areas that may have disproportionate rates of lead exposure for continued testing, mitigation, and outreach. These data could help to inform government intervention to minimize risk of lead exposure and encourage behavioral changes (e.g. flushing pipes before use and point of use filters, Pieper et al. 2019) to limit lead exposure from drinking water.

Our project aimed to create an atmosphere of community and inclusion to inform and influence a major public health issue, namely lead in drinking water. By using a mixture of community-engaged research methods, we were able to join forces with community partners to organize educational events that facilitated this research. Though each event employed different methods of participant recruitment and engagement, the project used commonalities of community-engaged research to educate rural Mississippi residents and their families about drinking water quality and behavioral changes that can decrease the risk of lead exposure from their own drinking water. Furthermore, our research on public water systems (PWS) has allowed us to focus our ongoing efforts to higher exposure risk residents (those on private wells) and communities.

Because it focused on a specific rural area in the United States, our study was limited in scope. However, our investigative water results and successful community-engagement practices can be applicable in other rural regions of the world. Lead poisoning through environmental exposure is a concern for all children regardless of geographical location. Research, education, awareness, and public policy adjustments regarding environmental contaminants can be life-saving and essential to the health and well-being of the overall population.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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Lead Exposure & Drinking Water:
Understanding the Risks in Quitman County

According to the Centers for Disease Control, 4 million households across the United States have children living in them that are being exposed to high levels of lead. **No safe blood lead level in children has been identified.**

- Lead exposure can cause serious damage to children's developing brains, leading to reductions in IQ, learning and behavioral problems, and other challenges.
- Lead exposure is hard to detect, as signs and symptoms don't appear until dangerous amounts have accumulated in a child's body.
- Childhood lead exposure can also increase health risks later in life, including increase risk of hypertension, heart disease, and for pregnant women, low birth weight or preterm birth.

Mississippi ranks as the 11th worst state for childhood lead poisoning in the United States. The most common route of exposure for children is dust from lead-based paint, which was used in many homes until the late 1970s. Drinking water, however, can be a significant source of lead, especially for infants fed formula made from unfiltered tap water. Children can also be exposed to lead through contaminated soil, food, and toys. **All sources of lead exposure for children should be eliminated.**

Blood Lead Level Screening in Quitman County

Mississippi's approach to blood lead level screening is targeted at high-risk populations, rather than universal. All Medicaid-eligible children are required to be screened for lead poisoning at 12 and 24 months of age. Screening for other children is suggested only if a risk assessment indicates possible exposure, such as living in a home built before 1950 or drinking well water.

- 205 children out of an estimated population of 679 were screened for lead poisoning in Quitman County in 2015 (30%).
- There were no reports of elevated blood lead levels (EBLLs) above CDC's "Reference Level" of 5 micrograms per deciliter in 2015.
- 10 reports of EBLLs over 10 micrograms per deciliter since 2005.

Source: MSDH Lead Poisoning Prevention and Healthy Homes Program Surveillance Reports.

Community-Based Research to Reduce Childhood Lead Exposures from Drinking Water

An interdisciplinary team of researchers from the University of Mississippi has been working with community partners in the Delta region since 2016 to investigate lead exposure risks and increase awareness of prevention strategies, such as the use of water filters. The team is available to work collaboratively with community leaders in Quitman County on a range of activities, including:

- Informational briefings on lead exposure and drinking water risks.
- Drinking water sampling events to test tap water in homes, childcare centers, and schools for lead.
- Water screening and workshops for private well owners.
- Collection and synthesis of data related to housing, drinking water, water infrastructure, and lead screening.

If your organization is interested in working with the project team, please contact us at leadinwater@olemiss.edu.

Supplemental Figure 1: Lead Exposure and Drinking Water Understanding the Risks in Quitman County (Document Provided to Participants)

January 11, 2017

Sample #XX
Address XX

Thank you for your participation in the lead sampling research initiated by the University of Mississippi in collaboration with Mississippi State University Extension. One benefit of this program is to provide you with important information. The results of your water sample are shown below.

Lead is a toxic metal that can be harmful to human health even at low exposure levels. Young children, infants, and fetuses are especially vulnerable. Low level of lead in blood of children can cause behavioral and learning problems, lower IQ, and slowed growth. Children can be exposed to lead through a variety of sources, such as lead-based paint in older homes or through drinking water. See the enclosed Lead Fact Sheet from the Mississippi State Department of Health for more information on sources of lead and how to protect your child from lead exposure.

Lead can also enter drinking water when lead service pipes and household plumbing that contain lead corrode. Corrosion is a dissolving or wearing away of a metal like lead caused by a chemical reaction between water and your plumbing. Each home has a unique lead contamination risk that depends on the type and age of service pipes and plumbing fixtures. Water chemistry also plays a role, as water with a low pH (less than 7) or mineral content is more likely to corrode pipes. The normal range for pH in groundwater systems is 6 to 8.5.

To protect human health, the U.S. Environmental Protection Agency establishes limits on the number of contaminants that may be present in drinking water. For lead, public water systems must ensure that lead is not present in concentrations greater than 0.015 mg/L (15 ppb). Public water systems actively monitor and manage the chemistry of drinking water.

We are pleased to report that water sample you provided from your home tested within the normal range for pH and below the EPA's lead action level for public water systems.

pH Value: 6.43
Lead: 9.032 ppb

Despite your lead concentration being below the EPA limit of 15 ppb, this limit is not a health-based standard. Rather, it is a technology-based standard that, when exceeded, indicates a problem with a public water system's corrosion control. Some public health researchers consider lead concentrations greater than 5 ppb cause for concern, especially if there are infants or small children in the household. 5 ppb is also the Federal Food and Drug Administration's regulatory limit for lead in bottled water.

Because your lead sample was greater than 5 ppb, we have purchased a water filter for installation on your kitchen sink or another faucet used primarily for drinking water and cooking. This Brita water filter is certified by NSF International for effective lead removal. Many water

This Brita water filter is certified by NSF International for effective lead removal. Many water filters and water treatment devices are certified by independent organizations for effective lead reduction. For future purchases, look for the NSF International mark to ensure the filter or cartridge you are buying is certified by NSF International to NSF/ANSI 53 or NSF/ANSI 58, and that lead is listed on the packaging as one of the contaminants that will be reduced. If you would like to confirm if a filter or treatment system is NSF certified for reducing lead in drinking water, please call NSF International's consumer information specialist at 1.800.673.8010 or send an email to info@nsf.org.

In addition, the following practices will help limit your family's exposure to lead from water:

- **Flushing your pipes before drinking:** The more time water has been sitting in your home's pipes, the more lead it may contain. Anytime the water in a particular faucet has not been used for six hours or longer, "flush" your cold-water pipes by running the water until it becomes as cold as it will get. This could take as little as five to thirty seconds if there has been recent heavy water use such as showering or toilet flushing. Otherwise, it could take two minutes or longer.

- **Using only cold water for eating, cooking and drinking, and especially for making baby formula:** Hot water is likely to contain higher levels of lead. Run water from the cold water tap until it becomes as cold as it can get.

Thank you again for participating in our study. If you would like more information, please do not hesitate to contact us.

Sincerely,

Stephanie Otts, Dr. Kristie Willett, and Dr. John Green
UM Lead in Drinking Water Project Team

Supplemental Figure 2: Lead Results Letter Template (Letter Sent to Participants)

Supplemental Figure 3: "Know the Facts" Postcard (Shared with Public)