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BARRIERS
to Managing Private Wells and Septic Systems in Underserved Communities

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ABOUT THE COVER

This month's cover article, "Barriers to Managing Private Wells and Septic Systems in Underserved Communities: Mental Models of Homeowner Decision Making," explores underbounded communities that are disproportionately exposed to water contaminants and face elevated health risks. Through semistructured interviews with residents in such communities, the authors sought to identify knowledge gaps and misconceptions regarding the monitoring and maintenance of private wells and septic systems. The interview results suggest that testing is inhibited by a lack of awareness of well maintenance guidelines, overreliance on sensory information, poor understanding of exposure pathways, and cost. The highlights of the article point to the need for risk communication materials that target at-risk communities

See page 8.

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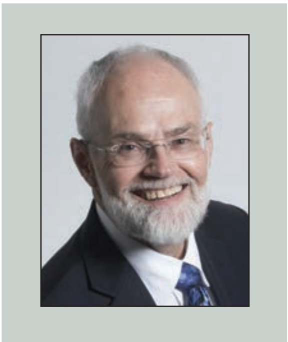

Vince Radke, MPH, RS, CP-FS, DLAAS, CPH

Vector and Pest Control: What Are You—What Are We—Doing About It?

According to the Centers for Disease Control and Prevention (CDC), vectorborne disease cases tripled in the U.S. from 2004–2016. Since 2004, nine new pathogens spread by mosquitoes and ticks have been discovered or introduced. Commerce and transportation can move vectors and pests across borders and around the world. Infected travelers can introduce and spread pathogens across the globe. Rodents, fleas, mosquitoes, and ticks can move disease-causing organisms into new areas of our cities, such as suburban and rural areas, putting more people in our communities at risk. New pathogens, such as chikungunya and Zika, have caused outbreaks in the U.S. for the first time. Recall last month's column where I mentioned the impact of climate change on vectors and the pathogens they carry.

Mosquito-borne and tickborne disease epidemics are happening more frequently. A case in point is the spread of Lyme disease in the U.S. Each year more than 30,000 cases of Lyme disease are reported nationwide. It is estimated by CDC that there are actually 300,000 cases of Lyme disease in the U.S.

Another example is a pest of environmental and public health interest that has been confronted by many environmental health professionals over the last decade—the bed bug. Although bed bugs are not a vector (i.e., disease causing), it is a pest that can cause both physical and mental health problems. Many health departments and environmental health professionals have had to spend their limited resources to control bed bugs in their communities.

> *State and local environmental health programs face increasing demands to respond to vector and pest threats.*

Another problem is that 80% of vector control organizations lack critical prevention and control capabilities. State and local environmental health programs face increasing demands to respond to these outbreaks and vector and pest threats. Environmental health programs and professionals need the training, resources, and skills to deal with this ever-increasing threat. More proven and publicly accepted vector and pest control and prevention methods are needed.

While working at CDC, Captain Michael Herring and I developed a vector and pest control course in collaboration with the National Environmental Health Association (NEHA) and a group of subject matter expects. We had heard the concerns more than a decade ago from environmental health professionals about the threats in their communities from an increase in vector and pest problems. Environmental health professionals also lacked the training and skills needed to deal with this problem. In collaboration with NEHA and our subject matter experts, we developed a multiday, face-to-face, hands-on course on the biology and control of vectors and pest of public health concern.

The outline of that course was done on the back of a Starbucks napkin. The basis of the course was integrated pest management (IPM)—some folks now use the term IVM (integrated vector management). Today you can take a free online course call Vector Control for Environmental Health Professionals (www.cdc.gov/nceh/ehs/elearn/vcehp.html). This course was done in partnership with CDC, the National Network of Public Health Institutes, Tulane University, and NEHA.

NEHA is working with vector control expects to update existing policies and to develop new policies on vector and pest control. NEHA's board of directors recently passed a policy on mosquito control to aid local and state environmental health professionals (www.neha.org/node/60010). In September 2018, NEHA and CDC hosted the 15th International Conference on Lyme Borreliosis and Other Tick-Borne Diseases. Over 300 scientists and vector control professionals from around the world attended the conference.

NEHA affiliates need to work with their partners (e.g., health departments, universities, law makers, vector and pest control companies, entomologists, etc.) to help identify needs in their areas to bring vector problems under control. One of these needs might be training of environmental health professionals. Other needs might be the monitoring and tracking of vectors and pest locally over time.

I have a few other suggestions.

- Use data to drive decisions in the community about vector control.
- Develop an action plan to control a vector of concern during all stages of life.
- Use multiple types of methods to control vectors.
- Conduct pesticide resistance testing.
- Educate the public on how to prevent bites and control the environments around their homes and neighborhoods to reduce the risk of vectorborne disease.

Recently, while still a CDC employee, I was fortunate to visit a large privately-owned vector and pest control company in Atlanta, Georgia. It had a very extensive training facility. The training facility consisted of indoor and outdoor areas to train the company's staff and technicians. I thought it would be a wonderful place to train some of our CDC staff that are involved in vector and pest control issues. I asked the company's leadership if CDC could send a few employees to their facility for training. They thought it was a wonderful idea. The moral of this visit was twofold: 1) don't be afraid to ask if it can help others and 2) public–private collaborations are important to gain control over vectors and the pathogens they spread.

Vince

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Barriers to Managing Private Wells and Septic Systems in Underserved Communities: Mental Models of Homeowner Decision Making

Editor's Note: Supplemental figures were submitted along with this peer-reviewed article and have been posted online due to space limitations. The Journal did not copy edit these figures; the authors are providing them as extra resources should the reader want more information. The supplemental information can be accessed at www.neha.org/supplemental.

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Abstract **Some African-American communities in the U.S. South are excluded from nearby municipal water and sewer services and therefore rely on private wells and septic systems. These "underbounded" communities are disproportionately exposed to water contaminants and face elevated risks for poor health outcomes. Outreach efforts encouraging proper well testing and maintenance are needed to protect health in these communities. To identify knowledge gaps and misconceptions that such outreach programs should target, we conducted semistructured interviews with 18 residents of such communities in Wake County, North Carolina. Only one interviewee conducted annual well testing as recommended by the county health department. Interview results suggest that testing is inhibited by lack of awareness of well maintenance guidelines, overreliance on sensory information, poor understanding of exposure pathways, and cost. Links between private septic systems, well water contamination, and health are poorly understood, hindering proper septic maintenance. These findings highlight the need for risk communication materials targeting at-risk communities.**

Introduction

Throughout the U.S. South, some African-American communities have been systematically excluded from municipalities through exclusionary zoning practices known as "underbounding" (Aiken, 1987; Lichter, Parisi, Grice, & Taquino, 2007). Today, municipalities control land use in these underbounded communities without providing services such as piped water, sewage disposal, and trash collection (Aiken, 1987; Lichter et al., 2007). Underbounded African-American neighborhoods frequently rely on private wells and septic systems, although municipal water and sewer lines encircle or bisect these communities to reach majority White neighborhoods (Heaney et al., 2013; Johnson, Parnell, Joyner, Christman, & Marsh, 2004; MacDonald Gibson, DeFelice, Sebastian, & Leker, 2014). African-American communities excluded from municipal services are disproportionately exposed to water contaminants and face increased health risks (Heaney et al., 2013; Stillo & MacDonald Gibson, 2017).

To minimize waterborne illness risk, households in underbounded areas should routinely test their water and take action when contaminants are detected (Centers for Disease Control and Prevention, 2014). Few private well owners, however, test their water as frequently as public health experts recommend (Schwartz et al., 1998). Although educational programs could promote well testing (Simpson, 2004), we are unaware of any research identifying what information and resources residents of underbounded communities need to improve stewardship of their water quality.

To identify homeowner perceptions, practices, and preferences related to private well and septic system maintenance and operation, we conducted semistructured interviews with residents in underbounded neighborhoods of Wake County, North Carolina. Our interviews followed the "mental models" framework, which involves assessing risk perceptions and behaviors and comparing them with expert recommendations to identify intervention needs (Bruine de Bruin & Bostrom, 2013; Morgan, Fischhoff, Bostrom, & Atman, 2002).

Here, we sought to inform outreach programs targeted at improving drink-

TABLE **1**

Interview Questions

Introduction

- What is it like to have well water?
- Could you please describe how your well water works?
- Do you have a septic system? If so, how does that work?
- Tell me what you think about city water in comparison to well water.
- What else can you tell me about well water?

Water quality perception

- How do you feel about the quality of your water?
- How would you rate your well water quality on a scale from 0 to 10, with 0 being the worst and 10 being the best?*
- Why did you give that rating?
- How would you rate the city water quality on a scale from 0 to 10, with 0 being the worst and 10 being the best?*
- Why did you give that rating?

Water source preferences

- If you had a choice, would you like to have well water or city water?* Why?
- Any other reasons? Can you explain (each reason)?
- Do most of the people in this area also want (the preferred water)?*
- If yes, why do they want (the preferred water)?
- Does anybody want (the nonpreferred water)? Why (not)?
- If no, why don't they want (the preferred water)?
- Does anybody want (the preferred water)? Why? If preference is city water, what are some things that are keeping you from getting city water? If preference is not city water, what are some things that are keeping people who want city water from getting city water?

Well testing

- Have you ever tested the water in your well?*
- Why do you (not) test it?
- How often do you test the water in your well?*
- What kinds of tests do you do?
- Where do you send your water samples for analysis?
- When was the last time you tested the water in your well?*
- What did the test results say?
- Did anything change after you got the test results?* Why (not)?
- Do your neighbors test their well water?* Why (not)? If yes, what do they do to test it?

Well maintenance

- Do you do anything to maintain your well?* Why (not)?
- How often do you do maintenance work on your well?*
- What do you normally do?
- When was the last time you did maintenance work on your well?*
- What did you do then?
- What does it generally cost you to do maintenance on your well?*

Septic maintenance

- Do you do anything to maintain your septic system?* Why (not)?
- What do you do to maintain your septic system?
- How often do you do maintenance on your septic system?*
- When was the last time you did maintenance work on your septic system?*
- What did you do then?
- What does it generally cost you to do maintenance on your septic system?*

Characteristics of well

- Do you know when your well was installed?*
- How deep is your well?*
- Is your well a hand-dug well, a bored well, or a drilled well?

Pros and cons of water types

- Overall, have you enjoyed having well water?*
- What are some good things about having well water?
- What are some bad things about having well water?
- What do you think are some good things about having city water?
- What do you think are some bad things about having city water?
- Do you know of anyone on city water who has noticed any unusual water tastes, colors, or smells?* If so, please explain.
- Do you know of anyone on city water who has gotten sick from their water?* If yes, please explain.
- Have you ever noticed any unusual tastes, colors, or smells with your water?* If yes, please explain.
- Do you know of anyone else on well water who has experienced unusual tastes, colors, or smells with their water?* If yes, please explain.
- Have you ever gotten sick from your water?* If yes, please explain.
- Do you know of anyone else who has gotten sick from their well water?* If yes, please explain.

Exit question

- Is there anything else you did not have the chance to tell me?

Note. Questions were asked in the same order for each interviewee. Answers to questions marked by an asterisk are summarized in Table 3.

ing water quality in communities without access to municipal water services in North Carolina and elsewhere. Specifically, our research objectives were to 1) assess current well and septic system monitoring and maintenance behaviors in underbounded communities, 2) identify factors influencing these behaviors to guide future risk communication development, and 3) assess community preferences for private wells versus community water systems.

Methods

Participant Recruitment

Following approval by the University of North Carolina (UNC) Institutional Review Board, interviewees were recruited from 57 households participating in a previous UNC study of water quality in underbounded Wake County neighborhoods (Stillo & MacDonald Gibson, 2017). Recruitment letters were mailed to all 57 households offering a $50 gift card for participation. The first 20 respondents were enrolled. Two were excluded due to poor interview audio quality.

Interview Design

Interviews began with five open-ended questions about well water, septic systems, and city water (Table 1). Following the mental models approach, the script used neutral wording and avoided leading questions (Morgan et al., 2002). As the interviews progressed, more focused questions were asked. Specifically, we focused on water quality perceptions, water source preferences, well testing, well maintenance, septic maintenance, well and septic system characteristics, and experiences with city and well water. To conclude, participants were invited to discuss any topics not previously covered.

Interview Coding

Each interview statement was coded to identify whether it addressed specific topics in expert models of private wells and septic systems. These models are represented as qualitative influence diagrams; they were created through a combination of literature review and expert consultations (see supplemental figures). Nodes in the expert diagrams represented critical factors influencing well and septic system management and performance. For example, private well diagram nodes included contamination sources (e.g., septic systems and groundwater contamination), well system components potentially affecting water quality (e.g., corrosion of plumbing), and specific contaminants that should be routinely monitored. Each node was assigned a code.

If an interview transcript statement referred to a node, it received the corresponding code. When most interviewees vaguely discussed a group of codes rather than mentioning each individually, multiple codes were merged into one new, more general code. For example, septic drain field parts received the same code because most interviewees did not discuss the drain field in detail. Another list of codes was added to represent topics commonly raised by interviewees but absent from expert models. For example, expert diagrams did not include cost, but all participants mentioned cost.

A team of coders was trained to apply codes to statements from three transcripts. Following training, the coding system was adjusted to improve accuracy. Subsequently, two coders independently coded each interview statement. Coders agreed on 55% of statements (Cohen's $\kappa = 0.54$, excluding the three training transcripts). In cases of disagreement, a third coder decided between the first two codes. Finally, the number of interviewees mentioning each code was computed.

TABLE **2**

Demographic Characteristics of Study Participants in Comparison With Participants of Prior Water Sampling Study and With Wake County

Characteristic			
Race/ethnicity (%)	Study Participants (*n* = 18)[a]	Original Cohort (*n* = 57)[b]	Wake County[c]
African-American	55.6	45.6	19.4
Asian	0	0	5.8
Hispanic	0	0	10.0
White	27.8	24.6	61.6
Other or preferred not to answer	16.7	29.8	3.2
Age (%)	Study Participants (*n* = 17)[e]	Original Cohort (*n* = 26)[e]	Wake County[c]
20–64	89.5	65.4	62.7
≥65	10.5	34.6	8.5
Income	Study Participants (*n* = 9)[e]	Original Cohort (*n* = 26)[e]	Wake County[c]
Median household income	$62,500	$40,000	$63,791
Percent below the poverty line	11.1	19.2	11.6
Education (%)	Study Participants (*n* = 10)[e]	Original Cohort (*n* = 26)[e]	Wake County[d]
≥25 years with less than a high school diploma	10.0	3.8	8.1
≥25 years with a high school diploma or GED	0	23.1	16.8
≥25 years with some college but no degree	20.0	11.5	18.0
≥25 years with an associate degree	10.0	3.8	8.2
≥25 years with a 4-year degree	30.0	34.6	31.2
≥25 years with a graduate/professional degree or higher	30.0	23.1	17.7

[a]Participants in this study.
[b]The original cohort population is from Stillo & MacDonald Gibson (2017); 57 households participated in that study.
[c]2012 U.S. Census.
[d]2015 American Community Survey.
[e]Refers to number of participants answering specific demographic questions.

Results

To assess homeowner practices, perceptions, and preferences related to private well and septic system maintenance in underbounded communities and inform future outreach efforts, we conducted semistructured interviews with 18 homeowners, following the mental models approach (Morgan et al., 2002). We sought to determine whether participants followed recommended monitoring and maintenance practices, to identify key beliefs and factors that might influence adherence to these recommendations, and to ask whether participants preferred private wells or would like to be connected to a nearby, regulated community water supply.

Characteristics of Study Participants

Table 2 compares our 18 participants with the 57 households in UNC's water quality study of underbounded communities and with Wake County. The proportion of African-American participants (55.6%) was

TABLE **3**

Summary of Responses to Direct Interview Questions

Interview Question	Statistic	Minimum	Maximum	*n*
Well characteristics				
Mean well age (year)	25 ± 13	1	50	17
Mean well depth (ft)	150 ± 88	30	290	10
Well type (*N* = 18)				
Dug	0%	–	–	
Bored	22%	–	–	
Drilled	44%	–	–	
Don't know	33%	–	–	
Well testing				
Has tested water	83%	–	–	19
Took action after testing	38%	–	–	13
Know neighbors who test water	12%	–	–	17
Frequency of well testing (year)	13 ± 14	1	~50	15
Well and septic maintenance				
Does anything to maintain well	44%	–	–	18
Does anything to maintain septic system	94%	–	–	16
Time since last well maintenance (year)	1.0 ± 1.4	<0.1	4.0	7
Time since last septic system maintenance (year)	3.4 ± 4.1	0.2	15.0	14
Well water quality perceptions				
Enjoys well water	89%	–	–	18
Has experienced unusual tastes, colors, or smells	22%	–	–	18
Knows others on well water who have noticed unusual tastes, colors, or smells	11%	–	–	18
Has been sick from own well water	0%	–	–	18
Knows others who have been sick from well water	5.6%	–	–	18
Water source preferences				
Well water rating (10 = best)	7.7 ± 2.0	2.5	10	18
City water rating (10 = best)	7.6 ± 1.7	5	10	16
Prefer well water to city water	72%	–	–	18
Anything preventing access to city water (% yes)	79%	–	–	14

slightly higher than for the 57 households in the UNC water quality study (45.6%) and much higher than in Wake County (19.4%). The proportion of participants over age 65 (10.5%) was lower than in UNC's water quality study (34.6%) but higher than in the county population (8.5%). Of interviewees choosing to report an education level (*n* = 10), 60% had a 4-year degree or higher, which was similar to the UNC water quality study (57.7%) and slightly higher than in the county's adult population (48.9%).

Testing and Maintenance Practices

One of 18 respondents tested their water annually as recommended by the Wake County Department of Health (Table 3, Figure 1, and see supplemental figures). Half of respondents reported testing less than every 5 years (*n* = 8) or never (*n* = 3). Additionally, eight respondents reported conducting well maintenance.

The North Carolina Division of Public Health recommends pumping septic systems every 3–5 years. Seven respondents, however, either were unable to recall their last septic system maintenance or reported last pumping more than 5 years ago. One respondent last pumped their system 15 years ago.

Although all 18 interviewees mentioned water testing, few knew what to test for or how often. For example, six respondents mentioned the need to test for bacteria, but only three were aware that health departments recommend annual bacterial testing. Only three mentioned needing to test for pH and total dissolved solids, and none mentioned pesticide testing. All but three homeowners were unaware that testing should be routine, rather than conducted only once. For example, after describing a previous bacterial contamination event, one participant said, "Oh, I haven't had it tested since that incident….Should I have had it tested again?"

To better understand testing barriers, we asked interviewees why they do not test their water. Answers included "I never thought of it, never thought it needed testing" and "I don't really know what all [testing] entails…. I don't know how to get it tested." One homeowner, although knowledgeable about well systems and contamination sources, justified not testing with "just hadn't gotten around to it." These statements indicate low awareness of testing procedures and their importance in ensuring safe drinking water.

Participants seemed unaware of the need to inspect their well each year or to conduct other routine maintenance activities (see supplemental figures). Only one interviewee mentioned having an annual well inspection. Three people mentioned inspecting wells to protect water sources and two others mentioned inspection by a licensed contractor, but these interviewees thought inspections were needed only upon home purchase. Additionally, 17 participants commented on issues related to well maintenance.

One interviewee described regularly shock chlorinating the well as "anything to do with a home or that comes attached to the home, you have to do maintenance on it and you have to keep it up, so when I first bought the house, I was kind of given just verbal instructions on how to maintain the well, how to keep it clean…every so often you have to shock [chlorinate] the water maybe about once a year and several things like that."

Nonetheless, of these 17 respondents, only one was aware of routine maintenance needs.

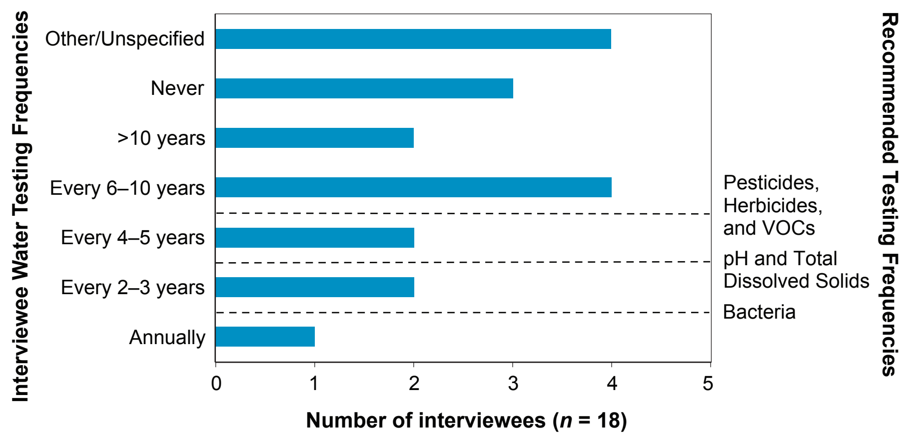
One homeowner stated, "I didn't realize that other than testing periodically that there were things that I could do [to maintain my well] because it's a covered well." Other participants described avoiding upkeep unless their well breaks or water quality becomes poor: "I don't do anything to maintain it…. It's just wait until something happens."

Of the 17 participants with a septic system, 16 conduct routine maintenance. Two people discussed inspecting septic systems and 13 mentioned septic system pumping (see Figure 2, supplemental figures), although as previously noted, only 11 participants followed the recommended pumping frequency (every 3–5 years or more often if the solids level surpasses one third of tank capacity). Misconceptions about pumping frequency were common. For example, whereas experts recommend pumping septic tanks when one-third full with solids, one homeowner said, "You know, once [the septic tank] gets full, you have to have them…clean it out." Another participant said, "I know if we ever get a bad odor, then we have to have [the septic tank] cleaned out…. I know it's been about 15 years [since I last had the septic tank pumped]." Thus, although pumping was frequently mentioned, some homeowners still lacked knowledge about its importance or recommended frequency.

Most or all participants overlooked several other factors identified by experts as affecting septic system performance. For example, none mentioned that flushing large water or waste quantities at once overloads the system and reduces functionality. Although one interviewee mentioned flushing chemical additives, no one correctly discussed how certain chemicals, solids, or cooking oils can harm the system. Only six participants recognized the need to avoid septic system additives. Only four realized that vegetation other than grass should not be planted in the septic drain field. These findings suggest that homeowners are generally unaware of how to ensure septic system functionality.

FIGURE **1**

Private Well Owners Self-Reported Water Testing Frequencies as Compared With Frequencies Recommended by the Wake County Department of Environmental Services



VOC = volatile organic compound.

Beliefs Influencing Well and Septic System Stewardship

In addition to low awareness of expert monitoring and maintenance recommendations, our interviews revealed three belief categories affecting well and septic system stewardship: 1) inaccurate beliefs that all water contaminants can be detected through sensory perception, 2) low awareness of septic systems as a water contamination source, and 3) poor understanding of contaminant exposure routes.

Assessing Water Quality With Sensory Information

All 18 interviewees mentioned reliance on appearance, smell, and taste to detect contamination. As one homeowner put it, "I don't know, [about my water quality] because I haven't had results from the tests, but right now I feel like [my water quality] is fine as far as the human eye can see and the nose can smell and my hands can feel. Those are the only things I have, my senses."

Another homeowner said, "I think water should be clear as water should be and if it's anything other than that, I wouldn't want to cook or drink with it." Many participants conveyed that sensory information prompts testing practices and remedial actions. One such interviewee stated "Basically, when we first moved in [we tested the water] because our water tasted funny." The majority of interviewees (14) reported not having noticed unusual tastes, colors, or smells in their water.

Links Between Septic Systems, Well Contamination, and Health

Only one interviewee mentioned septic waste as a well water contamination source and none mentioned failing septic systems as a waterborne disease source. These results indicate that homeowners do not realize important links between functioning septic systems, good water quality, and health.

Poor Understanding of Exposure Routes

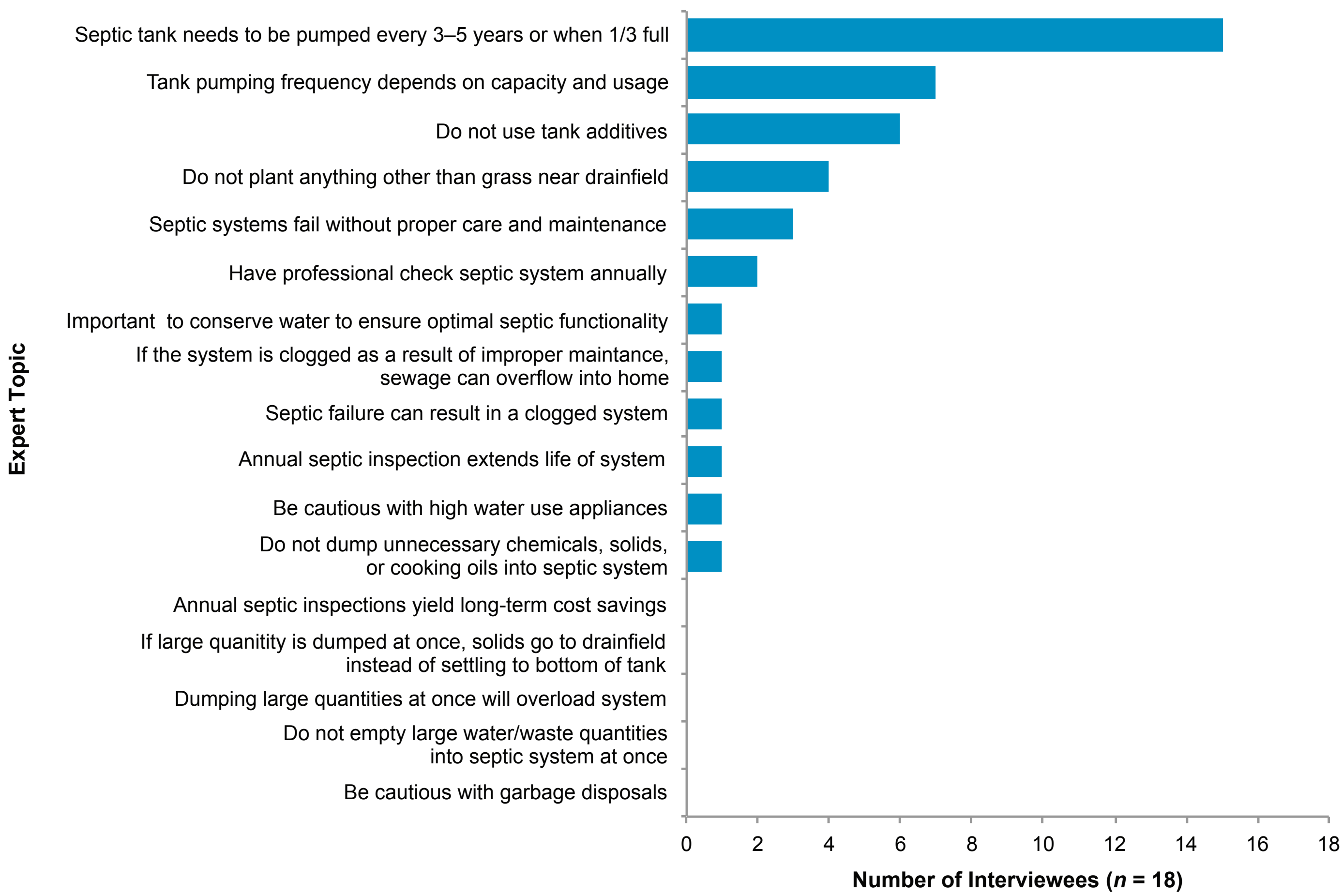
One person mentioned inhalation and three mentioned dermal contact as waterborne contaminant exposure routes. Five respondents mentioned that they avoided drinking their water because of its poor quality, yet they still used it to bathe and wash clothes or dishes. Three interviewees saw avoiding water ingestion as a rationale for forgoing testing. When asked why they did not test their water, one person responded, "Because we don't drink it." Thus, homeowners seem unaware of health effects from exposure via dermal contact and inhalation.

Private Well Versus Community Water Preferences

Overall, 16 respondents reported enjoying well water (Table 3). They generally rated the quality of their well water as similar to that of city water (7.7 ± 2.0 versus 7.6 ± 1.7 on a 10-point scale). Among respondents, 14 preferred well to city water; however, 14 mentioned barriers "that are keeping people who want city water from getting city water."

FIGURE **2**

Frequency With Which Interviewees Mentioned Key Factors Related to Private Septic System Maintenance as Recommended by Experts



Although not included in the expert models, all interviewees mentioned cost (see supplemental figures). Seven homeowners said they do not have to pay for well water and 13 specified not having monthly water bills. Seven elaborated upon well costs in comparison to city service costs: "I [do not] need a water bill….I [do not] have additional taxes to cover the cost of the water service….One of the downsides of well water is that you have to incur [maintenance] costs, and so there's risk if the pump fails or other parts fail."

Three interviewees expressed cost as a barrier to achieving better water quality. One stated that "cost and the issues about doing [testing] properly [are keeping me from testing more frequently]." Another explained that "the filter system…is very costly, so we just weren't in a position to purchase it."

Control over water quality, also not included in the expert models, was discussed in 10 interviews. Three interviewees described feeling more in control with private well water than city water. As one put it, "I like having more control over the quality of my water…I feel safer actually....You have more control over the quality of the [well] water…Having very little control over what is in the [city] water is the biggest thing, and very little knowledge of what's in it."

Another interviewee said, "I basically know what I'm drinking since I'm responsible for [my well water]." A third explained, "A terrorist attack on a municipal water system. That seems kind of scary….Also we have a very enclosed water system…we're not at the mercy of everyone else." Related to these comments was the perception that well water is more "natural" than city water due to the lack of chemical additives. These observations indicate that homeowner mental models emphasize being in control of water quality.

Fourteen participants mentioned water availability. Nine said that relying on wells instead of city systems provides freedom to use unlimited water. One interviewee stated, "I can use [my well] as I see fit….[My water is] not regulated by somebody telling me you can't use any water for this or you can't use any water for that the way they do." Conversely, three described having insufficient well water. One interviewee explained that "When I do laundry….I notice that the well tank, the pump will shut down…either it overheats or there's not enough water in the well because I'm using so much." Another participant said, "I would rather have [my well] water…add more convenience to my lifestyle….I would love to have [my well water] more accessible." These statements signal that homeowners value convenient access to an adequate water quantity.

Discussion

We sought to assess whether residents of underbounded neighborhoods of Wake County, North Carolina, follow expert recommendations for maintaining their wells and septic systems. We also sought to identify beliefs influencing maintenance practices and to determine preferences for private well water or municipal water service. Our results suggest that residents of these neighborhoods do not adequately test or maintain wells and septic systems. Nor are they aware of any guidelines. The perception that testing is unnecessary if water looks, tastes, and smells clean was common.

Only one respondent was aware of the need for annual well inspections. Similarly, only one respondent recognized the effects of septic system maintenance on well water quality. Some respondents—unaware of dermal and inhalation exposure routes—indicated they do not test their water because they use it only for bathing and cooking. Many respondents said that cost was a barrier to ensuring good well water quality. Cost also influenced preferences for well water over municipal water, which would require monthly utility bills. Despite not following well monitoring and maintenance guidelines, many respondents believed that they had more control over their water quality than would be possible with municipal water.

Although our study was the first to assess well and septic system maintenance in marginalized African-American communities, the low frequency of private well testing among our interviewees echoes recent findings in North American rural areas (Borsuk, Rardin, Paul, & Hampton, 2014; Jones et al., 2005; Swistock, Clemens, Sharpe, & Rummel, 2013). For example, a survey of 701 rural well owners in Pennsylvania found "Zero to 31% of homeowners with water supplies that contained unsafe levels of bacteria, nitrate-N, arsenic, or lead were already aware of these water quality problems" (Swistock et al., 2013).

Similar to what we found in our study, focus groups with private well owners in rural New Hampshire found that few were informed about local, state, and federal testing guidelines (Borsuk et al., 2014). Additionally, the misperception that testing is only necessary if the water tastes, looks, or smells contaminated has previously been reported among private well owners in New Hampshire and Ontario (Borsuk et al., 2014; Jones et al., 2005). The New Hampshire study indicated that among well owners who do not test their water, 20% reported cost as a barrier (Borsuk et al., 2014).

Our findings of low awareness of connections between septic system maintenance and well water quality, along with misperceptions about septic maintenance guidelines, are also consistent with prior studies. For example, our prior interviews with North Carolina city officials in charge of evaluating whether to extend municipal services to underbounded areas found that most were unaware of the effects of septic tank failure on water quality and health (Naman & MacDonald Gibson, 2015). A study in rural New York found that more than one third of septic systems had never been pumped (Schwartz et al., 1998).

This study was designed to use semistructured interviews to elicit beliefs, rather than to administer a large survey that presupposes what those beliefs are. Due to the small sample size, our results cannot be used to determine belief prevalence. Instead, our findings highlight *which* beliefs people may hold, not *how common* those beliefs are (Bruine de Bruin & Bostrom, 2013). Prior analyses of interview findings support that a sample size of 10–15 generally is adequate for identifying the most commonly held beliefs in a population (Bruine de Bruin & Bostrom, 2013; Morgan et al., 2002).

Yet, one limitation is potential bias introduced by enrollment methods. Participants previously volunteered for water testing as part of a related research project (Stillo & MacDonald Gibson, 2017). Additionally, we enrolled the first 20 people who responded to our recruitment letter. Our enrollment methods could have included participants who are more proactive than the general population. Furthermore, it is also possible that enrolled subjects experience more water quality problems, potentially from a lack of well and septic management, and therefore were prompted to act.

Conclusion

Our study reveals key factors influencing testing and maintenance of private wells and septic systems in majority African-American neighborhoods that are underbounded, or excluded from nearby municipal water and sewer service. Key factors include lack of knowledge of health department water testing guidelines, beliefs that contaminants can be detected through sensory perception and that testing is unnecessary when drinking bottled water (even when using well water for cooking and bathing), the presumption that well water is of high quality (even if never tested), lack of understanding of contamination sources, and cost.

To design effective risk intervention programs to improve water quality in underbounded communities, a large-scale survey measuring belief prevalence in the target population is needed (Bruine de Bruin & Bostrom, 2013). Subsequent risk communications can be designed to correct common misconceptions about the importance of testing and maintaining private wells and septic systems (Morgan et al., 2002). Additionally, due to emphasis on costs throughout these interviews, subsequent research should assess the degree to which removing cost barriers would influence water system stewardship and preferences.

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Editor's Note: A supplemental document was submitted along with this peer-reviewed article and has been posted online due to space limitations. The Journal did not copy edit the supplemental document; the authors are providing it as an extra resource should the reader want more information. The supplemental document can be accessed at www.neha.org/jeh/supplemental.

Cooling Tower Maintenance Practices and *Legionella* Prevalence, Allegheny County, Pennsylvania, 2016

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Abstract **Cooling towers have been linked to outbreak-related and nonoutbreak-related legionellosis. Proper cooling tower maintenance and disinfection are imperative for legionellosis prevention but not monitored in Allegheny County, Pennsylvania, which is a high incidence area. To investigate cooling tower maintenance and *Legionella* positivity, the Allegheny County Health Department (ACHD) performed a survey regarding the presence and maintenance of cooling towers and tested cooling towers for *Legionella pneumophila (Lp)*. ACHD surveyed healthcare facilities, senior apartment buildings, and county-owned buildings.**

Associations between maintenance practices and *Lp* were assessed using Wilcoxon rank-sum tests and multivariable linear regression. Of 408 building managers contacted, 377 (92%) completed the survey and 56 (15%) reported managing a building with a cooling tower. Among 42 cooling towers sampled, 20 (48%) tested positive for *Lp*. Factors associated with positivity included larger tower capacity, year-round usage, hospital status, and older tower age. Only cooling tower age was associated with *Lp* after stepwise regression.

Despite maintenance practices, many cooling towers were *Lp* positive. ACHD recommends that facilities develop a water management plan that is compliant with standards of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers and also conduct annual basin water emptying, quarterly cleaning, and diligent inspection of older towers.

Introduction

Legionnaires' disease (LD) is the second most common cause of bacterial pneumonia in the U.S., accounting for 2–9% of community-acquired pneumonia cases (Cunha, Burillo, & Bouza, 2016; Stout & Yu, 1997). Developed countries around the globe have experienced an increase in LD incidence since the 2000s (Beauté, Zucs, de Jong, & European Legionnaires' Disease Surveillance Network, 2013; Centers for Disease Control & Prevention [CDC], 2011; Farnham, Alleyne, Cimini, & Balter, 2014). From 2000–2014 in the U.S., legionellosis incidence, which includes LD and the milder, less commonly reported Pontiac fever, increased 286%, from 0.42–1.62 annual cases per 100,000 people (Garrison et al., 2016). This trend persists even after age-adjustment (CDC, 2011).

The majority of cases reported in the U.S. and worldwide occur sporadically with no identified source (Che et al., 2008; Fields, Benson, & Besser, 2002). The most common sources are speculated to be home potable water, travel-associated potable water, and evaporative cooling towers (Bhopal, 1995; Ricketts, Joseph, Lee, & Wilkinson, 2012). Through spatial analysis of LD in England and Wales, Ricketts and coauthors (2012) estimated that 20% of sporadic cases could be attributed to cooling towers.

Transmission of LD occurs through inhalation or aspiration of water containing *Legionella*. *Legionella* is a waterborne pathogen found in most aqueous environments and proliferates in warm, stagnant water. *Legionella* bacteria commonly inhabit amoeba as intracellular parasites and thrive in biofilms formed on surfaces (Cunha et al., 2016). Conditions for proliferation are commonly found in evaporative cooling towers. Prevalence of the bacteria in these structures has ranged from 2–87% and variations exist likely due to sample selection, maintenance practices, and possibly local cooling tower regulations (Lau, Maqsood, Harte, Caughley,

& Deacon, 2013; Mouchtouri, Goutziana, Kremastinou, & Hadjichristodoulou, 2010; Ragull et al., 2007; Türetgen, Sungur, & Cotuk, 2005; Witherell et al., 1986).

Both large and small LD community outbreaks have been caused by cooling towers. A 2014 review article described 19 outbreaks attributable to cooling towers with case counts ranging from 7–449 cases and a 6.3% average case fatality rate (Walser et al., 2014). A hotel cooling tower in the South Bronx neighborhood of New York City caused a 2015 outbreak that sickened 138 people and killed 16. Clinical *Legionella* isolates matched the strain of *Legionella* found in the cooling tower (Weiss et al., 2017). In response to this outbreak, both New York City and the state of New York issued emergency regulations requiring cooling tower registration, inspection, and *Legionella* testing (New York State Public Health and Health Planning Council and the Commissioner of Health, 2015).

The highest incidence of legionellosis in the U.S. occurs in the Mid-Atlantic Region. Allegheny County, Pennsylvania, which is part of this Mid-Atlantic Region, experiences rates 4 times higher than the U.S. age-adjusted rate (Allegheny County Health Department, 2014). Over two thirds of LD cases reported annually in Allegheny County are of unknown origin. These cases are unrelated to outbreaks or healthcare facilities. Cooling tower-related LD has not been identified recently in Allegheny County, but has occurred in the past. Investigating the conditions of cooling towers is an important component of LD prevention, especially in an area with a high burden of the disease. The purpose of this survey was to assess *Legionella* prevalence in Allegheny County cooling towers and then identify areas of improvement for cooling tower maintenance and *Legionella* contamination prevention in Allegheny County.

Methods

Cooling Tower Maintenance Survey

Buildings selected for the survey included those that house populations who are susceptible to LD. These buildings included hospitals, skilled nursing facilities, assisted living facilities, personal care homes, and senior apartment buildings identified through the Pennsylvania Department of Health and Department Human Services. Allegheny County senior apartment buildings were identified through a Google search using search terms "senior apartment AND Allegheny county." City- and county-owned buildings in Allegheny County, Pennsylvania, were also surveyed and identified through the Allegheny County Housing Authority, the Housing Authority of the City of Pittsburgh, and the Allegheny County Facilities Management Department.

A questionnaire was completed over the phone or sent via e-mail or fax based on facility preference. The questionnaire began with vetting questions to ensure the most knowledgeable persons at the facility completed the survey (see supplemental document). Survey questions were based on guidelines from the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), the Cooling Technology Institute, U.S. Environmental Protection Agency (2016), and the World Health Organization.

Structural questions addressed building size, number of cooling towers, cooling tower location, and name of water authority. Maintenance questions addressed use of water treatment professional, cooling tower cleaning and inspection procedures, water filtration, basin emptying, biocide treatment and monitoring, record keeping, bacterial load testing, and *Legionella* testing. Finally, facilities were asked by ACHD to consent to testing their cooling tower basin water for *Legionella*.

Cooling Tower Sampling

At consenting facilities, ACHD staff selected a single, random cooling tower for testing if the facility had multiple cooling towers. The cooling tower's make, model, serial number, year installed, and size (tonnage) were recorded. Basin water temperature was measured using a digital probe thermometer and pH was measured using test strips. Free and total chlorine were measured using test strips (range 0–10 ppm at increments of 0, 0.5, 1, 2, 4, and 10 ppm).

Basin water was collected in sterile 125 mL plastic bottles. Bottles were filled to 30 mL with basin water and a drop of sterile 0.1 N sodium thiosulfate was added to the bottle immediately after water collection using a sterile, disposable transfer pipette. Water samples were sent to the ACHD Public Health Laboratory on the same day as sample collection. Water samples were stored at 5 °C until processing.

Microbiological Methods

Water samples were cultured for *Legionella pneumophila* (*Lp*) within four days of collection at the ACHD Laboratory. Each specimen was plated onto GVPC agar directly after acid treatment and heat treatment. Specifically, *Legionella* acid buffer was added to each sample for 15 min at room temperature. Samples were heat treated at 50 °C for 30 min in a water bath before plating. Plates were incubated at 35 °C and read at 3 and 7 days. Any identified colonies were picked and plated on SBA and GVPC agar and incubated overnight at 35 °C. Isolates that grew on GVPC agar were tested with Oxoid *Legionella* Latex Test kit (Oxoid Ltd.) and confirmed positive for *Lp* serogroups 1, 3, 5, 6, Poly 1–14, or b-m with a direct fluorescent antibody test (Monoclonal Technologies, Inc.; rabbit anti-*Legionella* IgG fluorescein labeled).

Whole Genome Sequencing and Phylogenetics

Genomic DNA was extracted at the University of Pittsburgh School of Medicine, Infectious Disease Epidemiology Research Unit, using the Qiagen DNAeasy Tissue Kit on a QIAcube according to manufacturer's instructions (Qiagen). The DNA was eluted in 10 mM Tris/1 mm EDTA and sequenced according to the method of Baym and coauthors (2005) using Illumina Nextera genomic libraries on a MiSeq v2 (500-cycle) kit.

Fastq Reads were trimmed and assembled using SPAdes version 3.9.0. Assemblies were annotated using Prokka version 0.1.1. The sequencing depth ranged from 36–94X. The assemblies had a median of 96 contigs per sample with an average assembly length of 3.7 Mbp and an average N50 of 200,000 bp.

Sequence types (ST) were identified using SRST2. Reads were aligned to reference assembly, LEG551, using BWA-MEM version 0.7.12-r1039. For ST2329 pairwise comparisons, LEG443 was used as the reference genome. Single-nucleotide polymorphisms (SNPs) were identified using GATK HaplotypeCaller version 3.5 with a ploidy of 1. SNPs with low mapping quality (MQ < 20), strand bias (FS > 60.0), low variant confidence (QD < 2), only seen near the ends of reads (ReadPosRankSum < -8.0), or low depth (DP < 5) were filtered using GATK VariantFiltration. A phylogenetic tree of aligned SNPs was generated using RAxML version 8.2.9 with 100 bootstrap replicates under the generalized time-reversible model (GTRCAT) and Lewis correction for ascertainment bias. Phylogenies were visualized using the Python package ETE3.

Statistical Analysis

Descriptive statistics for the sample were presented using either the proportion or median. The outcome variable for this analysis, cooling tower *Lp* level (CFU/mL), was analyzed as a continuous variable. Each predictor variable was coded into two categories. Unadjusted analyses were performed to compare the distribution of *Lp* level between categories for each survey variable using Wilcoxon rank-sum test. Stratification by hospital status was employed to examine association among hospital and nonhospital facilities.

A multivariable linear regression model was created for the continuous outcome variable. Log transformation of the outcome variable was considered for improved model fit. Predictors that were univariately associated ($p < .1$) with *Lp* level were considered for the multiple regression model using a forward stepwise approach with an $\alpha = .05$ for entry and remaining in the final model. Interaction terms and confounding variables were assessed for inclusion in the final model. We used Epi Info version 7.1 and SAS version 9.4 for data management and analysis, respectively.

TABLE **1**

Survey and Sampling Response Rate by Building Type, Allegheny County, Pennsylvania, Summer 2016 (*n* = 412)

Facility Type	Total Buildings # (%)	Completed Survey # (%)	Cooling Tower on Premises # (%)	Completed the Cooling Tower Sampling # (%)
Hospital	27 (7)	27 (100)	21 (78)	15 (71)
Skilled nursing	62 (15)	60 (97)	12 (20)	7 (58)
Assisted living	1 (<1)	1 (100)	0	0
Personal care	106 (26)	93 (88)	3 (3)	2 (67)
Senior apartment	70 (17)	65 (93)	11 (17)	11 (100)
City- or county-owned residence	41 (10)	32 (78)	0	0
General county-owned building	100 (24)	100 (100)	9* (9)	7 (78)
Total	407	377 (93)	56 (15)	42 (75)

*Two buildings had cooling towers operational only in the winter months, which was outside of the sampling window.

TABLE **2**

***Legionella pneumophila* Concentration Levels by Building Type, Allegheny County, Pennsylvania, Summer 2016 (*n* = 42)**

Building Type	Concentration (CFU/mL) # (%)					Total
	0	1–9	10–99	100–999	≥1,000	
All building types	22 (52)	0	16 (38)	2 (5)	2 (5)	42
Hospital	5 (29)	0	9 (53)	1 (6)	2 (12)	17
Skilled nursing	4 (80)	0	1 (20)	0	0	5
Assisted living	0	0	0	0	0	0
Personal care	2 (100)	0	0	0	0	2
Senior apartment	7 (64)	0	3 (27)	1 (9)	0	11
City- or county-owned residence	0	0	0	0	0	0
General county-owned building	4 (57)	0	3 (43)	0	0	7

Results

Survey Response

Among 412 facilities approached, 377 (93%) completed the survey. The response rate by facility type ranged from 78–100%; the majority of facility types had response rates above 90%. Of those participating facilities, 56 (15%) reported having a cooling tower on the premises (Table 1). Hospitals more frequently had cooling towers (78%), followed by skilled nursing facilities (20%) and senior apartment buildings (17%). Very few personal care homes and city- or county-owned buildings had cooling towers (Table 1).

Cooling Tower Sampling

Of the 56 cooling towers identified, 42 (75%) facilities agreed to ACHD testing. *Lp* was detected in 20 (48%) cooling tower basin water specimens. Of 17 hospitals tested, 12 (71%) were positive (Table 2); 1 (20%) skilled nursing facility, 4 (36%) senior apartment buildings, and 3 (43%) county-owned buildings were positive. Neither of the two personal care facilities tested were positive. Of those positive, the median concentration level was 35 CFU/mL with a range of 10–2,000 CFU/mL. *Lp* counts >100 were found in 3 (12%) hospitals and 3 (9%) senior apartment building (Table 2). Of the 19 (95%) isolates assigned a serogroup, 14 (74%) isolates were identified as serogroup 1, 4 (21%) as serogroup 5, and 1 (5%) as serogroup 6.

Survey Results and Univariate Analyses

Among the 42 facilities with ACHD water testing, the majority of cooling towers had treatment programs administered by a water treatment professional, were treated with at least one biocide, were tested regularly for biocide level and *Legionella*, had an automatic biocide feed, and had the tower basin cleaned and emptied of stagnant water regularly (Table 3). Only 31% of cooling towers were

TABLE **3**

Unadjusted Associations Between Continuous *Legionella pneumophila (Lp)* Level and Dichotomous Factors, Allegheny County, Pennsylvania, Summer 2016

Variable	Count (n = 42) # (%)	Median and Range of *Lp* Contamination Level (CFU/mL)		*p*-Value
		Feature Present	Feature Absent	
Capacity of tower >422 tons	19 (45)	20 (0–2,000)	0 (0–90)	.0003
Year-round use	13 (31)	40 (0–2,000)	0 (0–100)	.0015
Hospital	17 (40)	20 (0–2,000)	0 (0–100)	.0061
>1 cooling tower on site	20 (48)	20 (0–2,000)	0 (0–100)	.014
Nonconsecutive water authority surface water supply	33 (79)	0 (0–1,140)	20 (0–2,000)	.021
August or September Allegheny County Health Department test compared with June or July	19 (45)	20 (0–2,000)	0 (0–90)	.025
Cooling tower age >13 years	21 (50)	20 (0–2,000)	0 (0–100)	.057
Water management plan	9 (21)	20 (0–2,000)	0 (0–1,140)	.068
Located on roof	22 (52)	20 (0–2,000)	0 (0–1,140)	.096
Located on the ground	17 (40)	0 (0–1,140)	20 (0–2,000)	.12
Inspected >once per month	13 (31)	20 (0–1,140)	0 (0–2,000)	.13
Contract with water treatment provider	38 (90)	0 (0–2,000)	50 (0–90)	.14
Use of drift eliminator	23 (55)	0 (0–600)	10 (0–2,000)	.15
Legionella test ≥annually	22 (52)	20 (0–2,000)	0 (0–100)	.15
Use of both oxidizing and nonoxidizing disinfectants	17 (40)	20 (0–2,000)	0 (0–100)	.22
Tower cleaned >twice annually	9 (21)	0 (0–40)	10 (0–2,000)	.25
Direct or open circuit system	28 (67)	10 (0–2,000)	0 (0–70)	.25
Basin emptying ≥annually	28 (67)	0 (0–90)	10 (0–2,000)	.25
Use of nonoxidizing disinfectant only	5 (12)	0 (0–70)	10 (0–2,000)	.33
Protected from sunlight	6 (14)	30 (0–70)	0 (0–2,000)	.33
Regular basin cleaning	39 (93)	0 (0–2,000)	0 (0–10)	.38
Seasonal chloramination by water authority	11 (26)	0 (0–40)	0 (0–2,000)	.43
Maintenance and testing records kept	38 (90)	5 (0–2,000)	0 (0–40)	.44
Use of oxidizing disinfectant only	12 (29)	15 (0–100)	0 (0–2,000)	.45
Test for bacteria ≥annually	34 (81)	0 (0–2,000)	15 (0–90)	.51
Year-round chloramination by water authority	11 (26)	10 (0–2,000)	0 (0–1,140)	.66
Water filtration	17 (40)	10 (0–1,140)	0 (0–2,000)	.70
Automatic biocide feed	36 (86)	0 (0–2,000)	5 (0–40)	.75
Free chlorine used by water authority	20 (48)	0 (0–1,140)	5 (0–2,000)	.76
Basin water temperature >77 °F	16 (38)	5 (0–600)	0 (0–2,000)	.84
Basin water pH >7	3 (7)	0 (0–90)	0 (0–2,000)	.86
Test for biocide routinely	27 (64)	0 (0–2,000)	0 (0–70)	.89

Note. Shaded rows indicate statistical significance, $p \leq .1$.

inspected more frequently than monthly. All cooling towers were cleaned at least annually, but only 21% were cleaned more than twice a year, as most cooling towers were cleaned at the beginning and the end of the cooling season, which is generally April–October.

Only 21% of facilities with a cooling tower had a cooling tower water management plan and of those, most qualified as corporate plans (Table 3). It was difficult to verify whether a facility diligently followed a corporate plan that was not developed specifically for their tower(s). Average age of cooling towers was 13 years, ranging from <1–38 years (Table 4). Average tonnage or capacity of the cooling tower was 422 tons, ranging from 29–14,950 tons (Table 4).

In unadjusted analyses, increased *Lp* concentration was associated with larger tower capacity, year-round usage, hospital status, multiple towers, late summer tower sampling, older tower age, water management plan existence, and roof location (Tables 3 and 4). Nonconsecutive water authority supplier (i.e., obtains water directly from surface water source rather than purchasing from another water authority) was associated with decreased concentration (Table 3).

The average cooling tower basin water temperature during ACHD testing was 76 °F (62–88 °F). The average pH during testing was 7.0 (6.0–11.0). Average total and free chlorine levels were <0.5 ppm (0–4 ppm) and <0.5 ppm (0–10 ppm), respectively. None of these water quality measurements was significantly associated with *Lp* concentration (Table 4).

When stratifying by hospital status, year-round usage and older tower age were univariately associated with increased concentration in hospital cooling towers, whereas larger tower capacity was univariately associated with increased concentration in nonhospital cooling towers (Table 5).

TABLE **4**

Unadjusted Associations Between Continuous *Legionella pneumophila* Level and Continuous Factors, Allegheny County, Pennsylvania, Summer 2016

Variable	Mean and Range (*n* = 42)	Regression Coefficient	*CI*	*p*-Value
Cooling tower age (years)	13 (<1–38)	20.5	6.8, 34.1	.0043
Number of towers on site	2 (1–6)	83.4	7.2, 159.7	.033
Allegheny County Health Department sampling month	July (June–September)	62.9	-42.8, 168.7	.24
Basin water temperature (°F)	77 (62–88)	5.7	-15.4, 26.8	.59
Basin water total chlorine level (ppm)	<0.5 (0–10.0)	-13.7	-88.2, 60.8	.71
Basin water free chlorine level (ppm)	<0.5 (0–4.0)	-23.0	-212.7, 166.7	.81
Capacity of tower (tons)	422 (29–17,950)	0.004	-0.04, 0.05	.82
Basin water pH	7.0 (6.0–11.0)	1.4	-152.7, 155.5	.99

CI = confidence interval.
Note. Shaded rows indicate statistical significance, $p \leq .1$.

TABLE **5**

Significant Unadjusted Associations With *Legionella pneumophila* Level Stratified by Hospital Status

Variable	Count # (%)	Mean and Range of Feature Present	Mean and Range of Feature Absent	*p*-Value
Hospital (*n* = 17)				
Year-round use	10 (59)	60 (0–2,000)	0 (0–40)	.014
Cooling tower age >13 years	12 (71)	50 (0–2,000)	0 (0–20)	.038
Nonhospital (*n* = 23)				
Capacity of tower >422 tons	7 (28)	10 (0–100)	0 (0–70)	.0098

Multiple Linear Regression

Cooling tower age was the only predictor significantly associated with the log transformed *Lp* concentration outcome based on stepwise regression methods. As cooling tower age increased, concentration level also increased. Year-round usage and hospital status were included in the final model to account for potential confounding between tower age and *Lp* level (Table 6).

Whole Genome Sequencing

Whole genome sequencing was performed on 13 isolates. Of those, 12 were *Lp* serogroup 1. The isolates belong to six serotypes (Figure 1). Five isolates belong to ST8 (LEG 322, 349, 507, 551, and 590) and four isolates belong to ST2329 (LEG443, 574, 575, and 588). LEG591 belongs to ST2330, a single locus variant of ST8. This isolate, however, is unrelated to ST8 isolates having >9,000 SNP differences. ST8 isolates LEG322, 507, and 551 had <80 SNP differences (Figure 1, Table 7).

In a pairwise comparison, LEG443 and LEG574 belonging to ST2329 were closely related with <40 SNP differences (Table 8). Interestingly, three of the ST2329 isolates came from cooling towers located within 1.2 miles of each other. No geographic clustering was observed between the ST8 isolates.

Discussion

Almost half of surveyed cooling towers in Allegheny County were positive for *Lp*, which causes the vast majority of LD (CDC, 2011). The most important indicator of concentration level was cooling tower age. Whole genome sequencing identified six different ST, with the majority belonging to either ST8 or ST2329, a previously undescribed ST. We observed no apparent geographic clustering. ST8 is commonly found in cooling towers and has been linked to outbreaks internationally, but not in the U.S. (Kozak-Muiznieks et al., 2014).

Previous studies have found a wide range in the prevalence of *Legionella* in cooling towers outside of outbreak settings. In international prevalence studies of various sample sizes, *Legionella* contamination ranged from 2–100% (Lau et al., 2013; Mouchtouri et al., 2010; Negrón-Alvíra, Pérez-Suarez, & Hazen,

TABLE **6**

Multivariable Linear Regression Model of Independent Factors and Log-Transformed *Legionella pneumophila* Continuous Outcome

Independent Predictor	Inclusion Criteria	Coefficient	*CI*	*p*-Value
Cooling tower age	Independent predictor after stepwise procedure	0.07	0.006, 0.1	.03
Year-round usage	Confounder between tower age and outcome	0.6	-0.4, 1.6	.2
Hospital status	Confounder between tower age and outcome	-0.6	-1.8, 0.6	.3

CI = confidence interval.

1988; Ragull et al., 2007; Türetgen et al., 2005; Witherell et al., 1986). The concentration ranged from <1–10,000 CFU/mL, with most samples <100 CFU/mL.

Concentration fluctuated over time, especially in summer months, and concentration increased with year-round usage (Ragull et al., 2007; Türetgen et al., 2005). In the U.S., 196 cooling towers were sampled nationwide for *Legionella* in the summer of 2016 and 84% were PCR positive, while 48% were culture positive. Half of those culture-positive towers were positive for *Lp* serogroup 1 (Llewellyn et al., 2017).

The results of our prevalence survey generally align with previous studies, given *Lp* contamination range was broad (from 10–2,000 CFU/mL) and the majority of positive results were <100 CFU/mL. Nevertheless, the conditions under which prior prevalence studies were conducted differ and should be considered. For example, a prevalence study in New Zealand assessed >1,200 cooling towers and found only 2% positive for *Legionella*. At the time of the study, a cooling tower registry had been in place for several years and the government required reporting of *Legionella* test results. This low prevalence could be due in part to strict national cooling tower oversight (Lau et al., 2013).

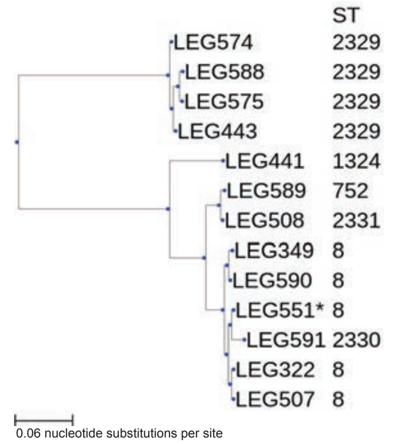
Cooling tower-related LD outbreaks have been caused by a large range of *Legionella* concentration levels. A 2011 review article summarized 38 cooling tower LD outbreak publications and found that 22% of outbreaks were caused by cooling towers with levels between 100–9,999 CFU/mL, while 13% were between 10,000–99,000 CFU/mL (Rangel, Delclos, Emery, & Symanski, 2011). A 2014 review of 19 cooling tower outbreaks described levels ranging from 10–10,000,000 CFU/mL (Walser et al., 2014). The contamination levels we observed were generally lower in comparison to these ranges.

Given that this sample of cooling towers in Allegheny County was limited and that the majority sampled were healthcare-associated cooling towers, we expected better cooling tower maintenance in comparison with a more general sample. This expectation was confirmed by our finding that 98% of the cooling towers sampled were treated with biocide and all cooling towers were cleaned at least annually. Despite maintenance practices, however, cooling tower age was the most important predictor of concentration level and *Legionella* grew even in well-maintained systems. A similar finding related to age was documented in a Greek *Legionella* prevalence study; however, the study sampled cooling towers of a wider maintenance scale and found decreased risk of *Legionella* colonization to be associated with biocide treatment, cleaning more frequently than every 6 months, and following a risk management plan (Mouchtouri et al., 2010).

Cooling tower LD outbreaks have been attributed mostly to inadequate maintenance such as lack of or insufficient biocide treatment and lack of cleaning within 6 months of an outbreak (Rangel et al., 2011). A 2011 cooling tower outbreak review article found that 26% of outbreak-associated cooling towers were described as adequately maintained and 66% neglected or inadequately maintained (Rangel et al., 2011). Nevertheless, "adequately maintained" is difficult to define. Of note, outbreaks have also been attributed to "well-maintained" cooling towers (Stout, 2007; Yu, 2008).

FIGURE **1**

Phylogeny of 13 Serogroup 1 *Legionella pneumophila* Genomes Based on Aligned SNPs to Reference Assembly LEG551*



ST = sequence type.
Note. Scale represents mean number of nucleotide substitutions per site.

Australia and Japan developed guidelines that mandate testing, inspections, and registration, yet Australia continues to experience cooling tower-associated outbreaks (Rangel et al., 2011). Generally, cooling tower guidelines vaguely specify cleaning frequency, biocide type, or amount. Most guidelines recommend regular inspections rather than specifying frequency. Occurrence of outbreaks due to "adequately maintained" or "well-maintained" cooling towers could be related to guideline inconsistencies (Rangel et al., 2011).

The availability of a clear and comprehensive cooling tower maintenance guideline would be extremely valuable to cooling tower engineering and maintenance personnel. Nevertheless, the lack of specificity in current guidelines could be due in part to the variability of cooling towers themselves. The cooling towers we sampled varied greatly in terms of size, age, and overall operation. Given these structural differences, creating a clear and comprehensive guideline appears difficult.

In 2018, ASHRAE updated its guideline describing minimum expectations for main-

TABLE **7**

Pairwise SNP Differences Among 13 Serogroup 1 *Legionella pneumophila* Isolates Using LEG551 as the Reference Genome

	LEG551	LEG507	LEG322	LEG590	LEG349	LEG591	LEG444	LEG508	LEG589	LEG441	LEG574	LEG588	LEG575	LEG443
LEG551	0	46	80	1,132	2,895	9,295	14,339	19,729	23,481	72,682	184,434	184,600	186,239	186,832
LEG507		0	57	1,110	2,879	9,262	11,652	19,640	21,099	70,670	184,328	183,338	184,977	186,615
LEG322			0	1,157	2,919	9,304	11,665	19,677	21,151	70,702	184,380	183,389	185,033	186,710
LEG590				0	1,818	10,360	11,666	20,013	21,466	70,517	184,017	183,033	184,690	186,300
LEG349					0	9,795	11,685	21,752	23,205	71,761	182,183	181,266	182,879	184,474
LEG591						0	10,528	25,695	27,973	73,999	173,203	173,409	174,160	175,491
LEG444							0	12,331	14,057	16,769	23,116	23,733	24,558	23,160
LEG508								0	1,998	68,029	177,310	177,875	178,033	178,962
LEG589									0	69,156	177,032	178,793	179,230	178,547
LEG441										0	179,130	180,010	181,095	180,368
LEG574											0	1,897	2,176	485
LEG588												0	1,480	3,778
LEG575													0	2,135
LEG443														0

TABLE **8**

Pairwise SNP Differences Among Four ST2329 Isolates Using LEG443 as the Reference Genome

	LEG443	LEG574	LEG575	LEG588
LEG443	0	38	1,330	4,257
LEG574		0	1,144	1,247
LEG575			0	400
LEG588				0

tenance and development of a water management plan in building water systems (ANSI/ASHRAE Standard 188-2018) for minimizing *Legionella*. The guideline specifies that if a building has a cooling tower, the water management plan must address the cooling tower. Less than one quarter of facilities we surveyed had developed a water management plan (Table 3). Facility managers and their water treatment professionals decide the specifics related to frequency of cleaning, inspections, and testing; ASHRAE guidelines do not state specific recommendations (American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 2000, 2018).

It is noteworthy that our survey indicated that contracting with a water treatment professional was associated with decreased concentration level, but this finding was not statistically significant. On June 2, 2017, the Centers for Medicare & Medicaid Services published a memorandum requiring that all hospitals, critical access hospitals, and long-term care facilities develop a water management plan in compliance with ANSI/ASHRAE Standard 188-2015 (an earlier version of the standard).

For facilities with cooling towers, ACHD published the following recommendations:

- Develop a water management plan in compliance with ANSI/ASHRAE Standard 188-2018.
- Cooling towers that run year-round should be cleaned and tested for *Legionella* at least quarterly. Cooling towers that run seasonally should be cleaned and tested for *Legionella* at least once before, during, and immediately following the cooling season.
- Collect basin water for routine testing.
- Clean the basin or sump tank and drain as part of routine cleaning.
- Inspect older cooling towers and clean diligently given their potential for *Legionella* contamination.

Our study has several limitations that should be considered when interpreting results. The first is our limited sample size. A larger sample size might have improved the robustness of our multivariable linear regression model. We chose to survey buildings that house susceptible populations because these populations are disproportionately affected and LD outbreaks have been associated with cooling towers on these types of buildings (Quinn et al., 2015).

To increase generalizability, we surveyed city- and county-owned buildings. External validity should nevertheless be considered, as the generalizability of these results is suspect. Also, some of the univariate analysis results are not intuitive, such as increased risk associated with water management plans, which is most likely due to our overrepresentation of hospitals. Hospital towers generally were larger and older than nonhospital towers and water management plans were more frequently developed by hospitals. After stratifying by hospital status, we found similar univariately associated variables compared with the overall analysis. The results suggest that the relationship between *Legionella* and cooling tower year-round usage and age was more relevant for hospital cooling towers, whereas tower capacity was more relevant for nonhospitals. Nevertheless, power was limited for this stratified analysis.

Another limitation to consider is survey response accuracy. We required a maintenance supervisor or an engineer to be involved in the completion of the maintenance practice survey; whether responses reflected true practice, however, was difficult to confirm. We emphasized when conducting the survey over the phone or when sending the survey via e-mail that all answers would be kept confidential and no punitive action would be taken based on survey response or cooling tower test results.

Strengths of our study include our overall survey response rate and consent for ACHD testing. All samples were collected by the same ACHD personnel and samples were processed at the ACHD Public Health Laboratory rather than at commercial labs to ensure consistency of results. In Allegheny County, this prevalence study is an important first step toward understanding the relationship between cooling towers and LD.

Conclusion

Cooling towers surveyed in Allegheny County were found to be relatively well maintained in comparison to findings from other *Legionella* prevalence studies and LD outbreak investigations. Nevertheless, *Lp* was detected in almost half of the cooling towers tested. Improving maintenance and reducing *Legionella* contamination in Allegheny County cooling towers would likely contribute to a reduction in the overall burden of disease and potential for outbreaks associated with cooling towers.

A detailed cooling tower maintenance guideline would be extremely beneficial for *Legionella* control, although the creation of such a guideline might not be feasible. At a minimum, ANSI/ASHRAE Standard 188-2018 should be followed. An important benefit of this prevalence study was increased contact with local water treatment professionals and facility engineers who are tasked with developing maintenance plans. Many times the facility's bottom-line can trump implementation of more intensive cooling tower maintenance practices. Through this health department initiative, ACHD encouraged facilities to comply with ANSI/ASHRAE Standard 188-2018 and improve maintenance practices. Other local and state health departments should note this important benefit and consider conducting a cooling tower *Legionella* prevalence study in their jurisdiction as a component of LD prevention efforts.

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Estimation of the Prevalence of Undocumented and Abandoned Rural Private Wells in McDonough County, Illinois

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Abstract **A systematic method of estimating undocumented private wells in the state of Illinois has not been established; this study fills that void. Data from a 1934 well survey of one quarter of McDonough County, Illinois, along with old plat books showing existing structures, were used to compute ratios of wells to structures for the rural portions of the county. Applying these ratios to the portions of the county that were not included in the 1934 well survey produced estimates ranging from 676–1,116 undocumented wells in 1934. Well-to-structure ratios as of 1997 were calculated by using the results of the 1934 estimate and incorporating records of well installation or well sealing from 1935–1997. Some of these anomalously high ratios were explained by the existence of structures that were not represented on the plat maps, but high ratios (>2) in the rural parts of the county were shown to provide evidence for the likely existence of abandoned wells or wells that were sealed without documentation.**

Introduction

Abandoned wells are a known safety and public health hazard. Their danger received national attention in 1987 when Baby Jessica fell into an abandoned well and the country followed her eventual rescue (Kennedy, 1987), but many years later, children are still falling into wells, a known hazard (Apel, 2015, among others). Aside from the physical hazard of falling into them, abandoned wells can also have a detrimental effect on groundwater quality, such as when surface pollutants enter an aquifer via unfilled abandoned wells (Gass, Lehr, & Heiss, 1977).

Illinois did not begin requiring permits for installation of water wells until the 1960s (Wilson, Rennels, & Roadcap, 2013), so many of the wells in the state are undocumented. The number of abandoned wells in Illinois has been estimated to be in the thousands (Hendrickson, Erickson, & Narve, 1996) and many of these wells were never documented. For example, a well survey in parts of three Illinois counties identified 1,706 total wells. Of these, 788 were not previously documented in the Illinois State Water Survey (ISWS) database (Wilson et al., 2013).

Although this type of well survey is the most accurate method of determining the abundance of undocumented wells, it is both costly and time-consuming to conduct. For this reason, a low-cost technique to estimate the prevalence of undocumented private water wells in a rural setting was developed that relies upon the assumed relationship between the number of structures in an area and the number of wells. This estimation method is not designed to locate individual wells, but to identify areas that are likely to contain undocumented and/or abandoned wells and warrant further investigation. This type of information could be useful to local health departments and/or companies planning to develop rural properties.

Data

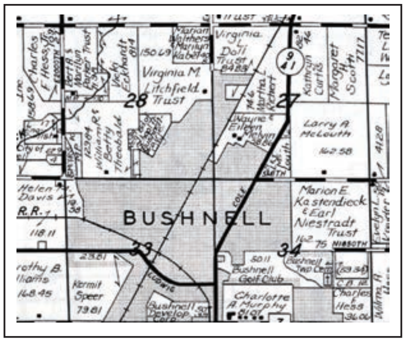
Well Data

A spreadsheet containing all well records of private wells (pumping less than 75 gal/min) in McDonough County, Illinois, as of September 2015, was provided by the ISWS. The well record information required for this study included the location of the well, date of installation, and the date of sealing if the well was sealed.

Although there was very little documentation regarding the location of private wells in Illinois prior to the 1930s, a survey of private water wells was conducted in 1934 that included 4 of the 16 townships in McDonough County (Illinois State Water Survey [ISWS], 1935). A total of 276 farm or rural wells were identified during the survey. Most of the rural wells (86%) were installed in glacial deposits with depths ranging from 12–90 ft (ISWS, 1935). For the purposes of this study, it was assumed that no wells were missed during the well survey, so the number of wells reported for these four townships was the actual number of wells in 1934. Wells with no installation date were assumed to be older than 1934.

FIGURE **1**

Portion of the Plat Map Containing Bushnell, Illinois



Note. Structures are depicted by black squares. As no structures are depicted within the city limits, we did not use any PLSS sections containing a portion of the city limits (sections 27, 28, 33, and 34 in this example) in this study.

TABLE **1**

Ratios of Wells to Structures for Townships in the 1934 Well Survey

Township	Structure Count		Estimate of Structures in 1934	Documented Wells in 1934	Ratio of Wells to Structures
	In year 1919	In year 1954			
T5N R1W	216	141	180	70	0.39
T7N R1W	177	155	126	78	0.62
T7N R2W	164	145	151	78	0.52
T7N R3W	182	164	153	64	0.42
Total	739	605	610	290	Mean = 0.49

Structure Data

Historical plat books with buildings marked in the rural parts of the county were used to determine the number of structures in the study area. As the plat books do not show individual structures inside city limits, any 1-mi^2 Public Land Survey System (PLSS) section that contained any portion of the city limits of any town were excluded from the study (Figure 1). Plat books that identified structures were not available for the year of the well survey (1934), so it was necessary to use plat books from 1919 (Howat & Son, 1919) and 1954 (Rockford Map Publishers, 1954) to estimate the number of structures at the time of the well survey. The most recent plat book available for McDonough County that included structures on the map (Rockford Map Publishers, 1997) was used when estimating the likelihood of abandoned wells in the county.

Methods

Previous researchers have used aerial photographs, topographic maps, plat maps, or a combination of these resources to identify likely locations of water wells (Blomquist, 1984) or petroleum wells (Aller, 1984; Stout & Sitton, 1984). Our basis for the method used to estimate undocumented wells relies on an assumed ratio between water wells and structures (e.g., houses, barns, churches). As this ratio can change through time as farming practices change (e.g., fewer barns and outbuildings used than in the past), the estimate of undocumented wells was computed for 1934, the time of the aforementioned well survey. Specifically, the four townships within the county that were part of the 1934 well survey were used to establish the ratio of wells to structures in the rural portions of the county at that time.

After scanning the plat maps from 1919 and 1954, GIS software was used to create a shapefile for both years with the locations of each structure marked. The number of structures per 1-mi^2 PLSS section was determined for the years 1919–1954, and these numbers were used to estimate the number of structures in 1934 through interpolation. PLSS sections were chosen as the base area for computing the well-to-structure ratio because some of the wells in the study area were located by section and township only. The ratio determined for the four surveyed townships was then applied to the remaining 12 townships in the county to estimate the number of undocumented wells in 1934. The well-to-structure ratio was not the same for each of the four surveyed townships, so a range of estimates of undocumented wells was computed using the highest and lowest calculated ratios.

Finally, in an effort to estimate the number of abandoned wells, the ratio of estimated wells to structures was recomputed for each PLSS section in the county for the year 1997. The 1997 plat book was used because it is the most recent plat book that included structures on the map. A section that displayed a high well-to-structure ratio was presumed to be an area that has a high likelihood of containing an abandoned well. Any well-to-structure ratio >2 was considered high, as most rural lots contain, at most, one well for the residence and potentially one well for livestock.

To determine the well-to-structure ratio as of 1997, the well records between 1935–1997 were added to the estimated number of wells in 1934. Any records of wells sealed between 1935–1997 were then subtracted from this total and the resulting number was divided by the number of structures present in the PLSS section in 1997. It should be noted that the number of wells in a section are probably underestimates, because well records were not required by law to be submitted to the ISWS until the 1960s, making well records between the years 1935 and the 1960s incomplete (Wilson et al., 2013).

Results and Discussion

Undocumented Well Estimates for 1934

The ratios of wells to structures determined for the four townships included in the 1934 well survey ranged from 0.39–0.62 with a mean of 0.49, so there were roughly two structures per well in 1934 (Table 1). The low, mean, and high well-to-structure ratios were used to compute the low, medium, and high estimates of undocumented wells for the remaining 12 townships in the county by multiplying the ratio by the estimated number of structures and subtracting the number of well records in the townships (Table 2). A map constructed using the mean well-to-structure ratio of approximately 0.5 shows that the estimated number of undocumented wells are evenly distributed around the county, ranging from 0–6 wells per 1-mi² PLSS section (Figure 2).

The estimates of the number of undocumented wells per section were not rounded to whole numbers so that false patterns due to rounding up or down from 0.5 would not be created. The number of documented well records in each of these townships was very low, ranging from 1–12, so nearly all of the wells in these 12 townships were undocumented in 1934. The roughly 650–1,100 estimated undocumented wells are only for the rural parts of the county that were included in this study. There are undoubtedly many more undocumented urban wells, so these figures represent conservative estimates for township-wide undocumented wells.

Identification of Potentially Abandoned Wells as of 1997

The well-to-structure ratios for each township as of 1997 (Table 3) were greater than those computed for 1934, with a mean (1.08) that is more than double the 1934 value. A well-to-structure value near 1 was not surprising considering the changes in farming practices between 1934–1997. For example, in 1930 there were 2,433 farms in the county (Illinois Cooperative Crop Reporting Service, 1970), but only 726 farms remained in 1997 (Census of Agriculture, 1997), with the result that farms were much larger in 1997. Specifically, in 1930 only 10.9% of the farms in the county were greater than 260 acres in size (Illinois Cooperative Crop Reporting Service, 1970), whereas in 1997 that percentage had increased to 50.7% (Census of Agriculture, 1997). Additionally, the increasing emphasis on growing crops versus raising livestock (Table 4) meant less need for buildings to house farm animals, thus fewer farm structures per well.

Although modern farms with larger acreages and fewer buildings per lot than in the past led to the nearly 1:1 ratio of wells to structures, when the ratios were computed for each PLSS section within the county, some areas with a higher-than-average ratio of wells to structures were identified (Figure 3). If the ratio of wells to structures was >2, then the section was flagged as potentially containing an abandoned well.

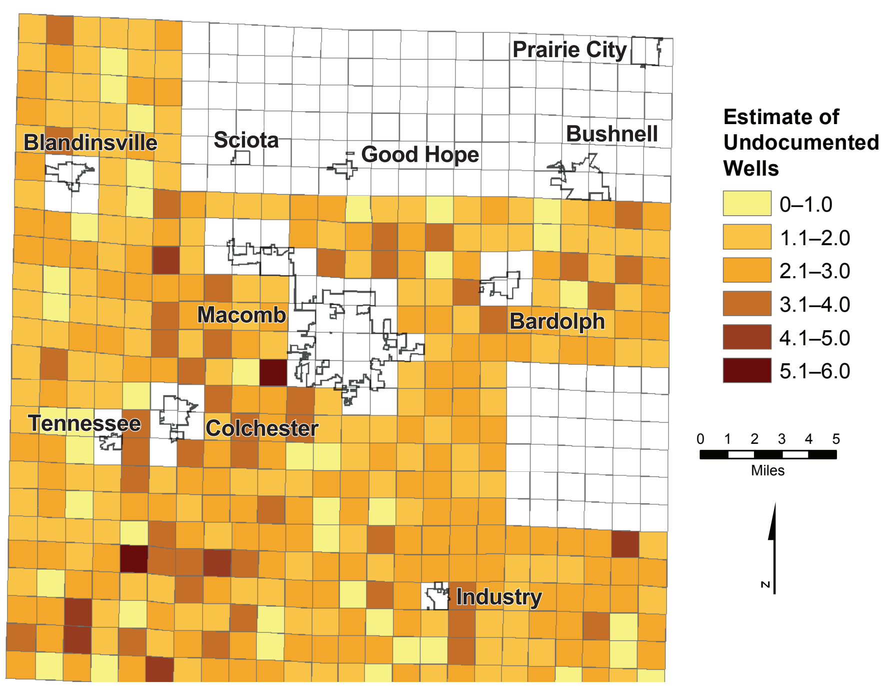
TABLE **2**

Estimates of Undocumented Wells in 1934

Township	Estimate of Structures in 1934	Well Records in 1934	Estimates of Undocumented Wells		
			Low	Medium	High
T4N R1W	171	1	66	83	105
T4N R2W	174	6	62	79	102
T4N R3W	180	4	66	84	108
T4N R4W	179	2	68	86	109
T5N R2W	158	10	52	67	88
T5N R3W	186	11	62	80	104
T5N R4W	152	12	47	62	82
T6N R1W	161	6	57	73	94
T6N R2W	143	12	44	58	77
T6N R3W	111	2	41	52	67
T6N R4W	161	3	60	76	97
T7N R4W	139	3	51	65	83
Total	1,915	72	676	865	1,116

FIGURE **2**

Estimate of Undocumented Wells per 1-mi² Sections in McDonough County, Illinois



Note. White squares represent areas that were excluded from the study analysis.

TABLE **3**

Ratios of Estimated Wells to Structures in 1997

Township	Estimated Number of Wells	Well Records From 1935–1997	Sealed Wells as of 1997	Estimated Wells in 1997	Structure Count in 1997	Ratio of Estimated Wells to Structures
T4N R1W	86	34	0	120	129	0.93
T4N R2W	87	62	2	147	112	1.31
T4N R3W	90	50	0	140	99	1.41
T4N R4W	90	39	0	129	123	1.04
T5N R1W*	70	18	0	88	127	0.69
T5N R2W	79	47	1	125	109	1.15
T5N R3W	93	149	2	240	135	1.78
T5N R4W	76	52	0	128	128	1.00
T6N R1W	81	31	0	112	134	0.83
T6N R2W	72	29	0	101	112	0.90
T6N R3W	56	67	2	121	64	1.88
T6N R4W	81	30	3	108	116	0.93
T7N R1W*	78	39	2	115	104	1.11
T7N R2W*	78	44	0	122	138	0.88
T7N R3W*	64	42	0	106	107	0.99
T7N R4W	70	31	1	100	118	0.84
Total	1,251	764	13	2,002	1,855	Mean = 1.08

*Well numbers for these four townships were taken from the 1934 well survey.

TABLE **4**

Agricultural Changes in McDonough County From 1930–1997

	1930	1997	Percent Change
Cropland (acres)			
Corn	115,000	134,609	17
Soybeans	4,200	128,736	2,965
Wheat	28,800	2,215	-92
Oats	46,000	667	-99
Hay	28,200	9,151	-68
Barley	3,500	0	-100
Rye	1,300	0	-100
Total	227,000	275,378	21
Livestock (animals)			
All cattle	26,300	19,581	-26
Milk cows	10,000	274	-97
Hogs	115,500	33,390	-71
Sheep	8,100	1,520	-81
Horses	11,800	554	-95
Total	171,700	55,319	-68

A closer examination of the flagged PLSS sections showed that many of the highest ratios of wells to structures were in areas that did not show all of the structures present on the plat map, such as trailer parks and rural housing developments with small tracts of houses. Each of these anomalously high sections was scrutinized to see if they were, in fact, evidence for an abandoned well. For example, a rural PLSS section between the cities of Colchester and Macomb (Figure 4) had a well-to-structure ratio of 10.5 (7 document wells, 3.5 estimated wells, 1 structure) but on an aerial photo of the same area, as many as 20 houses can be identified. Rather than being a section with a high likelihood of abandoned wells, this area might actually have more undocumented wells than estimated, as there are many houses.

The identification of likely areas containing abandoned wells was more successful for rural parts of the county that have not experienced the construction of housing developments. For example, a section in the northeast portion of the county with a well-to-structure ratio of 2.5 had as many as six farmsteads on historic plat maps, but only two remained by 1997 (Figure 5). This portion of the county was part of the 1934 well survey, so the locations of five wells are known (open white triangles on Figure 5). Three of the wells are near existing structures and presumably are still in use. ISWS records show that one of the remaining wells was sealed in 2005, but the location of the 5th well (north–center of the section) is presently cropland with no existing structures, suggesting that it was abandoned and filled at some point.

For comparison purposes, another rural section of the county with a well-to-structure ratio of 2.5 (7.5 wells, 3 structures) was identified from an area that was not included in the 1934 well survey and therefore has fewer documented wells (Figure 6). This section has 3 documented wells and an additional 4.5 estimated wells based upon the prevailing well-to-structure ratio for the county. The wells that were likely associated with the former structures shown on older plat maps have presumably been abandoned and/or filled, but there is no record of sealing in the ISWS well records.

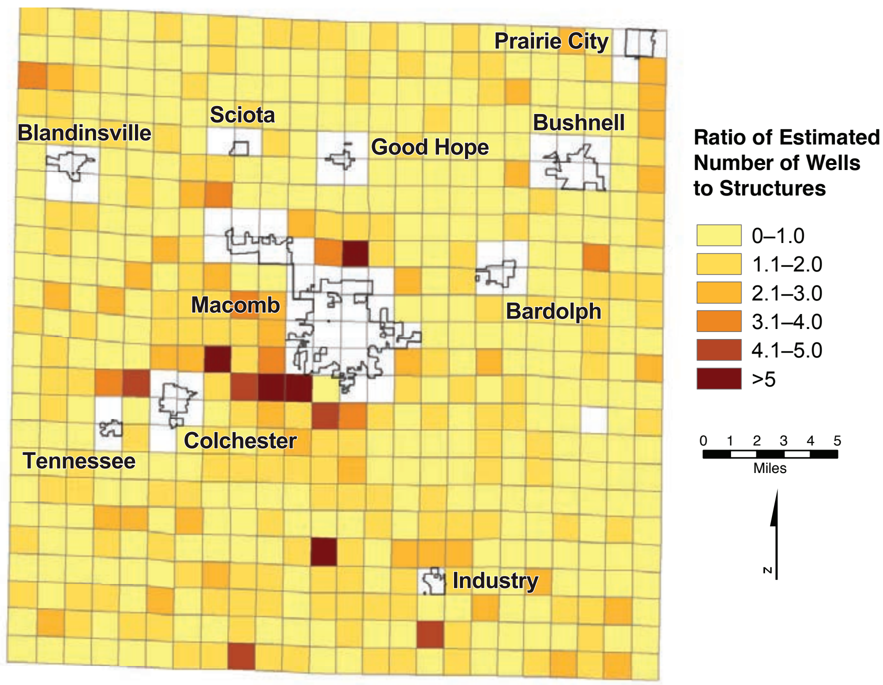
Local Geology and Potential Contamination Sources

The U.S. Environmental Protection Agency (U.S. EPA) toxic release inventory for McDonough County identified only two potential industrial sources of potential water pollution (U.S. EPA, 2018); the potential sources are located in the cities of Macomb and Bushnell. Oil wells are present in the southwest portion of the county that tap a reservoir that is approximately 500 ft deep (Illinois State Geological Survey, 2018). As most of the farm or rural wells (86%) identified during the 1934 well survey in McDonough County were shallow dug, bored, or well-point types ranging from 12–90 ft deep (ISWS, 1935), they are fed by aquifers within glacial deposits. Wells in glacial deposits typically tap unconfined aquifers that are recharged from the infiltration of local precipitation and are parts of local flow systems (Fitts, 2012).

Therefore, the most likely potential sources of contamination to the abandoned or undocumented wells would be from the ground surface through infiltration of nonpoint source agricultural chemicals (e.g., herbicides, pesticides, fertilizer) or from feed lots and septic tanks. Water in local ground-

FIGURE **3**

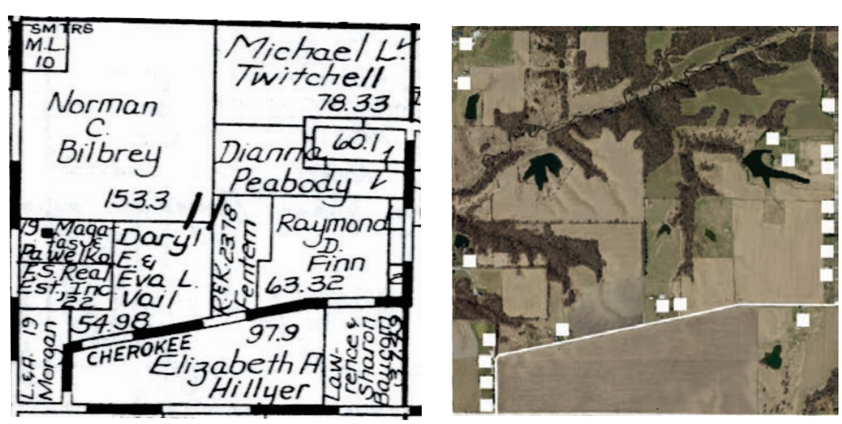
Ratio of the Number of Estimated Wells to Structures in 1-mi² Sections in McDonough County, Illinois



Note. Sections with a ratio >2 are areas that are likely to contain abandoned wells. White squares represent areas that were excluded from the study analysis.

FIGURE **4**

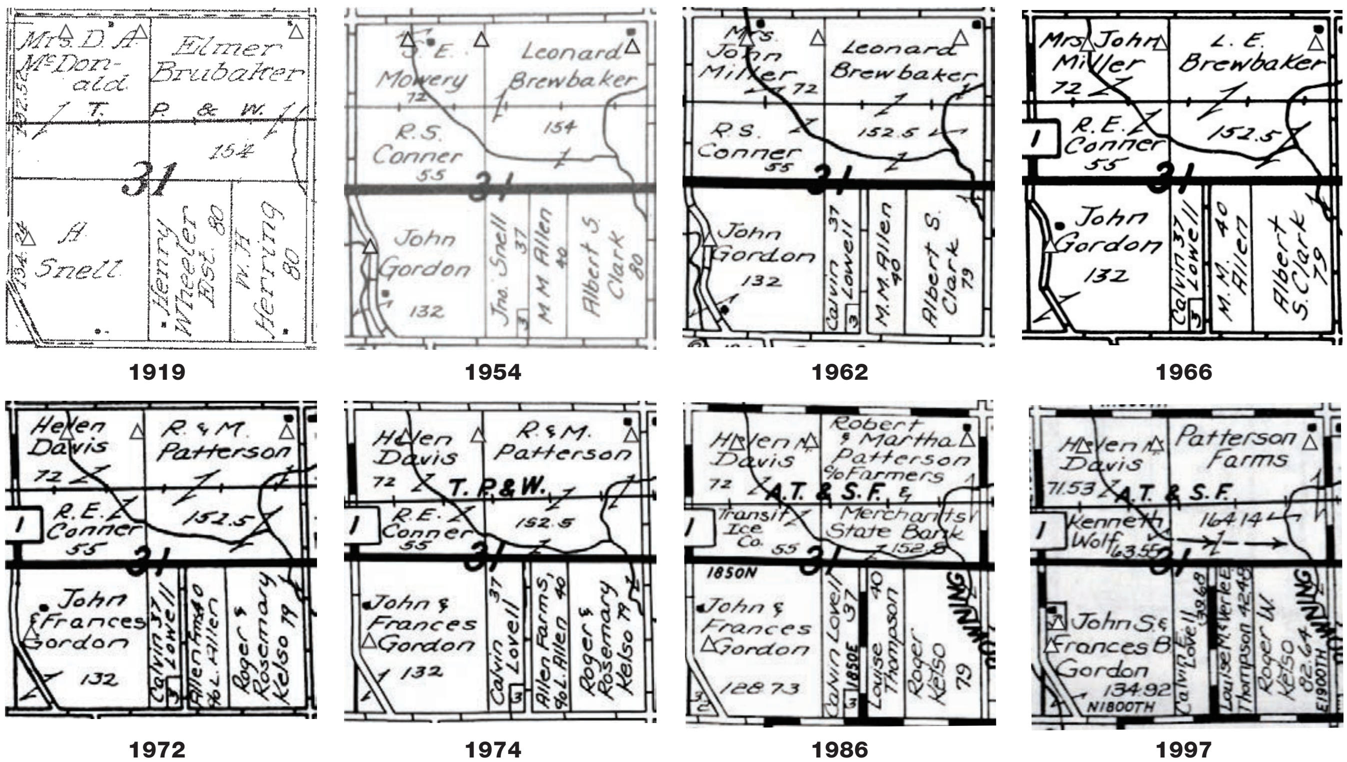
Plat Map Comparison to an Aerial Photo



Note. This section had a very high well-to-structure ratio (10.5) due to the inaccurate structure information on the plat map compared with those identified on an aerial photo of the area (white squares).

FIGURE **5**

First Example Section With a High Likelihood of an Abandoned Well



Note. The well-to-structure ratio was 2.5 (5 wells, 2 structures) as of 1997. This section was part of the 1934 well survey, so the locations of the wells are known. Two of the wells in the northwest quarter of the section (depicted by open triangles) were last near a structure on the 1962 plat map. One of these wells was sealed in 2005 and the other is presumed to be abandoned.

water flow systems generally travels from the point of infiltration to the nearest surface water body (lake or stream), so any human exposure to contamination of abandoned wells in the study area would most likely occur in active wells that are located between the abandoned well and a nearby stream.

Conclusion

The total population in McDonough County increased by 20% between 1930–2000, but the population in the rural townships analyzed in this study decreased by 48% during the same time period (Illinois Cooperative Crop Reporting Service, 1970; U.S. Census, 2000). In the process, a large number of rural wells were abandoned. The technique developed in this study could be used as another tool—along with existing methods that employ aerial photographs, topographic maps, plat maps, or a combination of these resources—to identify likely locations of undocumented or abandoned water wells.

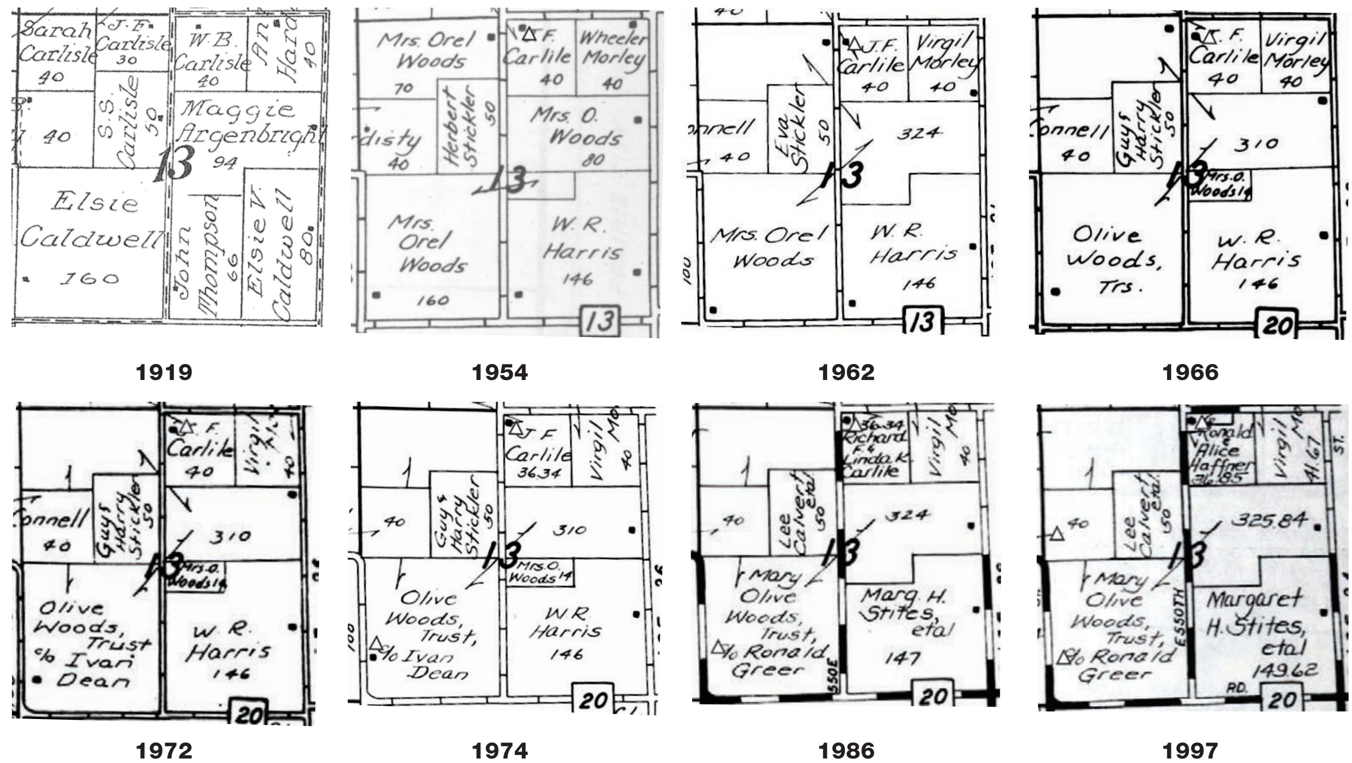
Many of the private well records in Illinois are not documented because submittal of their records to ISWS was not mandated until the 1960s (Wilson et al., 2013). The well-to-structure ratios established for rural McDonough County could be used to estimate undocumented wells in other areas of rural Illinois using old plat books from the local area. The average well-to-structure ratio changed from approximately 0.5 in 1934 to approximately 1 in 1997; however, the ratio was >5 in some PLSS sections within the county. The 1997 values are conservative estimates of undocumented wells, as they include only some of the wells installed between 1935 and the 1960s, when well drilling reports were first mandated. The assumption that a high (>2) well-to-structure ratio was an indicator or the likelihood of a PLSS section containing an abandoned well proved to be valid in the rural portions of the county, but was not as successful in areas surrounding towns.

The techniques used in this study could be applied to other areas of Illinois that are predominately involved in cropland and pasture activities. Identification of areas that have a high likelihood of containing undocumented and/or abandoned wells could be useful to county and municipal health departments, particularly when rural property is being developed (e.g., housing tracts, concentrated animal feeding operations).

If access to rural properties can be granted, future research might include a door-to-door

FIGURE **6**

Second Example Section With a High Likelihood of an Abandoned Well



Note. The well-to-structure ratio was 2.5 (7.5 wells, 3 structures) as of 1997; this section was not included in the 1934 well survey, so only 3 well records (depicted by open triangles) exist for this area. The wells that were presumable associated with the former structures might have been filled, although there is no record of their sealing.

well survey of randomly selected PLSS sections to test the accuracy of the number of undocumented wells estimated in this study. Additionally, a site survey could be conducted of areas that have been identified as likely locations of abandoned wells to see if any evidence of a well exists.

Acknowledgements: The authors thank Keisuke Nozaki (Western Illinois University GIS Center), Ken Hlinka (ISWS), Linda Zellmer (Western Illinois University Library), and Bill Cook (Western Illinois University Library Archives) for their assistance acquiring the data used in this study. Additionally, this article benefitted from comments of the anonymous reviewers during the manuscript submission process.

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DIRECT FROM AAS

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University of Washington

Environmental Health: The Invisible Profession

Editor's Note: In an effort to provide environmental health professionals with relevant information and tools to further the profession, their careers, and themselves, NEHA has teamed up with the American Academy of Sanitarians (AAS) to publish two columns a year in the *Journal*. AAS is an organization that "elevates the standards, improves the practice, advances the professional proficiency, and promotes the highest levels of ethical conduct among professional sanitarians in every field of environmental health." Membership with AAS is based upon meeting certain high standards and criteria, and AAS members represent a prestigious list of environmental health professionals from across the country.

Through the column, information from different AAS members who are subject-matter expects with knowledge and experience in a multitude of environmental health topics will be presented to the *Journal's* readership. This column strengthens the ties between both associations in the shared purposes of furthering and enhancing the environmental health profession.

Following 10 years with a local health department, Charles (Chuck) Treser was recruited to join the environmental health faculty at the University of Washington (UW) to lead a project developing a system for assuring the continuing competencies of environmental health professionals. Recently retired (sort of), he remains active in environmental health by teaching two courses each year at UW. He is the immediate past chairman of the American Academy of Sanitarians.

I recently read an article published by the *Journal of Public Health* titled, "Environmental Health in Australia: Overlooked and Underrated." The authors lament the fact that despite the importance of environmental health and the work of environmental health officers, they are practically invisible in Australia (Whiley, Willis, Smith, & Ross, 2018). This thought struck a chord with me as those of us in the U.S., as well as worldwide, have been singing the same lament for most, if not all, of my 40-plus-year career in environmental health.

The article cited three trends that have contributed to this lack of recognition and understanding of environmental health as a profession.

1. The shift in policy, particularly at the national level, away from ensuring adequate government-enforced safeguards for health to stressing personal responsibility for one's health status.
2. A shift in the focus of public health toward the social determinants of health and away from the environmental and regulatory aspects of environmental public health. While there is no denying that factors such as poverty, nutrition, and personal lifestyle choices are hugely important in determining an individual's health status, the shift ignores several important points:
    a. people living on the low end of the socioeconomic spectrum are the very ones most susceptible to illness or injury when environmental protective barriers do not exist;
    b. unless and until significant progress is made in finding solutions to the problems of poverty and homelessness, people living under these conditions seldom have the physical, fiscal, and emotional resources to help themselves; and
    c. one of the founding principles of the public health movement is the need to ensure the health status of the poor so that diseases do not spill over to the broader population.
3. The rise of neoliberalism and the consequent reduction in funding at the national, state, and provincial levels for public supported programs and activities. This trend results in local communities having to decide which, if any, environ-

mental public health programs they can continue to provide.

To these three trends I would add a fourth—the lack of a clear and easily understood definition of what environmental public health is. As the scope of environmental public health is so broad, spread across all media and among various government agencies at all levels of government, it is difficult to characterize the profession. People understand food inspector, hazmat responder, pest control, or just about any of the many program activities that environmental health professionals are responsible for. Very few, however, can put it all together to comprehend what environmental public health actually encompasses.

I would suggest that as a unifying characteristic, all environmental health professionals are risk assessors at the core of their practice. It does not matter what media, program, geographic area, or agency, environmental health professionals can enter a facility or area and be able to identify and characterize conditions that are likely to result in people becoming sick or injured. They can then propose an approach to prevent or resolve the risk. This ability is regardless of whether they call themselves sanitarians, environmental health specialists, industrial hygienists, or any other related title.

One final note, environmental health professionals tend to be too modest. Perhaps we feel intimidated by a physician's in-depth knowledge of a disease or condition, or an engineer's ability to design and oversee the construction of a drinking water plant. I would, however, posit that there is no other profession that has as broad a mandate and carries the responsibility of protecting the health status of our residents than the environmental health professional. Indeed, the physician contacts environmental health professionals when confronted by a child bitten by an animal for advice on what is the appropriate response. Environmental health professionals know (or can find out) what is the current level of rabies or other diseases in the community, what animals are potential vectors, and what is the appropriate prophylaxis. And the engineer is dependent on environmental health professionals for advice and approval for the design and installation of an onsite wastewater system.

We have nothing to be modest about. Environmental health professionals are the single most important practitioner when it comes to keeping the entire community healthy. What we need to do is step up to the plate and be involved and engaged at the policy level.

Reference

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DIRECT FROM CDC ENVIRONMENTAL HEALTH SERVICES



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Emergency Response Training in California: Piloting the Environmental Health Training in Emergency Response Operations Course in a Local Environmental Health Department

Editor's Note: NEHA strives to provide up-to-date and relevant information on environmental health and to build partnerships in the profession. In pursuit of these goals, we feature this column on environmental health services from the Centers for Disease Control and Prevention (CDC) in every issue of the *Journal*.

In these columns, authors from CDC's Water, Food, and Environmental Health Services Branch, as well as guest authors, will share insights and information about environmental health programs, trends, issues, and resources. The conclusions in these columns are those of the author(s) and do not necessarily represent the official position of CDC.

Marcy Barnett is the emergency preparedness liaison with the California Department of Public Health Center for Environmental Health. She is the program manager for California's Environmental Health Training in Emergency Response (EHTER). Bernice Zaidel is the assistant director of curriculum development and evaluation at the Federal Emergency Management Agency's (FEMA) Center for Domestic Preparedness (CDP). She is the FEMA/CDP lead for partnering with CDC's Water, Food, and Environmental Health Services Branch and developing EHTER courses. Martin Kalis is a public health advisor with CDC's Water, Food, and Environmental Health Services Branch. He is the program manager for CDC's EHTER.

In fall 2017, San Diego County, with assistance from the California Department of Public Health (CDPH), presented three sessions of the Environmental Health Training in Emergency Response Operations (EHTER Ops) course in a novel 2-day version. Until then, EHTER Ops had been offered exclusively at the Federal Emergency Management Agency's (FEMA) Center for Domestic Preparedness (CDP) in Anniston, Alabama, as a 4-day resident course. EHTER Ops is a course that prepares participants to assess disaster-related environmental health conditions and perform tasks in a hands-on and field team focused approach. The course emphasizes the use of field equipment and instrumentation, including personal protective equipment (PPE), under disaster conditions. EHTER Ops is a companion to the EHTER Awareness Level course.

California has a decade of experience with the EHTER Awareness Level course. A 2-day, state-specific version of EHTER Awareness has been provided through a partnership between CDPH and host counties since 2008. To date, nearly 2,000 environmental health and other responders have been trained through 36 EHTER Awareness sessions. Success of the California EHTER Awareness Level course is due to a large registered environmental health specialist (REHS) workforce who have been eager for this type of training. Nationwide, thousands of environmental health professionals and other responders have successfully completed EHTER Awareness and Operations Level courses through various delivery mechanisms (i.e., resident/classroom-based, independent study/online trainings) offered by the Centers for Disease Control and Prevention (CDC) and FEMA/CDP.

A California version of EHTER Ops began taking shape in summer 2017 when CDPH arranged for more than two dozen state agency and local jurisdiction representatives to attend a CDP train-the-trainer version of the course. That cohort included San Diego County Department of Environmental Health representatives who had already incorporated EHTER Awareness Level course concepts into their staff development program. After

Photo 1. Skill building stations allow participants to practice using radios and field guides.

Photo 2. Course participants assess a children's residential facility for reoccupancy.

Photo 3. The team briefs the shelter manager on assessment findings.

Photos courtesy of Marcy Barnett.

Environmental Health Training in Emergency Response (EHTER) Timeline of Success

- **July 2006:** First delivery of the Centers for Disease Control and Prevention's (CDC) EHTER Awareness Level course at NEHA's 70th Annual Educational Conference (AEC) & Exhibition.
- **February and June 2008:** Delivery of EHTER Train-the-Trainer courses in Sacramento, California, and Tucson, Arizona.
- **March 2009:** Delivery of CDC's EHTER Awareness Level course expanded through a partnership with the Federal Emergency Management Agency's (FEMA) Center for Domestic Preparedness (CDP) in Anniston, Alabama.
- **June 2010:** First delivery of an international EHTER course through a collaboration between CDC, the Pan American Health Organization, and the Caribbean Environmental Health Initiative at the 5th Annual Caribbean Environmental Forum & Exhibition in Jamaica.
- **August 2012:** Delivery of CDC's EHTER Awareness Level course expanded through a partnership with CDC University.
- **September 2014:** First delivery of the EHTER Operations course at FEMA/CDP.
- **October 2017:** EHTER Awareness Level is launched as an online independent-study course through FEMA's Emergency Management Institute.

The EHTER Operations course continues to be improved and expanded upon based on student feedback and partner engagement. For more information, visit www.cdc.gov/nceh/ehs/elearn/ehter.htm.

the train-the trainer experience and many months of planning, three 2-day EHTER Ops pilot sessions were presented in October 2017 using an earthquake as the disaster scenario.

Some adjustments and innovations were made to the original EHTER Ops format: less time in the classroom, more time with equipment at skill building stations (Photo 1), the addition of a departmental operations center that controlled team movements and tracked their progress, and an all-day field deployment on day 2 that sent teams to a now vacant former children's home (Photo 2). The teams responded to a mass feeding operation that had experienced a power outage and water supply disruption, assessed health and safety conditions at an emergency shelter (Photo 3), evaluated a damaged residential facility for reoccupancy, and identified safety and health hazards at a hazardous materials facility.

Instructional support was provided by San Diego County environmental health staff, as well as state university representatives who had attended the CDP train-the-trainer.

Selected environmental health specialists from outside San Diego County were invited to attend a pilot session in an effort to encourage other jurisdictions to begin planning their own EHTER Ops session. Evaluations from pilot session participants were overwhelmingly positive as the course offered an interesting opportunity to work together under realistic conditions using equipment they might have been unfamiliar with, all while having some fun. The San Diego EHTER Ops demonstration showed that a 2-day format can work provided that participants have had the basic EHTER Awareness Level course and that a suitable training location is available. For future EHTER Ops sessions, CDPH plans to work with FEMA/CDP and California universities as their campuses offer the potential for a variety of training venues, as well as instructional space and support. A big thank you to all who helped make the EHTER Ops pilot sessions a success!

FEMA is currently working with CDC and state environmental health programs to develop a just-in-time training package that will help environmental health professionals maintain their disaster response and recovery capabilities and assist them in situations when specific environmental health sector training is needed (e.g., shelters, food safety, vectors and pests). It is anticipated that this package will be ready for delivery sometime in 2019. For more information on EHTER training opportunities, please visit www.cdc.gov/nceh/ehs/elearn/ehter.htm.

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E-mail: marcy.barnett@cdph.ca.gov.

CAREER OPPORTUNITIES

Food Safety Inspector

UL Everclean is a leader in retail inspections. We offer opportunities across the country. We currently have openings for trained professionals to conduct audits in restaurants and grocery stores. Past or current food safety inspection experience is required.

United States
Albany, NY
Albuquerque, NM
Allentown, PA
Amarillo, TX
Anaheim, CA
Bakersfield, CA
Billings, MT
Birmingham, AL
Boise, ID
Boston, MA
Buffalo, NY
Cedar Rapids, IA
Charleston, SC
Chicago, IL
Coeur d'Alene, ID
Corpus Christi, TX
Eugene, OR
Eureka, CA
Fresno, CA
Galveston, TX
Grand Junction, CO
Grand Rapids, MI
Harrisburg, PA
Honolulu, HI
Houston, TX
Idaho Falls, ID
Little Rock, AR
Long Beach, CA
Los Angeles, CA
Lubbock, TX
Miami, FL
Midland, TX
Missoula, MT
Montgomery, AL
Oakland, CA
Odessa, TX
Orlando, FL
Owatonna, MN
Pasadena, CA
Philadelphia, PA
Phoenix, AZ
Portland, OR
Providence, RI
Rapid City, SD
Richmond, VA
Rochester, NY
Saint Louis, MO
San Pedro, CA
Santa Maria, CA
Santa Monica, CA
Seattle, WA
Shreveport, LA
Sioux Falls, SD
Syracuse, NY
Tulsa, OK
Wichita, KS
Yuma, AZ

Canada
British Columbia
Calgary
Montreal
Toronto
Vancouver
Winnipeg

If you are interested in an opportunity near you, please send your resume to ATTN: Sethany Dogra at LST.RAS.RESUMES@UL.COM or visit our website at www.evercleanservices.com.

EH CALENDAR

UPCOMING NEHA CONFERENCES

July 9–12, 2019: NEHA 2019 Annual Educational Conference & Exhibition, Nashville, TN. For more information, visit www.neha.org/aec.

July 13–16, 2020: NEHA 2020 Annual Educational Conference & Exhibition, New York, NY.

July 12–15, 2021: NEHA 2021 Annual Educational Conference & Exhibition, Spokane, WA.

NEHA AFFILIATE AND REGIONAL LISTINGS

Florida
July 30–August 2, 2019: Annual Education Meeting, hosted by the Florida Environmental Health Association, Howey in the Hills, FL. For more information, visit www.feha.org/events.

Idaho
March 12–14, 2019: Annual Education Conference, hosted by the Idaho Environmental Health Association, Boise, ID. For more information, visit https://ieha-idaho.com.

Kentucky
February 11–13, 2019: Annual Conference, hosted by the Kentucky Environmental Health Association, Lexington, KY. For more information, visit http://kyeha.org/events.

Ohio
April 11–12, 2019: 73rd Annual Educational Conference, hosted by the Ohio Environmental Health Association, Worthington, OH. For more information, visit www.ohioeha.org.

Utah
May 8–10, 2019: Spring Conference, hosted by the Utah Environmental Health Association, Cedar City, UT. For more information, visit www.ueha.org.events.html.

TOPICAL LISTING

Public Health
April 23–24, 2019: Iowa Governor's Conference on Public Health, Des Moines, IA. For more information, visit www.ieha.net/IGCPH.

JEH QUIZ

FEATURED ARTICLE **QUIZ #3**

Barriers to Managing Private Wells and Septic Systems in Underserved Communities: Mental Models of Homeowner Decision Making

Available to those holding an individual NEHA membership only, the *JEH* Quiz, offered six times per calendar year through the *Journal of Environmental Health,* is an easily accessible means to accumulate continuing-education (CE) credits toward maintaining your NEHA credentials.

1. Read the featured article carefully.
2. Select the correct answer to each *JEH* Quiz question.
3. a) Complete the online quiz found at www.neha.org/publications/journal-environmental-health,

   b) Fax the quiz to (303) 691-9490, or

   c) Mail the completed quiz to
   JEH Quiz, NEHA
   720 S. Colorado Blvd., Suite 1000-N
   Denver, CO 80246.

   Be sure to include your name and membership number!
4. One CE credit will be applied to your account with an effective date of December 1, 2018 (first day of issue).
5. Check your continuing education account online at www.neha.org.
6. You're on your way to earning CE hours!

Quiz Registration

Name

NEHA Member No.

E-mail

→ Quiz deadline: March 1, 2019

1. Research objectives were to
   a. assess community preferences for private wells versus community water systems.
   b. identify factors influencing behaviors to guide future risk communication development.
   c. assess current well and septic system monitoring and maintenance behaviors.
   d. all the above.

2. Interviewees were recruited from 57 households that participated in a previous University of North Carolina study of water quality in underbounded Wake County neighborhoods.
   a. True.
   b. False.

3. Overall, semistructured interviews were conducted with __ homeowners.
   a. 57
   b. 20
   c. 18
   d. 16

4. Of the study participants, __ were African-American and __ were White.
   a. 55.6%; 27.8%
   b. 45.6%; 24.6%
   c. 27.8%; 55.6%
   d. 19.4%; 61.6%

5. Of the study participants, __ reported an education level of a 4-year degree or higher.
   a. 10%
   b. 20%
   c. 30%
   d. 60%

6. The North Carolina Division of Public Health recommends pumping septic systems every
   a. six months.
   b. 1–2 years.
   c. 3–5 years.
   d. 6–8 years.

7. __ study participants either were unable to recall their last septic system maintenance or reported last pumping more than 5 years ago.
   a. Six
   b. Seven
   c. Eight
   d. Nine

8. Of the study participants, __ tested their water annually as recommended by the Wake County Department of Health.
   a. 1
   b. 4
   c. 6
   d. 9

9. Reliance on appearance, smell, and taste to detect contamination of well water was mentioned by __ of the study participants.
   a. 25%
   b. 50%
   c. 75%
   d. 100%

10. Overall, __ study respondents reported enjoying well water.
    a. 10
    b. 14
    c. 16
    d. 18

11. The study interviews revealed the following belief category(s):
    a. poor understanding of contaminant exposure routes.
    b. inaccurate beliefs that all water contaminants can be detected through sensory perception.
    c. low awareness of septic systems as a water contamination source.
    d. all the above.

12. Due to the small sample size, the findings highlight which beliefs people may hold, not how common those beliefs are.
    a. True.
    b. False.

JEH Quiz #1 Answers

July/August 2018

1. c	4. a	7. b	10. b
2. b	5. c	8. c	11. a
3. d	6. d	9. b	12. c


Don't Resource
REPLACE
The first new Lead Paint XRF Analyzer in more than a decade
The Heuresis Pb200i is a giant leap forwards in lead paint inspection technology, created by the people who invented handheld XRF. At only 1.3 lbs, this easy-to-use instrument packs heavyweight performance in a rugged, waterproof housing. With Positive/Negative readings in as little as 1 second*, you'll go from inspection to report in almost no time at all. Plus, the feature-rich platform takes advantage of an Android™ operating system to support an integrated color camera, GPS, Bluetooth™, Wi-Fi and email, all of which work together to help you document and share your results.
Learn more, contact us at www.heuresistech.com for specs, quotes, or to arrange a FREE demonstration
*Typical reading time at 1.0 mg/cm2 with 2-sigma confidence on most samples
HEURESIS CORPORATION

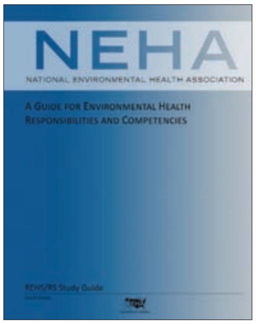
RESOURCE CORNER

Resource Corner highlights different resources that NEHA has available to meet your education and training needs. These timely resources provide you with information and knowledge to advance your professional development. Visit NEHA's online Bookstore for additional information about these, and many other, pertinent resources!

NEHA BOOKSTORE
www.neha.org/store

REHS/RS Study Guide (4th Edition)

National Environmental Health Association (2014)



The Registered Environmental Health Specialist/Registered Sanitarian (REHS/RS) credential is NEHA's premier credential. This study guide provides a tool for individuals to prepare for the REHS/RS exam and has been revised and updated to reflect changes and advancements in technologies and theories in the environmental health and protection field. The study guide covers the following topic areas: general environmental health; statutes and regulations; food protection; potable water; wastewater; solid and hazardous waste; zoonoses, vectors, pests, and poisonous plants; radiation protection; occupational safety and health; air quality; environmental noise; housing sanitation; institutions and licensed establishments; swimming pools and recreational facilities; and disaster sanitation.

284 pages / Paperback
Member: $149 / Nonmember: $179

Certified Professional–Food Safety Manual (3rd Edition)

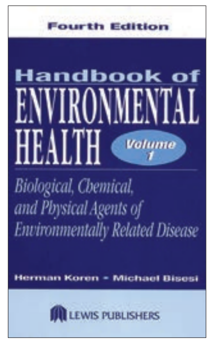
National Environmental Health Association (2014)

The Certified Professional–Food Safety (CP-FS) credential is well respected throughout the environmental health and food safety field. This manual has been developed by experts from across the various food safety disciplines to help candidates prepare for NEHA's CP-FS exam. This book contains science-based, in-depth information about causes and prevention of foodborne illness, HACCP plans and active managerial control, cleaning and sanitizing, conducting facility plan reviews, pest control, risk-based inspections, sampling food for laboratory analysis, food defense, responding to food emergencies and foodborne illness outbreaks, and legal aspects of food safety.

358 pages / Spiral-bound paperback
Member: $179 / Nonmember: $209

Handbook of Environmental Health, Volume 1: Biological, Chemical, and Physical Agents of Environmentally Related Disease (4th Edition)

Herman Koren and Michael Bisesi (2003)

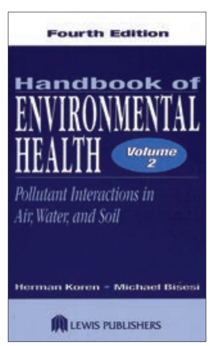


A must for the reference library of anyone in the environmental health profession, this book focuses on factors that are generally associated with the internal environment. It was written by experts in the field and copublished with the National Environmental Health Association. A variety of environmental issues are covered such as food safety, food technology, insect and rodent control, indoor air quality, hospital environment, home environment, injury control, pesticides, industrial hygiene, instrumentation, and much more. Environmental issues, energy, practical microbiology and chemistry, risk assessment, emerging infectious diseases, laws, toxicology, epidemiology, human physiology, and the effects of the environment on humans are also covered. Study reference for NEHA's Registered Environmental Health Specialist/Registered Sanitarian credential exam.

790 pages / Hardback
Volume 1: Member: $195 / Nonmember: $215
Two-Volume Set: Member: $349 / Nonmember: $379

Handbook of Environmental Health, Volume 2: Pollutant Interactions With Air, Water, and Soil (4th Edition)

Herman Koren and Michael Bisesi (2003)



A must for the reference library of anyone in the environmental health profession, this book focuses on factors that are generally associated with the outdoor environment. It was written by experts in the field and copublished with the National Environmental Health Association. A variety of environmental issues are covered such as toxic air pollutants and air quality control; risk assessment; solid and hazardous waste problems and controls; safe drinking water problems and standards; onsite and public sewage problems and control; plumbing hazards; air, water, and solid waste programs; technology transfer; GIS and mapping; bioterrorism and security; disaster emergency health programs; ocean dumping; and much more. Study reference for NEHA's Registered Environmental Health Specialist/Registered Sanitarian credential exam.

876 pages / Hardback
Volume 2: Member: $195 / Nonmember: $215
Two-Volume Set: Member: $349 / Nonmember: $379

PEOPLE **ON THE MOVE**

Vince Radke Retires

Vince Radke, MPH, RS, CP-FS, DLAAS, CPH, retired in September 2018 from the Water, Food, and Environmental Health Services Branch of the National Center for Environmental Health (NCEH) at the Centers for Disease Control and Prevention (CDC) after 17 years. In total, Radke's environmental public health career spans over four decades.

While at CDC, Radke was part of the Environmental Health Specialists Network conducting research on the contributing factors and antecedents of foodborne illness. He was instrumental in the development of the Environmental Assessment Training Series and the National Environmental Assessment Reporting System. He was also involved in vector control and emergency preparedness and response issues and training

Prior to working at CDC, Radke spent 22 years in the environmental health field at state and local levels in several states. Before that, he was part of the Smallpox Eradication Program, first as a Peace Corps volunteer and then later as a technical advisor with the World Health Organization (WHO).

Radke joined the National Environmental Health Association (NEHA) in 1980 and has been actively involved in the association, currently serving as its president. He's also been active in several NEHA affiliates, as well as other organizations.

As seen in the photo at the top, Radke's career has been marked with numerous awards. He's received the Order of the Bifurcated Needle from WHO (1980), Jerrold M. Michael Award from the National Capital Area Environmental Health Association (1997 and 1999), U.S. Department of Health and Human Services Secretary's Award for Distinguished Service (2005), Distinguished Service and Professional Achievement Award from the American Public Health Association (2006), and U.S. Environmental Protection Agency Bronze Medal Award (2011).

In 2013, Radke was named the recipient of the NEHA/NSF International Walter F. Snyder Award for his achievements in advancing environmental health. He also received the NEHA Past Presidents Award in 2013 in recognition of his longstanding service and contributions to the profession.

Beyond the accolades and the lengthy resume, however, Radke is a mentor and leader in environmental health. He's created a legacy through his work that has impacted numerous individuals, which is evident in the quotes from his colleagues.

"Over the years, Vince's expertise, sincere dedication, strong work ethic, and professionalism have served CDC and the American people well. He has made significant contributions to CDC's environmental health, emergency response, and food safety programs. Vince's public health achievements will continue to have an impact well beyond his years of service." – John Sarisky, chief of the Water, Food, and Environmental Health Services Branch, NCEH, CDC

Vince Radke's office at the Centers for Disease Control and Prevention (CDC) is a testament to a long, impactful, and successful career. Photo courtesy of Kirsten Reed, CDC.

"Working with Vince at CDC was one of the great honors and joys of my career. Vince and I started our work at CDC on the same day and for the next 14 years, we experienced many adventures, challenges, accomplishments, and disappointments together. While Vince and I shared countless laughs over the years, when it came to our work, it was serious business. I always admired how Vince put everything he had into the job. He truly cares about people and would always give his best to make people's lives better. For my dear friend, my great hope is that your retirement is filled with countless joys and continued laughter." – CAPT Mike Herring, U.S. Public Health Service (retired)

"To local public health professionals, Vince is the face of environmental health at CDC. His position as sanitarian there, his wide and varied experiences in many areas of environmental health, his national and international presence, and his willingness to always assist others in the execution of their work are consistent hallmarks of his dedication and professionalism. Coupled with his presentation skills, affable manner, and ability for engaging storytelling and handwashing skills, Vince personifies the best in environmental health." – Michéle Samarya-Timm, Somerset County Department of Health

"I will forever be honored to have worked closely with Vince in the many CDC-funded vector control workshops that were provided to the environmental health community. Workshop participants would consistently thank us for offering valuable 'field practice' information in dealing with insect and rodent control issues that were faced daily. Vince, please know you made a difference in advancing the careers of the environmental health professionals you encountered!" – Tom Dickey, retired NEHA employee

"Spending time with Vince is akin to the thoughts of Spanish novelist Miguel de Cervantes, 'the journey is better than the inn.' Time shared with Vince are gems, always rewarding and inevitably full of surprise." – Dr. David Dyjack, NEHA executive director

NEHA congratulates Vince on this milestone event and thanks him for his incalculable contributions to the professions. From everyone at the NEHA office, we wish Vince the best in this next stage of life!

People on the Move is designed to keep NEHA members informed about what their peers in environmental health are up to. If you or someone you know has received a promotion, changed careers, or earned a special recognition in the profession, please notify Kristen Ruby-Cisneros at kruby@neha.org. It is NEHA's pleasure to announce our reader's achievements and new directions of fellow members. This feature will run only when we have material to print—so be sure to send in your announcements!

ACCEPTING NOMINATIONS NOW

2019 Walter S. Mangold Award

The Walter S. Mangold Award recognizes an individual for extraordinary achievement in environmental health. Since 1956, this award acknowledges the brightest and best in the profession. NEHA is currently accepting nominations for this award by an affiliate in good standing or by any five NEHA members, regardless of their affiliation.

The Mangold is NEHA's most prestigious award and while it recognizes an individual, it also honors an entire profession for its skill, knowledge, and commitment to public health.

Nomination deadline is March 15, 2019.

National Environmental Health Association

For application instructions, visit www.neha.org/about-neha/awards/walter-s-mangold-award.

2019 Joe Beck Educational Contribution Award

This award was established to recognize NEHA members, teams, or organizations for an outstanding educational contribution within the field of environmental health.

Named in honor of the late Professor Joe Beck, this award provides a pathway for the sharing of creative methods and tools to educate one another and the public about environmental health principles and practices. Don't miss this opportunity to submit a nomination to highlight the great work of your colleagues!

Nomination deadline is March 15, 2019.

To access the online application, visit www.neha.org/about-neha/awards/joe-beck-educational-contribution-award.

National Environmental Health Association

NEHA ORGANIZATIONAL MEMBERS

Sustaining Members

Accela
www.accela.com

Advanced Fresh Concepts Corp.
www.afcsushi.com

Allegheny County Health Department
www.achd.net

American Chemistry Council
www.americanchemistry.com

Arlington County Public Health Division
www.arlingtonva.us

Association of Environmental Health Academic Programs
www.aehap.org

Baltimore City Health Department, Office of Chronic Disease Prevention
https://health.baltimorecity.gov/programs/health-resources-topic

Bureau of Community and Children's Environmental Health, Lead Program
www.houstontx.gov/health/Environmental/community_childrens.html

CDC ATSDR/DCHI
www.atsdr.cdc.gov/hac

Chemstar Corporation
www.chemstarcorp.com

Chester County Health Department
www.chesco.org/health

City of Independence
www.ci.independence.mo.us

City of Racine Public Health Department
http://cityofracine.org/Health

City of St. Louis Department of Health
www.stlouis-mo.gov/government/departments/health

Coconino County Public Health
www.coconino.az.gov/221/Health

Colorado Department of Public Health and Environment, Division of Environmental Health and Sustainability, DPU
www.colorado.gov/pacific/cdphe/dehs

Custom Data Processing, Inc.
www.cdpehs.com

Diversey, Inc.
www.diversey.com

DuPage County Health Department
www.dupagehealth.org

Eastern Idaho Public Health Department
www.phd7.idaho.gov

Ecobond LBP, LLC
www.ecobondlbp.com

Ecolab
www.ecolab.com

EcoSure
adolfo.rosales@ecolab.com

Erie County Department of Health
www.erie.gov/health

Georgia Department of Public Health, Environmental Health Section
http://dph.georgia.gov/environmental-health

Giant Eagle, Inc.
www.gianteagle.com

Gila River Indian Community: Environmental Health Service
www.gilariver.org

GOJO Industries, Inc.
www.gojo.com/foodservice

Green Home Solutions
www.greenhomesolutions.com

Health Department of Northwest Michigan
www.nwhealth.org

HealthSpace USA Inc
www.healthspace.com

Hedgerow Software US, Inc.
www.hedgerowsoftware.com

Heuresis Corporation
www.heuresistech.com

IAPMO R&T
www.iapmort.org

Industrial Test Systems, Inc.
www.sensafe.com

Jackson County Environmental Health
www.jacksongov.org/442/Environmental-Health-Division

Jefferson County Public Health (Colorado)
http://jeffco.us/public-health

Kanawha-Charleston Health Department
http://kchdwv.org

Kentucky Department of Public Health
http://chfs.ky.gov/agencies/dph/Pages/default.aspx

LaMotte Company
www.lamotte.com

Louisiana State Board of Examiners for Sanitarians
www.lsbes.org

Maricopa County Environmental Services
www.maricopa.gov/631/Environmental-Services

MFC Center for Health
drjf14@aol.com

Multnomah County Environmental Health
https://multco.us/health

Nashua Department of Health
http://nashuanh.gov/497/Public-Health-Community-Services

National Environmental Health Science & Protection Accreditation Council
www.nehspac.org

New Mexico Environment Department
www.env.nm.gov

New York City Department of Health and Mental Hygiene
www1.nyc.gov/site/doh/index.page

North Bay Parry Sound District Health Unit
www.myhealthunit.ca/en/index.asp

Nova Scotia Environment
https://novascotia.ca/nse

NSF International
www.nsf.org

Oklahoma Department of Environmental Quality
www.deq.state.ok.us

Oneida Indian Tribe of Wisconsin
https://oneida-nsn.gov/resources/environmental

Opportunity Council/Building Performance Center
www.buildingperformancecenter.org

Otter Tail County Public Health
www.co.ottertail.mn.us/494/Public-Health

Ozark River Portable Sinks
www.ozarkriver.com

Paper Thermometer Co.
www.paperthermometer.com

Polk County Public Works
www.polkcountyiowa.gov/publicworks

Procter & Gamble Co.
www.pg.com

Protec Instrument Corporation
www.protecinstrument.com

SAI Global, Inc.
www.saiglobal.com

Salcor, Inc.
jscruver@aol.com

Seattle & King County Public Health
www.kingcounty.gov/depts/health.aspx

Starbucks Coffee Company
www.starbucks.com

Stater Brothers Market
www.staterbros.com

Steritech Group, Inc.
www.steritech.com

Sweeps Software, Inc.
www.sweepssoftware.com

Taylor Technologies, Inc.
www.taylortechnologies.com

Texas Roadhouse
www.texasroadhouse.com

Thurston County Public Health and Social Services Department
www.co.thurston.wa.us/health

Tri-County Health Department
www.tchd.org

Tyler Technologies
www.tylertech.com

Washington County Environmental Health (Oregon)
www.co.washington.or.us/hhs/environmentalhealth

Wegmans Food Markets, Inc.
www.wegmans.com

Yakima Health District
www.yakimacounty.us/275/Health-District

Educational Members

Colorado State University
http://csu-cvmbs.colostate.edu/academics/erhs

Eastern Kentucky University
http://ehs.eku.edu

University of Illinois Department of Public Health
www.uis.edu/publichealth

University of Illinois, Illinois State Water Survey
www.isws.illinois.edu

University of Illinois Springfield
www.uis.edu/publichealth

Western Carolina University, School of Health Sciences
www.wcu.edu

Note. As of October 1, 2018, NEHA no longer offers organizational memberships. We will continue to print this section in the Journal to honor the membership benefits due to these listed organizations until their memberships expire.

SPECIAL LISTING

The board of directors includes NEHA's nationally elected officers and regional vice-presidents. Affiliate presidents (or appointed representatives) comprise the Affiliate Presidents Council. Technical advisors, the executive director, and all past presidents of the association are ex-officio council members. This list is current as of press time.

Adam London, MPA, RS
Immediate Past-President

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President@neha.org

President-Elect—Priscilla Oliver, PhD, Life Scientist, Atlanta, GA.
PresidentElect@neha.org

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sandral@plano.gov

Second Vice-President—Roy Kroeger, REHS, Environmental Health Supervisor, Cheyenne/Laramie County Health Department, Cheyenne, WY.
roykehs@laramiecounty.com

Immediate Past-President—Adam London, MPA, RS, Health Officer, Kent County Health Department, Grand Rapids, MI.
adamelondon@gmail.com

NEHA Executive Director—David Dyjack, DrPH, CIH, (nonvoting ex-officio member of the board of directors), Denver, CO.
ddyjack@neha.org

Regional Vice-Presidents

Region 1—Matthew Reighter, MPH, REHS, CP-FS, Retail Quality Assurance Manager, Starbucks Coffee Company, Seattle, WA.
mreighte@starbucks.com
Alaska, Idaho, Oregon, and Washington. Term expires 2020.

Region 2—Major Jacqueline Reszetar, MS, REHS, U.S. Army, Retired, Henderson, NV.
Region2RVP@neha.org
Arizona, California, Hawaii, and Nevada. Term expires 2021.

Region 3: Rachelle Blackham, MPH, LEHS, Environmental Health Deputy Director, Davis County Health Department, Clearfield, UT.
Region3RVP@neha.org
Colorado, Montana, Utah, Wyoming, and members residing outside of the U.S. (except members of the U.S. armed forces). Term expires 2021

Region 4—Kim Carlton, MPH, REHS/RS, Environmental Health Supervisor, Minnesota Department of Health, St. Paul, MN.
Region4RVP@neha.org
Iowa, Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin. Term expires 2019.

Region 5—Tom Vyles, REHS/RS, CP-FS, Environmental Health Manager, Town of Flower Mound, TX.
Region5RVP@neha.org
Arkansas, Kansas, Louisiana, Missouri, New Mexico, Oklahoma, and Texas. Term expires 2020.

Region 6—Lynne Madison, RS, Environmental Health Division Director, Western UP Health Department, Hancock, MI.
Region6RVP@neha.org
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NEHA NEWS

NEHA's New Climate Change Activities and Resources

The National Environmental Health Association (NEHA), in partnership with ecoAmerica, Climate for Health (https://ecoamerica.org/health/), is developing resources for NEHA members to address climate change impacts. Some of those resources include a video that features NEHA member climate change success stories and a Climate Change and Emergency Preparedness and Response White Paper that addresses how emergency preparedness and response are directly related to climate change.

Climate Change Success Story Video

The climate change success story video showcases NEHA members addressing climate change impacts from Cambridge, Massachusetts; Franklin County, Ohio; and Salt Lake County, Utah. Environmental health professionals and members of NEHA's Climate Change Committee share their inspiring stories that address strategies for adaptation, mitigation at the community level, and strong coalitions and collaborations. To view the video, please visit www.neha.org/node/60356.

Cambridge, Massachusetts

The city of Cambridge, Massachusetts, released a comprehensive climate change vulnerability assessment (CCVA) in 2015 and it was determined that the climate of the past is no longer a reliable indicator of the future. The CCVA endeavored to model what would happen to city residents and the built environment when there was an increase in temperature, precipitation, sea-level rise, and coastal storm surge, as well as the implications these increases would have on economics, health, and well-being. The assessment identified Cambridge's key physical and social vulnerabilities based on the assumption that no actions are taken and modeled risks were varied by neighborhood and demographic factors.

The city ranked vulnerability factors and critical assets that led to prioritizing two main neighborhoods to develop climate change preparedness and resilience plans (CCPR). The goal of a CCPR plan is to provide a realistic set of actions and strategies in both the short- and long-term that could be implemented in partnership with the city, its residents, and partner organizations and businesses. The CCPR plan is divided into sections that address social and physical vulnerabilities, including health status, buildings and infrastructure, and the natural ecosystem. Cambridge focused on novel community engagement strategies aimed at building neighborhood social capital, enhancing social connections before an emergency exists, and increasing resident self-determination and empowerment.

Franklin County, Ohio

In early 2016, the Ohio Public Health Association (OPHA) recognized a lack of funding and inconsistent local public health efforts to address climate change in Ohio. With dedicated statewide funding unavailable, OPHA convened a group of public health practitioners, academicians, and other interested subject matter experts to discuss the public health response to this issue. The Ohio Public Health Climate Resilience Coalition's (OPHCRC) purpose is to leverage knowledge and resources across the state to create a white paper and toolkit for local health departments to utilize and to encourage public health action.

Utilizing the Centers for Disease Control and Prevention's Building Resilience Against Climate Effects (BRACE) Framework, the group worked to assess climate impacts and identify vulnerabilities in Ohio. With this information, OPHCRC began development of a white paper to demonstrate a coordinated public health effort in Ohio that would also raise awareness of the need for local action. With priorities and budgets shifting, it is imperative for local governing bodies to take action when and how they can. The coalition is working to supply local health departments with tools and resources that they can use in their communities to build climate resilience.

Salt Lake County, Utah

Salt Lake City and County are addressing the challenge of climate change by helping clean the air. Fortunately, there has been a dramatic reduction in the cost and effectiveness of wind and solar energy in recent years, as well as an increase in the willingness of individuals, families, organizations, and many governments to step forward and act. Salt Lake County Health Department completed a comprehensive climate adaptation plan and hosted a seminar to introduce it to the community. The department also hosted its Fourth Annual Climate and Health Symposium—a time for local experts to discuss and report on climate activities.

Salt Lake City Mayor Jackie Biskupski is an ardent advocate for climate change response. She was selected as chair of the U.S. Conference of Mayors Alliance for a Sustainable Future and is one of the early adopters of the Sierra Club's Mayors for 100% Clean Energy goal. Salt Lake City recently opened the first net-zero energy fire station in the nation. Salt Lake County is a partner with the Utah Climate Action Network, an initiative led by Utah Clean Energy that provides a forum for all climate experts and leaders to share ideas and best practices on climate solutions. In October 2018 they hosted Utah Climate Week where a wide range of concerned community members, organizations, and businesses promoted awareness and action around climate change.

Climate Change and Emergency Preparedness and Response White Paper

NEHA is also developing a Climate Change and Emergency Preparedness and Response White Paper that addresses the relationship between climate change impacts and emergency preparedness and response. Increasing temperatures are changing weather patterns and the frequency and intensity of weather events. More severe weather events are producing more substantial and long-lasting damage, intensifying the need to incorporate environmental health professionals in the context of emergency preparedness when responding to disasters.

As of press, the white paper has not been posted but it is expected to be available by January. Please check www.neha.org/eh-topics/climate-change-0 for this resource, as well as for more NEHA and ecoAmerica resources that address climate change.

NEHA NEWS

NEHA Staff Profile

As part of tradition, NEHA features new staff members in the *Journal* around the time of their 1-year anniversary. These profiles give you an opportunity to get to know the NEHA staff better and to learn more about the great programs and activities going on in your association. This month we are pleased to introduce you to one NEHA staff member. Contact information for all NEHA staff can be found on page 49.

Angelica Ledezma

I began my journey with NEHA in December 2017 as a member services assistant. Through this position I had the opportunity to interact with our members and learn about the important work they do. I quickly became involved with NEHA's Annual Educational Conference (AEC) & Exhibition and have since moved into my new role as the AEC manager where I oversee the administrative portion of the conference. I also serve as the liaison for the association's board of directors.

Prior to joining NEHA, I graduated from the University of Denver (DU) where I studied biology and psychology. I was also involved with the University Programming Board coordinating various campus events. My interest in sustainable practices and addressing climate change grew while at DU. This interest is what initially drew me to NEHA. I have since loved learning more about the wide span of work our members engage in such as food safety, water quality, and everything else within environmental health. I am eager to continue learning from our members and eager to play such a big role in something as exciting as the AEC.

I grew up in California and have lived in Colorado for the last 12 years. While I'm not a fan of the cold winter weather, it's well worth it for the abundance of outdoor activities the state offers year-round. When I'm not working, I can usually be found enjoying beautiful Colorado with my husband or reading a book while snuggled up with my two adorable miniature dachshunds.

I'm glad to be part of all the exciting things happening at NEHA and I'm honored to serve such a dedicated profession. I hope to harness the energy from last year's AEC in Anaheim, California, and to grow the conference with every coming year. I look forward to working with many of you along the way!

DirecTalk

continued from page 54

the three plenary speakers have already been secured and we are more than 6 months away from the conference.

Disruption seems to be the hallmark of the modern world. Some of it is of our own making. Many relationships with our long-time business partners have been sunset because they had run their natural course. Over the last 3 years we have changed our meeting planner, retirement plan administrator, learning management system, and client relations management system, to name a few. We make principled decisions around price, quality, and service. At the same time, a senior staff member or I call the affected vendors personally to explain our rationale. In every case, the decision, while painful to people we have worked with for many years, is not a surprise.

There are many distractors and news of the moment that serve to dilute focus from our main reason for existing—you. The individual practitioner is our central concern. We ask ourselves repeatedly, “Do we have a dog in this fight?” and “How do our members benefit?” I grieve whenever I communicate to a partner that we make decisions based on principle and membership interests, which sometimes conflict with the partner’s desire for an alternate NEHA action.

A beneficiary of Dave’s roadside turtle assistance program. Photo courtesy of David Dyjack.

Our enemy is not an alignment inside a federal agency. Our adversary is not internal agency personnel decisions. Our foe is not another association. Our enemy is ignorance. Ignorance about the professional. Ignorance about the profession. Ignorance about your association. We combat ignorance by focusing our limited resources on influential people who share our vision to ensure everyone reaches their full human potential. At the same time, our disruptive quality improvements are intended to minimize unnecessary distractions so our staff can focus their energy on delivering the tools and resources you need to be effective.

Motorists shake their fists and grimace at me when I stop traffic to save turtles from extermination on our busy roads. I consider their momentary rage an opportunity cost as I do one small thing to improve the lives of creatures that make the world a safer (by eating insects) and more beautiful and interesting place to live. Over the last year we have implemented many changes and taken public positions that ensure we can provide you the support and representation you need to be effective. Not everyone is happy. Please know that our aim is at once noble and true.

Happy holidays and the best for 2019.

Dave

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DirecTalk MUSINGS FROM THE 10TH FLOOR

David Dyjack, DrPH, CIH

Shake the Snow Globe

Annoyed commuters honk their horns. Alarmed spouse frets over my safety. Agitated reptiles snap and hiss. Through it all, I remain unperturbed. I stop for turtles—on busy roads, very busy roads. It's a matter of principle. Disruption of the status quo, my own, and some courtesy of others seem to take up a lot of my time these days, and not everyone is delighted. Let's dive into some current examples.

California's 2018 Assembly Bill 626—the Homemade Food Operations Act—is a good first example. Yes, California Governor Jerry Brown recently signed into law legislation that legalizes home restaurants. Home cooks agree to a facility inspection if there are consumer complaints. Their food must be prepared, cooked, and served on the same day and delivered within a safe time period based on the holding capacity of their equipment. Home cooks must also obtain a professional food manager certification. I'm waiting for home cooking advertisements to pop up on my iPhone as I drive the amazing Pacific Coast Highway. When I inquired about mounting objections over this legislation earlier this year, I was told by an influential voice from within the profession in California to "get over it, the world has changed." Indeed.

Articles from this weekend's *New York Times* report that the U.S. Environmental Protection Agency (U.S. EPA) Office of Children's Health Protection has placed its director on administrative leave. This move sent Twitter aflutter and served to fill my digital inbox with requests to sign onto letters demanding the director be immediately returned to the position. We declined to sign on as the National Environmental Health Association (NEHA) does do not comment on internal agency personnel issues. Frankly, we don't know firsthand why the office director was placed on leave. Alternately, we are unequivocally supportive of a strong and effective Office of Children's Health Protection.

> *Our enemy is ignorance.*

There are reports from major news outlets this weekend that the U.S. EPA Office of the Science Advisor is being dissolved. Again, my inbox is full of requests to do something. NEHA's role is to not dabble in internal agency realignment decisions. On the other hand, we are adamantly supportive of effective public health decisions anchored in science. I reached out to someone I know within the agency, someone who cares deeply for the environment and health. They conveyed to me that this agency moved. While the information wasn't too not helpful, it's not the end of the world.

I can provide many other examples, such as recent Food and Drug Administration (FDA) and Centers for Disease Control and Prevention structural realignments, which generate panicked calls to my iPhone late at night. We also receive daily requests to weigh in on issues and make public statements on matters related to the environment and environmental health. Our policy is clear. We advocate for the profession and policies that advance effective practice. We will steer clear of individual personnel decisions and commentary on the seemingly endless federal agency reorganizations. We do, when asked, make ourselves available to agencies when they request our opinion on their plans, formally and informally. Just last week I completed a 45-minute written survey for FDA. We don't hold back. For the record, I have engaged in many terse one-on-one conversations with government leaders when their decisions harm our profession, our association's members, or our nation's health. There is a time and place.

Our membership categories were profoundly simplified in October of this year. We streamlined the categories from over 10 to down to 5. Some of you expressed unhappiness with our decision. At the same time, almost no member could explain to me the membership category they were in or the benefits associated with that category. Our staff was equally confused. Our aim is to provide you with world-class service and at the same time, be *really* easy to work with and understand.

Abstract submission for our 2019 Annual Educational Conference (AEC) & Exhibition provides yet another example of disruptive quality improvement. We have simplified the submission process and adjusted the schedule to solicit abstracts earlier in the year. We made these changes to have time to publish our final AEC program, which allows you, our members, to submit earlier in the year the proposed AEC program to those who approve your travel. With our new AEC format, we have three plenary events—two of

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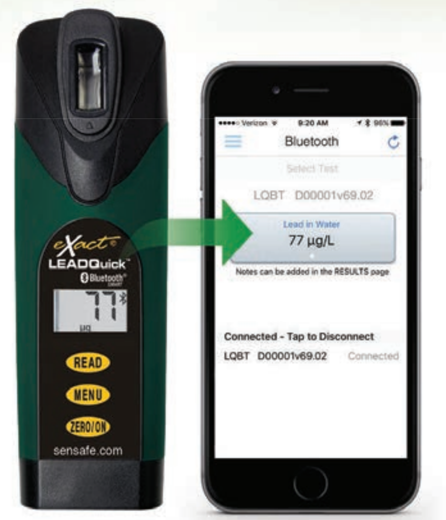

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INTERNATIONAL PERSPECTIVES

Is Air Pollution a Risk Factor for Sleep-Disordered Breathing in Children? A Study in the Province of Varese, Italy

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Abstract The role played by air pollutants on sleep-disordered breathing (SDB) in childhood thus far has been little analyzed, although susceptibility to environmental toxicity is higher in children than in adults. This ecological study, carried out in the province of Varese, Italy, explores the geographical pattern of SDB among children and investigates its relationship with combustion-related pollution. For each of the 754 patients admitted to the Sleep-Disorder Breathing Center of Varese due to sleep respiratory disturbances, the apnea-hypopnea index (AHI) upon which SDB diagnosis is based was recorded. Through spatial analysis methods, the geographical heterogeneity of SDB and its severity were analyzed using AHI-based indicators.

From available nitrogen dioxide (NO_2) levels, the geographical pattern of the pollutant—regarded as a marker for combustion-related mixtures—was obtained and compared with that of SDB. We identified an area of significantly higher SDB case density ($p < .05$) and found that the relative risk (RR) of SDB increased significantly for the children living in this area (RR = 1.307, 95% confidence interval [*CI*] [1.155, 1.477]). In this area, annual NO_2 levels were 1.5 times the provincial average. For the whole study region, moreover, we found a significant positive correlation ($p < .01$) between SDB severity and NO_2. These findings suggest that traffic-related pollution might contribute to SDB onset and level of severity.

Introduction

The geographical distribution of pediatric sleep respiratory diseases is believed to be influenced by air pollution, and consequently by the presence of industries, railway stations, vehicular congestion, and high intensity of transportation modes. In particular, the role of environmental air pollution among the pediatric population has frequently been investigated as a causal factor for respiratory diseases (Bates, 1995; Bedeschi et al., 2007; Brauer et al., 2002; Dockery et al., 1996; Nicolai et al., 2003; Orazzo et al., 2009; Sestini et al., 2005; Thurston, Lippmann, Scott, & Fine, 1997; Vigotti, Chiaverini, Biagiola, & Rossi, 2007) and for respiratory infections (Prieto, Mancilla, Astudillo, Reyes, & Roman, 2007).

Moreover, air pollution has been shown to be associated with the number of hospital admissions for respiratory diseases in children and adolescents (Jasinski, Pereira, & Braga, 2011), chronic respiratory diseases, acute respiratory symptoms frequency in children (Kukec, Farkas, Erzen, & Zaletel-Kragelj, 2013), and asthma symptom exacerbation or development (D'Amato et al., 2013; Esposito et al., 2014). Yet few authors have focused their attention on the relationship between environmental pollution and sleep-disordered breathing (SDB) in children.

A cross-sectional study by Abou-Khadra (2013) analyzed the possible associations between exposure to PM_{10} and sleep disturbances in school children 6–13 years who were recruited from four elementary schools in Egypt located in two districts with great differences in PM_{10}. A significant association was observed, namely between PM_{10} exposure and disorders of initiating and maintaining sleep. In the study, the relationship between SDB and air pollution was not specifically investigated and only some of the examined patients had SDB. The proven association of poor sleep quality with environmental pollution, however, is noteworthy.

Zanobetti and coauthors (2010) studied the relationship between PM_{10} air levels and SDB in adults in seven U.S. urban areas, and reported that increasing levels of daily particulate matter in summer are associated with increases in SDB and decreases in the percentage of sleep efficiency. Some authors suggest an influence from air pollutants on the central nervous system. It has previously been reported that particles can translocate from the nose up to the olfactory nerve and to the brain (Elder et al., 2006; Wang et al., 2007), causing an inflammatory response and changes in neurotransmitter levels. Such consequences could be related to adverse effects on sleep and its duration and architecture, as well as on SDB (Kleinman et al., 2008).

Other authors hypothesize that pollution can influence the ventilatory control centers of the central nervous system and, moreover, that particulate matter can trigger a nasal and pharyngeal inflammatory response, causing an increase in upper airway resistance and a reduction in airway patency (DeMeo et al., 2004; Mehra & Redline, 2008). Kuehni and coauthors (2008) conducted a population survey of 6,811 children ages 1–4 years from Leicestershire, UK, to determine prevalence, severity, and risk factors for snoring; they found habitual snoring to be associated with exposure to air pollutants.

Particularly noteworthy is the study performed by Kheirandish-Gozal and coauthors (2014) exploring the relationship between air quality and the prevalence of habitual snoring in school-age children in five distinct neighborhoods of Teheran. The neighborhoods were characterized by considerable differences in air composition, and consequently in air pollutant concentration. A statistically significant association between the prevalence of habitual snoring and environmental air pollution was found, even when considering the influence of other factors such as age, sex, clinical history, and familial history components.

In school-age children, SDB can lead to important consequences, including impacting school performance. This aspect was studied by Gozal (1998), who analyzed the prevalence of sleep-associated gas exchange abnormalities (SAGEA) among children attending elementary school whose educational performance was in the lowest 10th percentile of their class. SAGEA was found to frequently be present in poorly performing first-grade students, in whom it is assumed to have adversely affected learning performance.

In light of the aforementioned considerations, an analysis of the geographical distribution of SDB could help better identify and label geographical areas with higher risk, namely local areas where an unusually higher frequency of children and adolescents are observed to be affected by SDB. These areas could then be more closely investigated in search of possible sources of environmental pollution. A match between unusual SDB intensity/severity peaks and areas where specific sources of air pollution are reported would highlight a positive association.

The aim of the present ecological study was to analyze the geographical distribution of pediatric SDB in the Italian province of Varese using data collected in the provincial reference hospital center for children with SDB. To highlight possible associations between SDB and exposure to combustion-related pollutants, these results were compared with the spatial pattern of nitrogen dioxide (NO_2), which is regarded as a marker for such pollutants, as it is a significant constituent of emissions and is highly correlated with other combustion products, including fine particles (World Health Organization [WHO], 2013).

Methods

Patient Data

We used data provided by the Sleep Disordered Breathing Center of the Pediatric Unit Insubria University–Filippo del Ponte Hospital of Varese, which is the largest hospital in the province of Varese and a specialized center for SDB in Northern Italy. Data were collected from 2010–2014 and focused on children who resided in 112 municipalities in the province of Varese, were over 1 year of age, and who were admitted to the hospital because of recurrent respiratory disturbances during sleep.

The total number of children analyzed was 754; for each patient, we gathered information about the child's municipality of residence, sex, and the value of the apnea-hypopnea index (AHI). AHI is based on polysomnographic recordings conducted overnight by means of Embla's *Embletta Gold* sleep system, a recording system that can discriminate the SDB severity level. All of the children were diagnosed with respect to SDB based on their AHI index.

In comparison with adults, for whom AHI-based classification of SDB is consolidated, there currently are no universally accepted guidelines as to when SDB is sufficiently severe in children to warrant treatment. Considering that most pediatric sleep specialists regard values of AHI >1 as already abnormal (American Academy of Sleep Medicine, 2006; Loughlin & Eigen, 1994; Scholle, Wiater, & Scholle, 2011; Uliel, Tauman, Greenfeld, & Sivan, 2004), this cutoff point was taken to identify SDB.

For the purpose of this study, each patient was assigned to a municipality according to the place of residence at the time of hospital admission. The parent(s) of each child gave written informed consent for researchers to access the child's clinical data. The study procedures were in accordance with Italian privacy laws (Italian Personal Data Protection Code, Italian Legislative Decree no. 196, 2003).

Air Pollution Data

According to a recent report about air quality in the province of Varese (Algieri et al., 2013), combustion-related pollutants such as fine particulate matter, ozone, and NO_2 were at particularly critical levels in 2013. Considering that NO_2 is the main source of ozone and nitrate aerosols—which in the presence of ultraviolet light and hydrocarbons end up forming an important fraction of the fine particulate mass—we used the mean annual concentration of NO_2 as a marker for the mixture of combustion-generated pollutants (WHO, 2013).

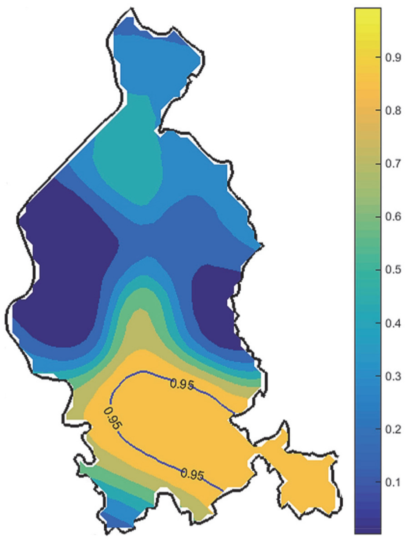
Pollution data for 2013 were provided at the municipality level by the Lombardy Agency for Environmental Surveillance (ARPA). These pollution data were the result of numerical simulations performed using the ARPA Regional modeling system and were based on emissions data and took into account several meteorological parameters (Peroni, Fossati, & Abbattista, 2013).

Statistical Spatial Analysis

For the purpose of this study, we explored the spatial pattern of SDB in the Varese province through AHI-based indicators, namely the proportion of children with AHI >1, I_{SDB}, and the mean AHI value, I_{AHI}, by which we analyzed the spatial heterogeneity of SDB throughout the province in terms of prevalence and mean severity degree. I_{SDB} was evaluated at each point on a grid covering the study region as a ratio of the estimates of cases over population densities, obtained by a variable kernel method (Silverman, 1986; Tentoni et al., 2012). A smooth isopleth map was computed to visually represent the geographical heterogeneity of the indicator and capture its salient spatial structure.

FIGURE 1

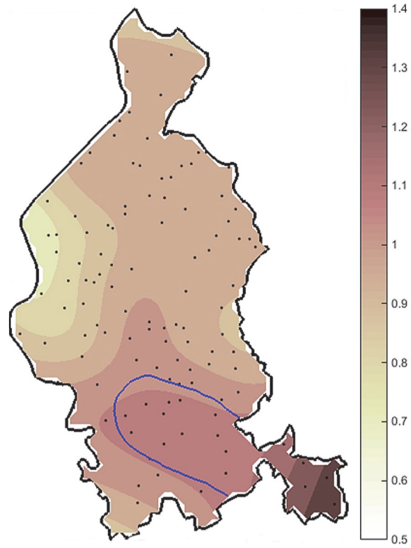
Probability Map of I_{SDB} Under the Null Hypothesis



SDB = sleep-disordered breathing.
Note. Values >0.95 correspond to sites where the observed SDB prevalence is higher than expected.

FIGURE 2

Map of I_{SDB}



SDB = sleep-disordered breathing.
Note. The significant higher prevalence area $S^+(I_{SDB})$ is highlighted.

TABLE 1

Distribution of the Apnea-Hypopnea Index (AHI), Frequency of Sleep-Disordered Breathing (SDB)-Diagnosed Cases (AHI >1), and Annual Mean Nitrogen Dioxide (NO_2) Concentration (µg/m³) in the Province of Varese, Inside and Outside $S^+(I_{SDB})$

	Inside S^+	Outside S^+	Province of Varese
Municipalities (#)	17[a]	95	112
Children (#)	93	661	754
AHI mean ± *SD*	4.9 ± 9.3	3.3 ± 5.1	3.5 ± 5.8
AHI 25th, 50th, and 75th percentile	1.5, 2.0, 6.0	1.0, 2.0, 4.0	1.0, 2.0, 4.0
AHI >1 (# (%))	73 (78.5)	397 (60.1)	470 (62.3)
NO_2 annual mean (µg/m³)	31.8	19.7	21.6

[a]List of the 17 municipalities that correspond to S^+: Arsago Seprio, Besnate, Cairate, Caronno Pertusella, Casorate Sempione, Cassano Magnago, Cavaria con Premezzo, Cislago, Fagnano Olona, Gallarate, Gerenzano, Jerago con Orago, Oggiona con Santo Stefano, Olgiate Olona, Saronno, Solbiate Olona, and Uboldo.

Areas of elevated prevalence were assessed for significance using a Monte Carlo procedure, which lead to the construction of the probability surface of I_{SDB} under the null hypothesis of spatial homogeneity (Kelsall & Diggle, 1995; Lisa, Astolfi, Zei & Tentoni, 2015). The 0.95-probability contour that bounds the rejection region $S^+ (I_{SDB})$ where observed values of I_{SDB} are to be considered significantly higher than expected (significance level $\alpha = .05$), was then superimposed on the map of I_{SDB}.

We estimated the mean severity indicator I_{AHI} through a spatial interpolation method (Lisa et al., 2015) by which the unknown value at a grid point was estimated as a weighted average of the known AHI values at the municipality level according to their proximity to the estimation point. Similarly, a smoothed map for the combustion-related pollution indicator I_{NO2} was computed from the mean annual concentration data of NO_2. Numerical procedures for kernel density estimation, spatial smoothing, isopleth mapping, Monte Carlo hypothesis testing, and identification of significant excess areas were all developed ad hoc using the software application MATLAB version 8.3 (R2014a).

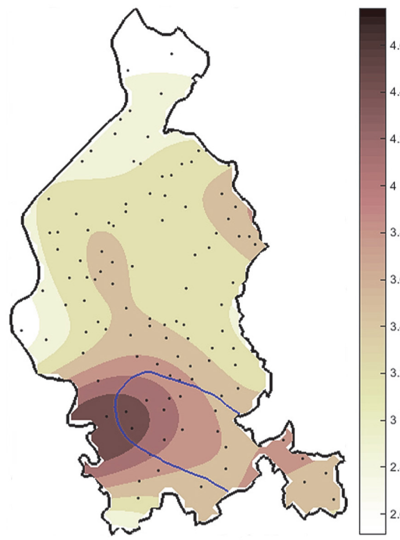
Results

As described in Methods (Statistical Spatial Analysis), we analyzed the probability surface associated with indicator I_{SDB} under the null hypothesis and singled out the 0.95-probability contour (Figure 1). The prominent geography of SDB is represented by the isopleth map of I_{SDB} (Figure 2). In this figure, the probability contour singled out in Figure 1 is superimposed onto the map of I_{SDB} to highlight the significant higher prevalence area $S^+(I_{SDB})$. In this area, located in the south of the province, the proportion of SDB-diagnosed children was significantly higher than we would expect under the hypothesis of spatial homogeneity of SDB cases with respect to the population. The critical area $S^+(I_{SDB})$ has an extension of approximately 200 km², which amounts to 17% of the whole Varese province. In the following text, we will refer to the sample of children living in the 17 municipalities that correspond to $S^+(I_{SDB})$ as the inside S^+ group and the remaining children as the outside S^+ group.

In Table 1, we report descriptive statistics of the AHI distribution and the frequencies of SDB cases within each group as well as in the whole province. As highlighted by the quartiles, for the inside group the AHI distribution is shifted markedly toward higher values: we observed higher severity degrees of SDB in the inside-S^+ children, with a mean AHI value of 4.9 versus 3.3 in the outside group. The proportion of SDB-diagnosed children (AHI >1) was 1.3 times higher in the inside than in the outside group, namely 78.5% and 60.1%, respectively. A highly significant association was found between SDB and residing in the critical area S^+ ($\chi^2 = 11.801$, $df = 1$, $p < .01$). The relative risk of SDB significantly

FIGURE 3

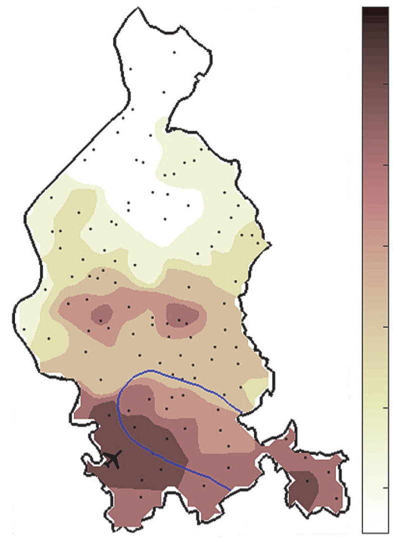
Mean Level of Sleep-Disordered Breathing (SDB) Severity (I_{AHI})



Note. Values >0.95 correspond to sites where the observed SDB prevalence is higher than expected.

FIGURE 4

2013 Annual Mean Concentration of Nitrogen Dioxide (µg/m³)



Note. The location of the Milan-Malpensa International Airport is indicated on the map.

increased for the inside versus outside group, namely RR = 1.307 with a 95 % confidence interval, *CI* [1.155, 1.477].

To illustrate the spatial variation of SDB severity, the smoothed map of I_{AHI} is shown in Figure 3. Higher severity levels were observed in the southern part of the province, with a large overlap to the critical area S^+. This finding is in agreement with the data reported in Table 1 and provides spatial information as to where SDB of higher severity was observed, thus focusing attention on the area's most western part.

Based on NO_2 concentration data, the map of I_{NO2} (Figure 4) represents the spatial pattern of combustion-related pollution. A significant positive correlation was found between mean AHI and NO_2 concentration: $R = 0.74$, with 95% *CI* [0.722, 0.763]. The map of I_{NO2} highlights that the southwestern part of the province had the highest NO_2 emissions. The mean NO_2 values within and outside the critical S^+ area are reported in Table 1 along with the provincial average: the mean annual concentration of NO_2 within the higher SDB prevalence area $S^+(I_{SDB})$ is 1.5 times higher than the provincial average. Finally, we notice that the Milan–Malpensa International Airport, ranked second in Italy for overall aircraft movements, represents an important source of air pollution and is located remarkably close to the observed peak areas for both NO_2 emissions and SDB severity.

Discussion

The results of the current study, with regard to the relation between respiratory diseases and air pollution levels, are consistent with the data reported in the existing literature (Bates, 1995; Bedeschi et al., 2007; Brauer et al., 2002; Dockery et al., 1996; Nicolai et al, 2003; Orazzo et al., 2009; Sestini et al., 2005; Thurston et al., 1997; Vigotti et al., 2007). For respiratory infections, see Prieto and coauthors (2007). By analyzing hospital data regarding children with respiratory symptoms who reside in a highly polluted area in Northern Italy, we found a positive association between SDB and air pollution levels. Even if positive associations cannot prove causal relationships, our results are highly suggestive for a direct adverse effect of traffic-related pollution (NO_2) on children's respiratory health.

It is noteworthy that few authors so far have focused on the geographic distribution of SDB, especially regarding the pediatric population. Although many studies can be found about the role of air pollution in the new onset and exacerbation of pediatric asthma (Brauer et al., 2002; Burte, Nadif & Jacquemin, 2016; Esposito et al., 2014; Favarato et al., 2014; Thurston et al., 1997; Velická et al., 2015), only a few authors have studied the relationship between environmental pollution and SDB in children. Zanobetti and coauthors (2010) carried out a multicenter longitudinal study in adults focused on seven urban areas in the U.S. during the summer, when air pollutant concentration increases. They observed an increased risk of SDB and of the respiratory disturbance index.

The geographical distribution of SDB with relation to air pollution was previously studied by Kheirandish-Gozal and coauthors (2014), who found a higher prevalence of habitual snoring among school-aged children in the southern districts of Teheran, Iran, where air quality is poor and pollutant concentrations are higher due to proximity of the central desert plains. The diagnosis of SDB in these studies was based substantially on the caregiver's subjective perception that their child suffered from a sleep disorder, but a validated questionnaire instrument was also used that focused on symptoms associated with SDB. Habitual snoring was defined as loud snoring ≥3 nights/week (Accinelli et al., 2015; Kheirandish-Gozal, Ghalebandi, Salehi, Salarifar, & Gozal, 2014).

In the present study, the device used for polysomnographic recording allowed us to rely on the AHI index to more objectively diagnose SDB and differentiate its severity level on a quantitative basis. We observed a significantly higher prevalence of SDB-diagnosed children in an area, $S^+(I_{SDB})$, in the south of the province of Varese. The spatial pattern of indicator I_{AHI} further highlighted that SDB severity increased westward.

A yearly report of ARPA (Algieri et al., 2013) indicates that in a wide southern area of the province of Varese, the observed mean daily PM_{10} concentration levels in 2013 repeatedly exceeded the admitted threshold of 50 µg/m³ and also that NO_2 emissions were higher than in the rest of the province. Our study results are consistent with this report: on the one hand, they indicate $S^+(I_{SDB})$ as an area where children have a higher relative risk of SDB, possibly due to environmental sources. On the other hand, the positive correlation we found between the annual mean concentration of NO_2 and SDB severity suggests an adverse effect of traffic-related pollution. The southern part of the province is indeed characterized by a higher population density, a great number of industrial plants, and a significant level of vehicular and air traffic.

The peculiar geography of the Po Valley, which extends from the Western Alps to the Adriatic Sea and includes the southern part of the province of Varese, makes it prone to high levels of air pollution. The almost-enclosed conformation of the Po basin, surrounded by the Alps and the Apennine mountains, along with the influence of the Adriatic Sea, cause high levels of relative humidity throughout the year, along with stagnant air—all factors that make the dispersion of air pollutants difficult. These factors explain the higher concentration of air pollutants in the southern part of the province that ARPA reported.

Outdoor air pollution contributes to respiratory problems in children in urban areas around the world. Children generally spend much time outside engaged in physical activity, and as such, they can have greater exposure to pollutants. Children as a population are more susceptible to adverse health effects because the immune system in the early stages of life is still underdeveloped. Children, while smaller than adults, have a higher respiratory frequency— therefore they inhale and absorb more pollutants in relation to their weight compared with adults.

The detrimental effects to lung function and development constitute another important chronic effect of air pollution. Poorly soluble particles deposited in a person's oral passages can often be cleared by coughing or be expectorated, or can be swallowed into the gastrointestinal tract. Soluble particles are likely to be rapidly absorbed after deposition, but deposition depends on the rate of dissolution of the particle and the molecular size of the solute (Orazzo et al., 2009). With specific regard to the sample of children we analyzed, intense vehicular and air traffic likely played a role in increasing SDB severity.

There are some limitations of the present study that need to be considered. No information on the level of exposure of children to outdoor air pollution (e.g., prevalence of diesel and gasoline combustion engines) was available; additionally, neither the length of residence nor the amount of time they spent outdoors was known. No corrections for indoor pollution exposure (such as heating and cooking habits within homes, type of home construction and ventilation) and family secondhand smoke exposure were studied due to the lack of the necessary information. Studies in literature have pointed out the relationship between secondhand smoke and SDB (Jara, Benke, Lin, & Ishman, 2015), sleep pattern changes (Yolton et al., 2010), and snoring (Zhu et al., 2013) in children.

In the current study, we analyzed patients residing in the province of Varese who visited the hospital in Varese. Although the SDB Center of the Hospital of Varese has an excellent reputation and attracts patients from the region, the possibility of some distortion in the data cannot be dismissed. Pediatric patients could have been seen outside the province for various reasons, such as for convenience in going to a more nearby hospital, even though the nearer hospitals were less specialized.

Finally, this study is an ecological study, where the analysis unit is represented by the population of children admitted to the hospital because of reported respiratory symptoms during sleep and thereby investigated for SDB. It is therefore possible that a bias (ecological fallacy) has occurred, as the association observed between the variables analyzed in the population might not correspond with the effective association found in the individuals.

Conclusion

The results reported in the present study have to be considered preliminary and exploratory due to the limitations pointed out in the previous section. Nevertheless, the positive association we observed between SDB in children and the fact that they were living in an area characterized by a high density of traffic-related pollutants should be more carefully examined, as airway inflammation is a potential mechanism connected with the effect of air pollution and SDB exacerbations—such effect can be due to the oxidative stress related to the incomplete combustion of fossil fuels that produces high levels of polyaromatic hydrocarbons.

Therefore, further research is desirable to clarify the role of air pollutants on SDB and on respiratory diseases in children. This additional work would allow the wider acquisition of knowledge about potentially modifiable contributors to the risk of developing SDB during childhood, which could then be the basis for improving children's pulmonary health.

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