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Volume 78, No. 5 December 2015

Legionella:

Learning From a Past Outbreak to Prevent Future Ones

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Environmental Health

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ABOUT THE COVER



In July 2013, an outbreak of Legionnaires' disease occurred at a long-term care facility in a suburb of Columbus, Ohio. Thirty-nine cases were con-

firmed; of those cases, six were fatal. Our cover feature this month, "Legionnaires' Disease Outbreak at a Long-Term Care Facility Caused by a Cooling Tower Using an Automated Disinfection System—Ohio, 2013," describes the epidemiologic and environmental investigation conducted to determine the scope of the outbreak, identify the source, and recommend control measures to prevent additional cases. Unused cooling towers with automated disinfection systems can become reservoirs for amplification and dissemination of *Legionella*. See page 8.

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Official Publication



Journal of Environmental Health
(ISSN 0022-0892)

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Published monthly (except bimonthly in January/February and July/August) by the National Environmental Health Association, 720 S. Colorado Blvd., Suite 1000-N, Denver, CO 80246-1926. Phone: (303) 756-9090; Fax: (303) 691-9490; Internet: www.neha.org. E-mail: kruby@neha.org. Volume 78, Number 5. Subscription rates in U.S.: \$135 per year and \$250 for two years. International subscription rates: \$160 per year and \$300 for two years (airmail postage included). Single copies: \$12, if available. Reprint and advertising rates available at www.neha.org/JEH. CPM Sales Agreement Number 40045946.

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Periodicals postage paid at Denver, Colorado, and additional mailing offices. POSTMASTER: Send address changes to *Journal of Environmental Health*, 720 S. Colorado Blvd., Suite 1000-N, Denver, CO 80246-1926.



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► PRESIDENT'S MESSAGE



Bob Custard,
REHS, CP-FS

Environmental Health Without Borders

Environmental health is global by its very nature. Pollutants carried by air or water move readily across national boundaries. International trade puts products manufactured in many other nations in the hands of every U.S. consumer. A trip to your local grocery store's produce or seafood department reveals foods harvested in dozens of different countries. Dining out in many cities now presents the opportunity to enjoy the unique cuisines and food products of many cultures.

Our global interconnectedness brings environmental health risks with it. To cite just a few examples:

- **Accidental import of a vector species**—In 1985, the Asian tiger mosquito (*Aedes albopictus*) was accidentally introduced into the U.S., probably in a cargo of used tires shipped to Houston from Asia. Since then the Asian tiger mosquito has become endemic in 26 southeastern, mid-Atlantic, Mississippi valley, and Missouri valley states. It has developed into a significant nuisance species and a potential disease vector for LaCrosse encephalitis, dengue fever, and chikungunya.
- **Introduction of diseases previously not endemic in the U.S.**—In 1999, West Nile virus appeared in the U.S. The epidemiologic evidence suggests that the virus most likely was introduced via infected humans arriving in New York from Israel, where there was an epidemic of West Nile virus infection at the time. By 2004, West Nile virus was found in all 48 of the contiguous states in the U.S.
- **Import of contaminated pet food ingredients**—In 2007, pet food companies

We can no longer pretend that what happens outside the borders of the U.S. will not directly impact the residents of our country.

recalled numerous products because the wheat gluten or rice protein they contained was contaminated with melamine. The ingredients in question were thought to have originated in China.

- **Import of toys containing toxic materials**—Also in 2007, thousands of Curious George plush dolls from Marvel Toys and Barbie accessories from Mattel were recalled after it was discovered that the toys contained an excessive amount of lead in their surface paint. The products were manufactured in China.
- **Humanitarian crises**—In January 2010, a major earthquake devastated Haiti, internally displacing many people and badly damaging the already inadequate water and sanitation infrastructure. Within months a major cholera epidemic broke out, which still has not been entirely controlled. A number of persons entering the

U.S. from Haiti have brought the disease to the U.S. with them.

- **Travel of persons infected with rare infectious diseases to the U.S.**—In 2014, a Liberian national visiting Dallas, Texas, was diagnosed with Ebola virus and subsequently died. Two of the nurses who helped treat the man subsequently contracted Ebola virus. The incident caused nationwide alarm and sparked renewed emphasis on hospital sanitation and infection control measures.
- **Import of food products contaminated with pathogens**—This year, cucumbers imported from Mexico appear to be responsible for an outbreak of *Salmonella* Poona that CDC says has sickened at least 558 persons in 33 states as of this writing (www.cdc.gov/salmonella/poona-09-15/).

We can no longer pretend that what happens outside the borders of the U.S. will not directly impact the residents of our country. As chikungunya, dengue fever, and Ebola have recently shown us, few environmental health issues are geographically limited. It is increasingly important that NEHA be globally engaged on issues of international importance.

How Is NEHA Becoming More Globally Engaged?

NEHA has begun a conscious effort to become more engaged internationally. Our strategic directions include a commitment to become both more active and more effective in the international arena. Some of NEHA's initiatives include the following:

- Several years ago NEHA created a new class of membership: international members.



Nsubuga Benedict, director general, Environmental Health Support Association—Uganda (EHSA-U) and Bob Custard, NEHA president, at the dedication of the EHSA-U's environmental health library in 2011.



Laptops and environmental health books being prepared for shipment to Jamaica.

Today NEHA has about 60 international members. Approximately half of NEHA's international members live in Canada. It is expected that the number of international members will grow steadily over time. NEHA's goal is for 10% of our membership to be international members within 10 years.

- In 2011, NEHA donated over 100 books to the Environmental Health Support Association—Uganda (EHSA-U) to start an environmental health library there (see photo above left). About 30 bimetal bayonet thermometers were also donated to EHSA-U members. In 2012, NEHA arranged the donation of three laptops to EHSA-U through Global Environmental Health Partnerships (GEHP). In 2014, Virginia Environmental Health Association Past President Eric Myers delivered another shipment of books to EHSA-U on behalf of NEHA and GEHP. Many of the books were donated by NEHA member Denise Sockwell, the Arizona Environmental Health Association (AEHA), and AEHA President Tom Dominick.
- In 2012, NEHA worked with GEHP to donate a number of books to the Zambian Institute of Environmental Health (ZIEH). Additional books are now waiting for someone traveling to Zambia to take them to ZIEH.
- Over the last several years, NEHA has increased its participation in the International Federation of Environmental Health (IFEH). Former NEHA President Mel

Knight has chaired IFEH's Americas Region Group for the past three years. In 2014 NEHA hosted the IFEH Biannual Congress and Educational Conference at the NEHA Annual Educational Conference & Exhibition in Las Vegas. As your president, I will participate in the IFEH Congress and Educational Conference in Malawi next May.

- NEHA Regional Vice President Tim Hatch has partnered with IFEH members from other countries to begin offering the Environmental Health Training in Emergency Response (EHTER) course outside the U.S. The course was recently presented in both Australia and Portugal.
- NEHA members from academia are becoming increasingly engaged in training our environmental health colleagues in foreign countries. Dr. D. Gary Brown (Eastern Kentucky University) has been a frequent lecturer at the University of the West Indies. Dr. Bryan Brooks (Baylor University) has also been very involved in working with our environmental health colleagues overseas.
- As your president, I recently attended the Canadian Institute of Public Health Inspectors' (CIPHI's) Annual Educational Conference in Ottawa. I met with the CIPHI Governing Council and began discussing possible opportunities for increased collaboration.
- In September, NEHA Executive Director Dr. David Dyjack, NEHA Past President

Dr. Carolyn Harvey, Mel Knight, and Tim Hatch attended the First World Environmental Health Academic Conference in Coimbra, Portugal. We expect this conference will open up further opportunities for international collaboration on training and education.

- In October, Dr. Dyjack, Mel Knight, and Dr. D. Gary Brown traveled to the Jamaica Association of Public Health Inspectors (JAPHI) Annual Educational Conference in Lucea, Jamaica. In an effort to assist JAPHI, they took three laptops and 36 environmental health books donated to JAPHI by GEHP (see photo above right).
- NEHA has created a new organizational structure called an International Partner Organization (IPO). IPOs will function as NEHA's international affiliates. NEHA is currently discussing possible IPO status with environmental health associations from two countries.
- This year the NEHA board of directors created a new volunteer position within NEHA titled NEHA Ambassador. In September the first three ambassadors were named: Ron deBurger, ambassador to Canada; Rachel Stradling, ambassador to Europe; and Dr. D. Gary Brown, ambassador to the Caribbean. Their role will be to build relationships within the international environmental health community.

continued on page 60



Legionnaires' Disease Outbreak at a Long-Term Care Facility Caused by a Cooling Tower Using an Automated Disinfection System—Ohio, 2013

Abstract On July 9, 2013, an outbreak of Legionnaires' disease (LD) was identified at Long-Term Care Facility A in central Ohio. This article describes the investigation of the outbreak and identification of the outbreak source, a cooling tower using an automated biocide delivery system. In total, 39 outbreak LD cases were identified; among these, six patients died. Water samples from a cooling tower were positive for *Legionella pneumophila* serogroup 1, reactive to monoclonal antibody 2, with matching sequence type to a patient isolate. An electronic control system turned off cooling tower pumps during low-demand periods, preventing delivery of disinfectant by a timed-release system, and leading to amplification of *Legionella* in the cooling tower. Guidelines for tower maintenance should address optimal disinfection when using automated systems.

Introduction

Legionnaires' disease (LD) is a severe and potentially fatal pneumonia caused by colonization of human-made water systems and subsequent aerosolization and inhalation of *Legionella* bacteria (Fraser et al., 1977; McDade et al., 1977). *Legionella* amplifies in warm, stagnant water systems (25°C–42°C), particularly in the presence of scale, sediments, biofilms, and amoebae, and in the absence of adequate biocides (e.g., chlorine) (Cooling Technology Institute, 2008). Outbreaks have been associated with multiple sources, including evaporative cooling systems (e.g., cooling towers), potable water, whirlpool spas, industrial equipment, and decorative water features (Blatt et al., 1993; Centers for Disease Control and Prevention [CDC], 1997; Dondero et al., 1980; Fiore et al., 1998; Hanrahan et al., 1987; Hlady et al., 1993;

Kool et al., 1998; Lau, Maqsood, Harte, Caughley, & Deacon, 2013; Mahoney et al., 1992; Nguyen, et al., 2006; Rangel, Delclos, Emery, & Symanski, 2011). Hospitals and long-term care facilities are particularly prone to LD outbreaks because they serve susceptible populations (Hanrahan et al., 1987; Kool et al., 1998).

During July 9–July 12, 2013, Franklin County Public Health (FCPH) and the Ohio Department of Health (ODH) were notified of nine cases of LD among residents of Long-Term Care Facility A (LTCFA), a retirement community located in a suburb of Columbus, Ohio. With the assistance of the Centers for Disease Control and Prevention (CDC), an epidemiologic and environmental investigation was conducted to describe the scope of the outbreak, identify the source, and recommend control measures to prevent additional cases.

Celia Quinn, MPH, MD
*Epidemic Intelligence Service assigned to Ohio Department of Health
Centers for Disease Control and Prevention*

Alicia Demirjian, MMSc, MD
Louise Francois Watkins, MPH, MD
Sara Tomczyk, MSc, PHN
*Epidemic Intelligence Service
National Center for Immunization and Respiratory Diseases
Centers for Disease Control and Prevention*

Claressa Lucas, PhD
Ellen Brown
Natalia Kozak-Muiznieks, PhD
Alvaro Benitez
Laurel E. Garrison, MPH
*National Center for Immunization and Respiratory Diseases
Centers for Disease Control and Prevention*

Jasen Kunz, MPH
*National Center for Environmental Health
Centers for Disease Control and Prevention*

Scott Brewer, MPH
Samantha Eitnienar, MPH
Franklin County Public Health

Mary DiOrio, MPH, MD
Ohio Department of Health

Methods

Setting

LTCFA is a retirement community offering independent living in single-story duplex condominiums and a high-rise building (Building 1), assisted living (Building 2), and memory care and hospice care (both housed in one building, Building 3) (Figure 1). An acute rehabilitation facility (Building 4) was completed during March 2013. The typical census for LTCFA is >200 older adults; approximately 70% are women.

Case Definitions

A case of LD associated with LTCFA required clinical criteria and laboratory criteria consistent with LD with illness onset during May 1–August 31, 2013, among persons who lived in, worked at, or visited LTCFA 2–10 days before symptom onset. Clinical criteria for

FIGURE 1

Long-Term Care Facility A, Ohio, July 2013



LD were signs or symptoms of pneumonia, defined as cough or shortness of breath plus one or more of the following: fever, nausea, diarrhea, confusion, malaise, or headache; or physician diagnosis of pneumonia; or chest radiograph consistent with pneumonia. Cases were classified as suspect or confirmed according to laboratory criteria defined in the 2005 national legionellosis surveillance case definition (CDC, 2005). Cases that met clinical criteria for LD associated with LTCFA but did not meet laboratory criteria for either a suspect or confirmed case, including those with unavailable or negative laboratory testing, were classified as possible cases.

Case Finding

LD is a reportable disease in Ohio. To identify all cases of LD associated with LTCFA, we used enhanced surveillance and conducted retrospective case finding. To enhance surveillance, we requested that LTCFA residents with pneumonia symptoms be evaluated for LD with *Legionella* urine antigen testing (UAT) and respiratory culture. LTCFA notified the local health department of all residents transferred to hospitals during the outbreak. Information about the outbreak was communicated to residents, their families, and their physicians directly by LTCFA; to physicians, hospitals, and emergency departments by FCPH; and to the community

through media reports, further enhancing surveillance for outbreak-associated cases.

For retrospective case finding, we queried the Ohio Disease Reporting System, an electronic reportable diseases database, for LD cases among residents of the three counties surrounding LTCFA during May 1–July 15, 2013. Each patient was contacted by their local health department to determine whether the patient had any connection to LTCFA during their 2–10-day incubation period. We reviewed death certificates for LTCFA residents who had died during the three months before the outbreak onset and searched death certificates for all residents of six central Ohio counties during January 1–July 15, 2013, for any decedents with legionellosis (or any variation) listed as the immediate or contributing cause of death.

Case Investigation

Each possible, suspect, and confirmed case of LD associated with LTCFA was investigated by using an outbreak-specific patient questionnaire and a medical record and long-term care facility chart abstraction tool developed by the investigation team. The patient questionnaire collected patient demographics, illness characteristics, LD risk factors, and water exposures and was administered through an in-person or telephone interview by members of the investigation team, either

with the patient or a proxy. Proxies were used when the patient was unable to be interviewed because of illness, advanced dementia, or death. When available, medical records and long-term care facility charts were reviewed to document onset and duration of symptoms, medications, medical history, and documented LTCFA water exposures (e.g., showering) for each case under investigation.

Environmental Assessment

A multidisciplinary team from FCPH, ODH, and CDC visited the facility during July 12–14 to perform an environmental assessment. The team included epidemiologists, physicians, nurses, environmental health specialists, a plumber familiar with Ohio plumbing code, and a microbiologist. The design and construction of the facility, design of the potable water system, and maintenance practices were discussed with facility administrators and building facilities staff. The design, use, and maintenance of a newly installed cooling system for Building 4 was discussed with the system manufacturer, facility administrators and staff, and contractors involved in its installation and maintenance.

Laboratory Testing

Environmental Specimens

The investigation team collected environmental bulk water and biofilm swab samples to evaluate possible *Legionella* colonization of the potable and other water systems at LTCFA during July 13–14. Samples were taken from hot water tanks, sinks and showers in selected patient rooms and rooms located at the distal end of the water distribution system, and sinks and showers from common areas, including the salon and kitchens in Buildings 1–3 and the condominiums. Bulk water and biofilm swab samples were taken from the below-ground reservoir and above-ground drip pan of a newly installed cooling tower and from an outdoor decorative fountain.

Environmental swabs and 1-L water samples were collected and maintained in an insulated cooler at room temperature according to CDC's *Legionella* recovery procedures (CDC, 2005). Bulk water samples and environmental samples were processed by using previously published standard procedures (CDC, 2005) at CDC's *Legionella* laboratory. Isolates with suspect morphology that required L-cysteine

for growth were typed by a dot blot with specific antisera to determine whether the organisms were *Legionella pneumophila* serogroup 1 and if they were monoclonal antibody 2 (MAb-2) positive (Joly et al., 1986; Sanden, Cassidy, & Barbaree, 1993). Five isolates were selected for further sequence-based typing (SBT) (Farhat, Mentasti, Jacobs, Fry, & Lück, 2011; Gaia et al., 2005; Ratzow, Gaia, Helbig, Fry, & Lück, 2007). MAb and SBT typing are complementary methods of strain discrimination and are epidemiologic tools used during outbreak investigations but not for treatment decisions or patient care.

Clinical Specimens

Patients were tested for LD at LTCFA by submission of clinical specimens to a commercial laboratory or at hospital laboratories. In Ohio, adult patients with pneumonia are frequently tested for LD by using UAT only. FCPH requested that LTCFA, local hospitals, and physicians order collection of sputum for *Legionella*-specific culture for all patients with pneumonia symptoms and exposure to LTCFA or any other patient with suspected LD. Sputum specimens were cultured for *Legionella* either at hospital laboratories or at CDC's *Legionella* laboratory. Polymerase chain reaction was performed on respiratory specimens at CDC according to published methods (Benitez & Winchell, 2013). SBT was performed on the one available clinical isolate to compare with SBT of *Legionella* isolated from environmental samples.

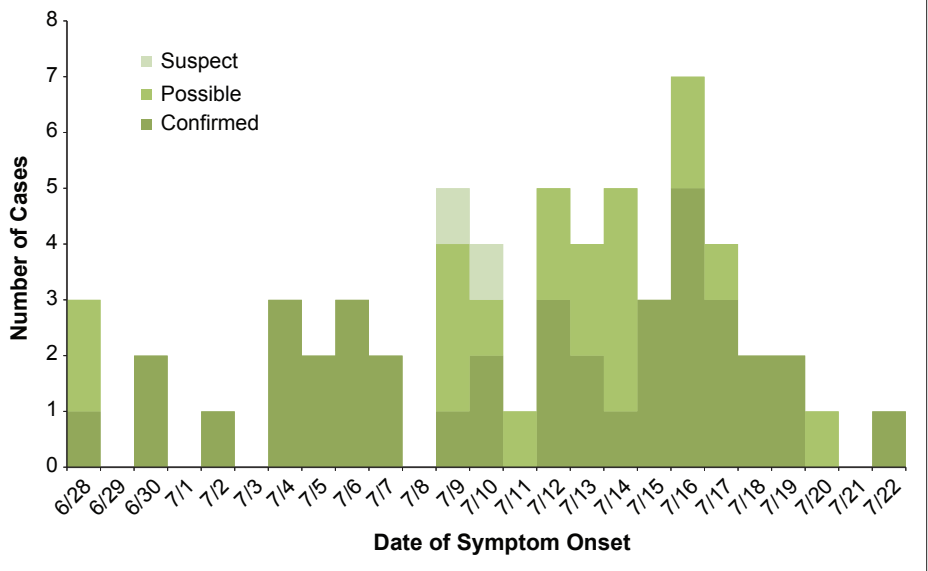
Results

Case Finding and Investigation

A total of 39 confirmed, 2 suspect, and 19 possible LD cases associated with LTCFA were identified, with illness onset dates during June 28–July 22, 2013 (Figure 2). Among confirmed cases, 69% of patients were women; ages ranged from 53 to 99 years (median: 88 years; interquartile range: 83–92.5). Six patients with confirmed LD died (Table 1). Interviews with patients revealed that a majority of residents were exposed to potable water sources within their building of residence. Seven patients, however, were visitors to LTCFA who did not report showering or assisting residents with showering or bathing during their visit, and therefore had only minimal exposure to the facility's potable water. Attack rates for LTCFA

FIGURE 2

Epidemic Curve, Legionnaires' Disease Outbreak, Long-Term Care Facility A, Ohio, 2013



residents with confirmed LD were calculated by building of residence by using the facility census on July 7, 2013, before recognition of the outbreak (Table 1). Higher attack rates were observed among settings with higher levels of care, reflecting the greater risk for contracting LD among older adults with higher care needs. Three patients (two residents of Building 3 and one resident of Building 2) reported that they did not leave their building of residence for any reason during their incubation period.

Environmental Assessment

Potable Water Systems

LTCFA's campus consists of four large buildings and six smaller buildings (condominiums), comprising 16 single-story homes for independent living. All construction was completed during 1998–2013. The four large buildings range from two to six stories. During March 2013, construction was completed for Building 4, a two-story acute rehabilitation facility; however, only a limited number of patients had used the building before the outbreak, and none were ill with pneumonia. All buildings were supplied by chlorine-disinfected municipal water from

a surface water reservoir, processed through one of three water treatment plants serving the greater Columbus area. Each building (Buildings 1–4) had independent potable water systems consisting of water heaters (set to 140°F), with thermostatic mixing valves located adjacent to the main holding tanks. The condominiums had individual residential water heaters regulated by the residents. No whirlpool spas, pools, or indoor fountains were located at the facility. Virtually all occupant rooms contained showers only. Communal showers were used in Building 3.

Nonpotable Water Systems

Two nonpotable water sources were identified. One, an outdoor decorative fountain, contained only a limited amount of circulating water. The second, a cooling tower, had been installed as part of Building 4 construction (Figure 1). The cooling tower was located behind Building 1 and approximately 15 feet from the fresh air intake for that building, and it provided cooling to Building 4 and the common spaces between Buildings 1 and 4. The three largest buildings on campus were located less than 500 feet from the cooling tower. Fresh air intakes for Building 1 were located on the side of the build-

TABLE 1

Characteristics of Confirmed Legionnaires' Disease Cases, Long-Term Care Facility A (LTCFA) Outbreak, Ohio, 2013

Characteristic	#	%
Outcome		
Survived	33	85
Died	6	15
Demographics		
Women	27	69
Median age (yrs; interquartile range)	88 (83–92.5)	
Medical conditions	36 ^a	
Heart condition	15	42
COPD ^a or chronic bronchitis	3	8
Immunocompromised	5	14
Dementia	5	14
Diabetes	5	14
Type of Exposure to Facility	#	Attack Rate ^b
Employee	1	Unknown
Visitor	7	Unknown
Adult day care (building 3)	1	Unknown
Resident	30	12
Condominiums	3	12
Building 1	12	10
Building 2	8	14
Building 3	7	19

^aMedical conditions reported on patient questionnaire or with LTCFA chart; three cases had missing data from both sources. COPD = chronic obstructive pulmonary disease.

^bOn the basis of LTCFA census (*N* = 243) reported on July 7, 2013.

ing more than 20 feet of the cooling tower, whereas fresh air intakes for Building 3 were located on the building roof.

Cooling Tower Operation

The cooling tower system was controlled electronically with set points for indoor and outdoor temperature and indoor humidity. When indoor or outdoor temperature or indoor humidity reached certain levels, the water pump and fans turned off automatically. The cooling demand for the system was likely lower than anticipated during the spring because of low occupancy in Building 4 and below-average temperatures for central Ohio during March–June 2013. Therefore, frequent periods when the cooling tower pump system was not operating were likely. Because of the tower's water treatment system setup, frequent on-and-off cycling prevented adequate delivery of biocide.

Cooling Tower Water Treatment

Water for the cooling tower was supplied by a connection with the potable water system. Three chemicals were used for water treatment, including two biocides (dimethyl-imino ethylene and sodium hypochlorite or sodium hydroxide) and one corrosion inhibitor (potassium hydroxide or hydroxyethylidene-1,1-diphosphonic acid). Each chemical was delivered by an automated pump programmed to inject a specific amount of chemical at a particular time; however, the facility had no record of the actual biocide delivery schedule before the outbreak. To prevent excess delivery of chemicals, the pumps had a lockout mechanism that prevented chemical delivery when the system was not operating. If the system was not operating (e.g., because of cool temperatures), even for a brief period, at the time of programmed biocide delivery no chemical was injected into the system.

The cooling tower was serviced monthly by a subcontracted water treatment company after becoming operational on February 19, 2013. Monthly service visits from the water treatment company included visual inspection and might have also included a check of residual corrosion inhibitor and a dip slide for total bacteria count. Biocide residuals were not routinely tested. Water treatment company records indicated that at two of four visits during February–July 2013, technicians noted the system was not operating (presumably because cooling was unnecessary or the programmed set points for temperature had been reached), and no residuals were checked. LTCFA was unable to provide information about when the system was operating during the months preceding the outbreak. The water treatment company was unable to provide further detail about the total amount of biocide used by the system during the months preceding the outbreak.

Laboratory Results

All confirmed cases were diagnosed by UAT for *L. pneumophila* serogroup 1. Two suspect cases were diagnosed by detection of *Legionella* species by using a validated nucleic acid assay. Of 15 clinical respiratory specimens available for *Legionella*-specific culture at CDC's *Legionella* laboratory (10 from patients with confirmed LD and 5 from patients with possible LD), only one was positive for *Legionella* spp.

Legionella was isolated from multiple potable water sampling sites in Buildings 1 and 2 and from the cooling tower reservoir and above-ground drip pan. Results of *Legionella*-specific culture of environmental and clinical specimens identified a matching strain of *Legionella* (sequence type 222) in the cooling tower, Building 2 potable water system, and one patient (Table 2). The patient, a resident of Building 1, denied exposure to potable water systems in Building 2.

Discussion

Our investigation revealed that a newly installed cooling tower with a disinfection system set to inject biocide only when it was in active use was the primary source of illness during this outbreak. The mechanism for patient exposure included aerosolized water from the cooling tower entering the fresh air intakes for the nearby buildings up to 500 feet away. This is supported by the fact

that LD was confirmed among six residents of Building 3 (furthest building from the cooling tower), where no *Legionella* was recovered from the potable water, and two of these patients reported never having left the building during their incubation period. Microbiologic evidence that supports this conclusion includes matching Lp1 strains between environmental isolates and a clinical isolate obtained from a patient who did not have exposure to the potable water in Building 2.

Although initial assessment of the cooling tower system at LTCFA indicated that it was an unlikely source because of its limited size, newer design, and reportedly adequate maintenance since installation fewer than five months earlier, the finding that both the drip pan and reservoir were heavily colonized with multiple strains of *Legionella* led to the immediate cessation of its use followed by cleaning and remediation. Our investigation revealed that the timed delivery of biocide to the system only when it was in use, combined with intermittent use of the system during February–June, likely resulted in inadequate provision of disinfectant to the system and led to the amplification of *Legionella*. Aerosolized water from the *Legionella*-contaminated system might be delivered into the buildings on the LTCFA campus through the fresh air intake systems.

Nineteen possible cases of LD among patients who experienced an illness compatible with pneumonia and had negative UAT were reported. Because multiple species and serogroups of *Legionella* were isolated from environmental samples at LTCFA, a negative UAT might represent an infection with a non-Lp1 *Legionella* species or might represent another etiology entirely. Heightened concern among residents and staff at LTCFA might have prompted persons with relatively mild illness or nonspecific symptoms to seek medical attention, and knowledge of the outbreak in the community might have led to overdiagnosis of pneumonia. Without

Sample	Culture Result	SBT ^a Result
Clinical isolate, resident of Building 1	<i>Legionella pneumophila</i> serogroup 1, MAb-2 positive	ST222 ^a
Building 1	<i>L. pneumophila</i> serogroup 3	ST995
	Blue-white <i>Legionella</i> species	N/A ^a
Building 2	<i>L. pneumophila</i> serogroup 1, MAb-2 positive	ST222
Building 3	No <i>Legionella</i> isolated	N/A
Condominiums	No <i>Legionella</i> isolated	N/A
Cooling tower	<i>L. pneumophila</i> serogroup 1, MAb-2 positive	ST222
	<i>L. pneumophila</i> serogroup 1, MAb-2 negative	ST1
	<i>L. dumoffi</i>	N/A
Fountain	No <i>Legionella</i> isolated	N/A

^aSBT = sequence-based typing; ST = sequence type; N/A = not applicable; SBT can only be performed on *L. pneumophila*.

obtaining respiratory specimens from these patients, conclusively determining whether their illness was caused by an infection with *Legionella*, another etiology of pneumonia, or another disease process is impossible.

Conclusion

This investigation has important implications for cooling tower design in preventing LD outbreaks. Cooling towers that rely on a timed delivery of biocide only when the system is actively being used can become a reservoir for amplification and dissemination of *Legionella*. This is a particular concern during season changes, when cooler or warmer than expected temperatures can lead to variations in cooling demand, causing automated systems to turn on and off and creating environments more conducive to the growth of *Legionella*. Manu-

facturers should consider other alternatives to this design, and building facilities managers and treatment contractors should be knowledgeable about the methods of biocide delivery and measurement in cooling towers that they maintain. Public health should partner with hospitals and long-term care facilities, experts in facility construction and maintenance, and the heating, cooling, and plumbing industries to ensure that recommendations for the prevention of *Legionella* in water systems will protect vulnerable populations. 🐼

Corresponding Author: Celia Quinn, Centers for Disease Control and Prevention Career Epidemiology Field Officer assigned to New York City Department of Health and Mental Hygiene, 42-09 28th Street, Queens, NY 11101. E-mail: fyq6@cdc.gov.

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Geothermal Gases—Community Experiences, Perceptions, and Exposures in Northern California

Abstract Lake County, California, is in a high geothermal-activity area. Over the past 30 years, the city of Clearlake has reported health effects and building evacuations related to geothermal venting. Previous investigations in Clearlake revealed hydrogen sulfide at levels known to cause health effects and methane at levels that can cause explosion risks. The authors conducted an investigation in multiple cities and towns in Lake County to understand better the risk of geothermal venting to the community. They conducted household surveys and outdoor air sampling of hydrogen sulfide and methane and found community members were aware of geothermal venting and some expressed concerns. The authors did not, however, find hydrogen sulfide above the California Environmental Protection Agency air quality standard of 30 parts per billion over one hour or methane above explosive thresholds. The authors recommend improving risk communication, continuing to monitor geothermal gas effects on the community, and using community reports and complaints to monitor and document geothermal venting incidents.

Introduction

Lake County, California, is in north central California, north of San Francisco Bay. Lake County sits on tectonic plate conjunctions, generally described as areas where separate slabs of the earth's crust meet. Consequently, Lake County's population—currently at some 64,323 persons—has long been subjected to volcanic activity resulting from plate tectonics, or the movement of these giant slabs (U.S. Census Bureau, 2012; U.S. Geological Survey [USGS], 2004). Plate tectonics make Lake County vulnerable to a variety of environmental hazards, including earthquakes, volcanic eruptions, and geothermal venting. When a complex mixture of geothermal gases vents into the atmosphere from holes in the ground or diffuses through the soil, geothermal venting occurs. Gases such as hy-

drogen sulfide and methane release into the environment, which at high exposure levels can cause adverse health effects (both) and risk of explosion (methane) (Agency for Toxic Substances and Disease Registry [ATSDR], 2006; Etiope et al., 2006; International Programme on Chemical Safety, 2000a, 2000b; USGS, 2010). Hydrogen sulfide and methane can be summarized as follows:

- Hydrogen sulfide is a toxic gas with a characteristic rotten egg odor detected at 0.0005–0.3 parts per million (ppm), with olfactory fatigue at >100 ppm where continued exposure can temporarily disable the sense of smell (ATSDR, 2006). At 10–20 ppm, exposure can cause irritation to the eyes (World Health Organization [WHO], 2000); higher levels can cause headache, dizziness, and breathing dif-

Cindy H. Chiu, MPH, PhD
*Epidemic Intelligence Service, Centers for Disease Control and Prevention
Health Studies Branch, National Center for Environmental Health*

Matthew J. Lozier, MPH, PhD
*Epidemic Intelligence Service, Centers for Disease Control and Prevention
Air Pollution and Respiratory Health Branch, National Center for Environmental Health*

Tesfaye Bayleyegn, MD
Health Studies Branch, National Center for Environmental Health

Karen Tait, MD
Lake County Public Health Division

Tracy Barreau, REHS
Lori Copan, MPH, RPh
Rachel Roisman, MPH, MD
Rebecca Jackson, MPH
Svetlana Smorodinsky, MPH
Richard A. Kreutzer, MD
*Division of Environmental and Occupational Disease Control
California Department of Public Health*

Fuyuen Yip, MPH, PhD
Air Pollution and Respiratory Health Branch, National Center for Environmental Health

Amy Wolkin, MSPH, DrPH
Health Studies Branch, National Center for Environmental Health

ficulty. Exposure to extremely high levels (1,000–2,000 ppm) can result in immediate collapse and death (WHO, 2000).

- Methane is an odorless but highly flammable gas with risk of explosion at 5%–15% in air (International Programme on Chemical Safety, 2000b). At high levels, methane can also cause death through asphyxiation; however, explosion is likely to occur before reaching asphyxiation levels, making explosion risk the primary concern.

Most hydrogen sulfide health effects studies evaluated high-level occupational or accidental release exposures. One example is Poza Rica, Mexico, where in 1950, 22 people died and 320 people were hospitalized (McCabe & Clayton, 1952; National Institute for Occupational Safety and Health, 1977). More recent studies, however, suggest health

FIGURE 1

Sampling Frame for Household Survey Conducted in Lake County, California, During November 26–28, 2012



effects in communities chronically exposed to low environmental hydrogen sulfide levels (Bates, Garrett, Graham, & Read, 1997, 1998; Bates, Garrett, & Shoemack, 2002; Durand & Wilson, 2006; Hansell & Oppenheimer, 2004; Legator, Singleton, Morris, & Philips, 2001). In Rotorua, New Zealand, residents living in an area with hydrogen sulfide levels ≥ 1 ppm were at increased risk of hospitalization for nervous system and sense organ diseases compared with residents living where hydrogen sulfide exposure levels were < 50 parts per billion (ppb) (Bates et al., 2002; Horwell, Patterson, Gamble, & Allen, 2005). Compared with a control community, a Puna, Hawaii, community close to a geothermal plant with periodic releases of hydrogen sulfide ranging from 200 to 500 ppb showed a greater risk of diseases for all body

systems, especially for central nervous system and respiratory system disorders (Legator et al., 2001). Other studies have demonstrated adverse health outcomes associated with hydrogen sulfide concentrations in the window between the odor and irritant thresholds (Jaakkola, Vilkkka, Marttila, Jappinen, & Haahtela, 1990; Kilburn & Warshaw, 1995; Schiffman & Williams, 2005).

In Lake County's Clearlake area, researchers have identified several geothermal vents. Documentation of geothermal venting and its effects in this area began in the early 1990s, when a home was demolished because of persistent hydrogen sulfide intrusion (ground-level hydrogen sulfide detected at 150 ppm). In 2010, a vent was discovered in Clearlake with high levels of hydrogen sulfide (750–800 ppm) and methane (55%–58% lower explosive limit

[LEL]) at the vent surface (Ecology and Environment, 2011). This vent was capped with a scrubber, a specialized equipment to capture and neutralize the vented hydrogen sulfide. In 2011 Lake County Health Services Department (LCHSD) recommended that a community-based organization vacate its building due to hydrogen sulfide and methane intrusion (hydrogen sulfide detected at 53 ppb; methane detected at 12% LEL) (Ecology and Environment, 2011; K. Tait, personal communication, August 16, 2013). In response to these reports and findings, California Department of Public Health (CDPH), Lake County Public Health Division (LCPHD), the U.S. Environmental Protection Agency (U.S. EPA), and the U.S. Geological Survey (USGS) over the years have conducted a series of air sampling investigations in Clearlake. Areas beyond the small Clearlake neighborhood, however, have been largely unexplored.

This investigation described the knowledge and risk perception of Lake County communities about geothermal venting and determined whether areas beyond Clearlake were experiencing geothermal venting. Our objectives were to determine 1) vulnerability to geothermal gas exposure among Lake County residents; 2) perceptions of and experiences with geothermal venting among Lake County residents; and 3) outdoor air levels of hydrogen sulfide and methane concentrations in residential areas to identify potential areas of Lake County geothermal venting.

Methods

During November 26–28, 2012, we conducted a cross-sectional household survey and air sampling in Lake County between 8:30 a.m. and 5:00 p.m. PST each day.

Sampling Frame

The sampling frame contained 26,730 housing units (2010 census) and included all census blocks within or adjacent to the following cities and towns in Lake County (Figure 1): Clearlake, Clearlake Oaks, Cobb, Hidden Valley Lake, Kelseyville, Lakeport, Lower Lake, Lucerne, Middletown, Nice, and Upper Lake. To select a representative sample of households to interview, we used a two-stage cluster sampling methodology (30 census blocks, seven households). The methodology was modified from the World Health Organization's Expanded Program on Immuniza-

tion coverage survey methodology (Centers for Disease Control and Prevention [CDC], 2012). For the first stage of sampling, we selected 30 census blocks (clusters) within this sampling frame using probability-proportional-to-size. For the second stage of sampling, interview teams systematically selected seven households to interview from each of the 30 clusters.

Household Survey

The questionnaire included 12 closed-ended questions (e.g., multiple choice, yes/no) to collect information about household demographics, home characteristics, awareness, experiences, and concerns about geothermal venting. Fourteen two-person interview teams administered the survey, primarily consisting of CDPH, LCPHD, and Centers for Disease Control and Prevention (CDC) public health staff. The teams were trained on the overall purpose of the survey, the questionnaire, interview techniques, the household selection method, safety, and logistics. Participants who were at least 18 years of age and a household resident were eligible to participate in the study and were asked to respond to the questions on behalf of the entire household.

For questions about geothermal experiences in or around the home, and to assist recall, interview teams showed printed photos of “unusual corrosion on metal surfaces” and “bubbling in puddles.” Interview teams also recorded observations of geothermal venting evidence outside the homes where interviews occurred. We assessed vulnerability to geothermal gas exposure, including age of household members and characteristics and age of housing structures that make homes more susceptible to vapor intrusion and gas accumulation (ATSDR, 2006; U.S. Environmental Protection Agency [U.S. EPA], 2002; Zummo & Karol, 1996).

Air Sampling

We conducted air sampling to measure outdoor levels of gaseous hydrogen sulfide and methane in the same clusters where we conducted the interviews. We focused on hydrogen sulfide and methane because previous air sampling in the area indicated outdoor levels of hydrogen sulfide and methane that may pose a health or safety threat. The air sampling teams conducted systematic air sampling in residential areas, in water meter boxes (buried, dry, enclosed chambers approximately 1'

TABLE 1

Demographics of Interviewed Households for Survey Conducted in Lake County, California, During November 26–28, 2012

Demographic	<i>n</i> (%) (<i>N</i> = 161)	Projected Number of Households (<i>N</i> = 26,730)	Weighted % (95% Confidence Interval)
Household size			
1	42 (26.1)	6,570	24.6 (16.0–33.1)
2 to 4	103 (64.0)	17,712	66.3 (57.2–75.3)
5 or more	15 (9.3)	2,321	8.7 (3.3–14.0)
Age distribution in households			
<2 years old	13 (8.1)	2,244	8.4 (3.1–13.7)
2–17 years old	41 (25.5)	7,018	26.3 (16.8–35.7)
18–64 years old	125 (77.6)	21,083	78.9 (70.9–86.8)
≥65 years old	57 (35.4)	9,169	34.3 (24.6–44.0)
Main language spoken			
English	153 (95.0)	25,396	95.0 (91.3–98.7)
Spanish	8 (5.0)	1,334	5.0 (1.3–8.7)
Type of home lived in			
Mobile home	41 (25.5)	7,383	27.6 (17.5–37.8)
Single family home	114 (70.8)	18,512	69.3 (59.4–79.1)
Duplex	5 (3.1)	709	2.7 (0.4–4.9)
Multi-unit complex	1 (0.6)	127	0.5 (0–1.5)
<i>Note.</i> Missing: household size (<i>n</i> = 1).			

wide x 1.5' long x 0.75' deep), and in other public right-of-way areas outside systematically selected homes. In clusters with ≥50 homes, air sampling was conducted outside every 10th home. In clusters with <50 homes, air sampling was conducted outside at least five homes. At each selected home, the team took spot measurements of hydrogen sulfide levels in the water meter box associated with the home (where available), and at 6" and 30" above ground. Methane levels were only measured in the water meter box. Where water meter boxes were not available, methane was not measured, and hydrogen sulfide was measured at 6" and 30" above dirt or grass/gravel-covered surfaces free of pavement on public property in front of the selected house. Air sampling teams used a hydrogen sulfide analyzer to measure hydrogen sulfide levels (detection range = 3 ppb–50 ppm), and a combustible gas monitor to measure methane levels (detection range = 0%–100% LEL). All air sampling locations were geocoded using a GPS instrument (differential GPS accuracy = 3 m/10 ft.). For quality control, we calibrated

instruments daily and we took duplicate measurements at the first location in each cluster.

Data Analysis

We calculated the response rates and conducted unweighted and weighted analyses using SAS version 9.3 to account for the sampling probabilities of the interviewed households within each cluster. Unless otherwise stated, throughout this article the percentages represent unweighted percentages. For air sampling data analysis for each cluster, we used SAS version 9.3 to calculate the maximum, minimum, and median levels for the water meter box and at 6" and 30" above ground. We also mapped individual point measurements and used ArcGIS version 10.1 to look at the detected gases' geographical distribution.

We conducted stratified analysis to examine the survey responses among households in clusters with detectable hydrogen sulfide levels (≥80% of the individual measurements in the cluster were ≥3 ppb at the water meter box, 6", or 30") compared with clusters with undetectable levels. Univariate odds ratios

TABLE 2

Surveyed Cities and Towns With Detectable Levels and Undetectable Levels of Hydrogen Sulfide (H₂S) in Lake County, California, on November 26–28, 2012

Cities and Towns	Clusters <i>n</i>	Detectable H ₂ S levels* <i>n</i> (%)	Undetectable H ₂ S levels* <i>n</i> (%)	Unknown H ₂ S Levels* (not measured) <i>n</i> (%)
City of Clearlake	8	1 (12.5)	7 (87.5)	–
Clearlake Oaks	6	4 (66.7)	2 (33.3)	–
Cobb	1	1 (100.0)	–	–
Hidden Valley Lake	2	–	2 (100.0)	–
Kelseyville	1	1 (100.0)	–	–
Lakeport	3	–	3 (100.0)	–
Lucerne	3	–	–	3 (100.0)
Middletown	1	–	1 (100.0)	–
Nice	3	–	2 (66.6)	1 (33.3)
Paradise Cove	1	1 (100.0)	–	–
Total number of clusters	29	8 (27.6)	17 (58.6)	4 (13.8)
Total number of surveys	161	53 (32.9)	86 (53.4)	22 (13.7)

*A cluster is defined as having detectable levels when ≥ 80 of the individual H₂S measurements in the cluster were ≥ 3 parts per billion (ppb) at the water meter box, 6", or 30" levels. Highest reading detected was 5 ppb.

* No measurements were taken in four clusters due to weather conditions.

and 95% confidence intervals were calculated using SAS. Fisher's exact test was used to estimate odds ratio when cell size was ≤ 5 .

Results

Interview teams conducted household surveys in 29 clusters in 9 of the 11 sampled Lake County cities and towns; no clusters were selected in Upper Lake and Lower Lake. One cluster was selected twice; therefore, 14 interviews were attempted in this cluster. Interview teams approached 514 houses, of which 261 (50.7%) answered the door. The teams completed 161 interviews for a completion rate of 76.7% (compared with the target of 210 interviews). Air sampling was conducted in 25 clusters from nine cities and towns in Lake County, including 427 hydrogen sulfide measurements at 173 locations, and 83 methane measurements at 83 locations.

Demographics of Surveyed Households

Table 1 shows the demographics of the interviewed households. The majority of the surveyed households had a household size of 2–4 persons ($n = 103$; 64.0%). Fifty-seven (35.4%) households had one or more persons 65 years

or older, and 13 (8.1%) households had one or more persons younger than two years. Eight (5.0%) households spoke Spanish as their main language at home. The most common home types were single-family homes ($n = 114$; 70.8%) and mobile homes ($n = 41$; 25.5%).

Hydrogen Sulfide and Methane Levels in the Community

We conducted air sampling in 25 of the 29 clusters; weather conditions prohibited taking measurements in four clusters. All hydrogen sulfide measurements in water meter boxes were ≤ 1 ppb, and above ground median values (all 6" and 30" measurements) per cluster ranged from 0 to 4 ppb (minimum = 0 ppb; maximum = 5 ppb). All methane readings were 0% LEL, with the exception of two readings measured at 1% LEL. The maximum hydrogen sulfide and methane levels were both detected in Clearlake. Detectable levels of hydrogen sulfide were measured in eight (27.6%) clusters in Clearlake, Clearlake Oaks, Cobb, Kelseyville, and Paradise Cove (Table 2). Fifty-three (32.9%) surveys were conducted in clusters with detectable hydrogen sulfide levels.

Vulnerability to Geothermal Gas Exposure and Effects

Table 3 shows the vulnerability to geothermal gas exposure and effects among surveyed households. Of the 53 surveyed households living in clusters with detectable hydrogen sulfide levels, two (3.8%) had one or more children younger than two years, and 24 (45.3%) had at least one household member 65 years or older. Forty-one (25.5%) of the total surveyed households lived in mobile homes, five (12.2%) of which were located in a cluster with detectable hydrogen sulfide levels. Fifty-five (34.2%) lived in a home built on slab-on-grade, 25 (45.5%) of which were in a cluster with detectable hydrogen sulfide levels. Sixty-nine (42.9%) lived in a home with crawl space, 21 (30.4%) of which were in a cluster with detectable hydrogen sulfide levels. Sixty-seven (41.6%) of the surveyed households lived in homes built before 1980, 20 (29.8%) of which were in a cluster with detectable hydrogen sulfide levels.

Perceptions and Experiences of Geothermal Venting

After prompting about Mt. Konocti and geothermal venting in the area, 109 (67.7%) households interviewed said they were aware of hydrogen sulfide and methane coming up through the ground (Table 4). Fifty-eight (36%) households had at least one concern about potential health or environmental effects of geothermal venting: 55 (34.2%) about potential health effects on their family, 38 (23.6%) about potential health effects on their pets or livestock or both, and 33 (20.5%) concerning potential effects on their property. Thirty-three (20.5%) households reported ever having experienced geothermal venting in or around their homes; the most common reported experience was noticing a rotten egg smell at some time in the past ($n = 23$; 14.3%). No statistically significant differences were observed in geothermal venting perceptions and experiences for households living in clusters with detectable hydrogen sulfide levels compared with undetectable levels.

Discussion

Air Sampling Findings

We used spot air sampling in Lake County, California, to identify potential areas of concern for geothermal venting in residential areas.

TABLE 3

Vulnerability to Geothermal Gas Exposure and Effect Among Surveyed Households for Survey Conducted in Lake County, California, During November 26–28, 2012

Characteristic	<i>n</i> (%) (<i>N</i> = 161)	Projected Number of Households (<i>N</i> = 26,730)	Weighted % (95% <i>CI</i> ^a)	<i>n</i> (%) Detectable H ₂ S ^a Levels* (<i>N</i> = 53)
Households with vulnerable age groups				
<2 years old	13 (8.1)	2,244	8.4 (3.1–13.7)	2 (3.8)
≥65 years old	57 (35.4)	9,169	34.3 (24.6–44.0)	24 (45.3)
Home characteristics vulnerable to vapor intrusion and gas accumulation				
Mobile home	41 (25.5)	7,383	27.6 (17.5–37.8)	5 (9.4)
Slab-on-grade foundation	55 (34.2)	9,252	34.6 (23.7–45.5)	25 (47.2)
Home with basement	5 (3.1)	636	2.4 (0.4–4.4)	2 (3.8)
Home with crawl space	69 (42.9)	11,806	44.2 (33.3–55.0)	21 (39.6)
Home age (year built)				
2000 or later	18 (11.2)	3,488	13.0 (4.8–21.3)	5 (9.4)
1980 to 1999	40 (24.8)	6,108	22.8 (12.8–32.9)	20 (37.7)
Before 1980	67 (41.6)	11,755	44.0 (31.9–56.1)	20 (37.7)

Note. Missing: slab-on-grade foundation (*n* = 4); home with basement (*n* = 4); home with crawl space (*n* = 4); home age (year built) (*n* = 5). Don't know: slab-on-grade foundation (*n* = 6); home with basement (*n* = 6); home with crawl space (*n* = 6); home age (year built) (*n* = 31).

^a*CI* = confidence interval; H₂S = hydrogen sulfide.

*A cluster is defined as having detectable levels when ≥80 of the individual H₂S measurements in the cluster were ≥3 parts per billion (ppb) at the water meter box, 6", or 30" levels. Highest reading detected was 5 ppb; 22 household surveys were conducted in the four clusters where no measurements were taken.

Methane was virtually undetectable, and the hydrogen sulfide levels detected in the various cities and towns in Lake County were all ≤5 ppb, similar to ambient levels detected in Clearlake in a recent June 2012 LCPHD-CDPH investigation (K. Tait, personal communication, August 8, 2012). Hydrogen sulfide levels from natural sources usually range between 0.11 and 0.33 ppb, with hydrogen sulfide concentrations in urban areas generally <1 ppb (ATSDR, 2006). Although some measurements from this study were >1 ppb, all these outdoor measurements were well below the ambient California Environmental Protection Agency air quality standard of 30 ppb over one hour and below other international standards (ATSDR, 2006; California Environmental Protection Agency, 2009). We thus identified no immediate risk to the sampled communities. Continued vigilance and reporting of potent rotten egg smells by residents, however, could assist LCPHD in identifying new geothermal vents.

We detected hydrogen sulfide in Clearlake, Clearlake Oaks, Cobb, Kelseyville, and Paradise Cove. Only one of eight clusters in Clearlake had detectable hydrogen sulfide

levels, despite Clearlake geothermal venting experiences triggering this investigation. This finding suggests venting in Clearlake might be sporadic or highly localized. But detectable hydrogen sulfide levels were found in two-thirds of the clusters in Clearlake Oaks, suggesting more venting in Clearlake Oaks on the day of air sampling.

Given these findings, systematic tracking of reports of concerns and complaints from communities throughout Lake County could help LCPHD assess the need for further air monitoring and investigation in these areas. If warranted, long-term air monitoring in Clearlake and Clearlake Oaks could help LCPHD to characterize community exposure over time. One possible study design would be to use passive diffusers at multiple locations over an extended period, as done recently in Rotorua, New Zealand (Bates, Garrett, Crane, & Balmes, 2013; Horwell, Allen, Mather, & Patterson, 2004).

Experiences With Geothermal Venting

Risk perception is subjective. It can result from such factors as hazard characteristics,

voluntary nature of exposure, and the level of trust in public officials to manage risk adequately. We did not find risk perceptions and experiences to differ significantly between households living in clusters with detectable and undetectable hydrogen sulfide levels. We used odor as an exposure marker and asked households whether they ever noticed a rotten egg smell in or around their homes. One in seven households reported having noticed a rotten egg smell. This might not be concerning, given the odor threshold is much lower than the irritant threshold and historically, unpleasant odor was only thought to serve as a warning signal for potential risk. Still, studies have shown health effects associated with hydrogen sulfide concentrations in the window between the odor and irritant thresholds (Jaakkola, et al., 1990; Kilburn & Warshaw, 1995; Schiffman & Williams, 2005). Therefore, improving risk communication, responding to community complaints, and continued monitoring of geothermal gas effects on the community could reduce the risk of health effects.

TABLE 4

Perceptions, Experiences, and Evidence of Geothermal Venting for Surveyed Households Living in Area With Detectable and Undetectable Hydrogen Sulfide (H₂S) Levels for Survey Conducted in Lake County, California, on November 26–28, 2012

Survey Item	<i>n</i> (%) (<i>N</i> = 161)	Projected Number of Households (<i>N</i> = 26,730)	Weighted % (95% <i>CI</i> ^a)	Detectable H ₂ S Levels* <i>n</i> (%) (<i>N</i> = 53)	Undetectable H ₂ S Levels* <i>n</i> (%) (<i>N</i> = 86)	Odds Ratio (95% <i>CI</i>)
Geothermal gases						
Aware of geothermal gases	109 (67.7)	18,106	67.7 (58.6–76.9)	40 (75.5)	58 (67.4)	0.62 (0.28–1.37)
Had at least one concern about potential effects ^b	58 (36.0)	8,664	32.4 (23.7–41.1)	14 (26.4)	33 (38.4)	1.73 (0.82–3.67)
Concerned about effects on health of family	55 (34.2)	8,231	30.8 (22.1–39.5)	12 (22.6)	32 (37.2)	2.03 (0.93–4.41)
Concerned about effects on health of pets/livestock	38 (23.6)	5,995	22.4 (14.8–30.1)	10 (18.9)	22 (25.6)	1.48 (0.64–3.43)
Concerned about effects on property	33 (20.5)	5,287	19.8 (12.3–27.2)	9 (17.0)	20 (23.3)	1.48 (0.62–3.55)
Experiences in or around home						
Have had at least one experience with geothermal venting in or around home [†]	33 (20.5)	5,626	21.0 (12.3–29.8)	12 (22.6)	16 (18.6)	0.78 (0.34–1.81)
Noticed rotten egg smell	23 (14.3)	4,311	16.1 (7.5–24.8)	7 (13.2)	14 (16.3)	0.79 (0.30–2.10)
Seen unusual corrosion on metal surfaces	11 (6.8)	1,634	6.1 (1.7–10.5)	4 (7.5)	3 (3.5)	2.31 (0.37–16.46) [‡]
Seen bubbling in puddles	5 (3.1)	849	3.2 (0.3–6.1)	2 (3.8)	2 (2.3)	1.67 (0.12–23.75) [‡]
Encountered unexpected flames	1 (0.6)	127	0.5 (0–1.5)	1 (1.9)	0 (0)	–
Evidence of geothermal venting outside home						
Had evidence of geothermal venting outside home ⁺	4 (2.5)	849	3.2 (0–7.9)	0 (0)	4 (4.7)	–

Note. Don't know: aware of geothermal gases (*n* = 1); noticed rotten egg smell (*n* = 2); seen unusual corrosion on metal surfaces (*n* = 3); seen bubbling in puddles (*n* = 1).

^a*CI* = confidence interval.

*A cluster is defined as having detectable levels when ≥80 of the individual H₂S measurements in the cluster were ≥3 parts per billion (ppb) at the water meter box, 6", or 30" levels. Highest reading detected was 5 ppb; 22 household surveys were conducted in the four clusters where no measurements were taken.

^bAny household that reported concerns about effects on health of family, health of pets/livestock, or concern about effects on property.

[†]Any household that reported that they have noticed rotten egg smell, encountered unexpected flames, seen unusual corrosion on metal surfaces, or seen bubbling in puddles in or around their home.

⁺Any household where the interview teams noted unusual corrosion on metal surfaces, rotten egg smell, or bubbling in puddles outside home; unusual rusting on metal surfaces (*n* = 4); bubbling in puddles (*n* = 0); rotten egg odor (*n* = 0).

[‡]Fisher's exact test was used to estimate odds ratio when *n* ≤ 5.

Population Vulnerabilities

Vulnerability to a health hazard is determined by a set of characteristics that affect individual, household, or communal ability to cope with the hazard (Blaikie, 1994). We examined vulnerability to geothermal gas exposure, including age of household members and characteristics and age of housing structures. Greater susceptibility to air pollution–related health effects among children and the elderly is well documented and is attributed to the developing respiratory system in children and comorbidities in the elderly (Zummo & Karol, 1996). And as dense

hydrogen sulfide settles near the ground it might result in higher exposure to children due to their smaller stature (ATSDR, 2006). Still, although nearly half of the interviewed households had a child or elderly person in the home, our air sampling findings showed that no immediate concerns arose, given that gases present were not above the California Environmental Protection Agency air quality standard of 30 ppb over one hour.

We limited our investigation to outdoor air sampling in residential areas. This limitation was intended to identify only those areas with geothermal venting where a risk of vapor in-

trusion into homes might occur. Vapor intrusion is the process whereby geothermal gases seep via micro cracks in the concrete foundation under homes either directly into the living space, or into basement and crawl space where gases can accumulate to dangerously high concentrations as seen, for example, in Rotorua, New Zealand (Durand & Scott, 2005; U.S. EPA, 2002, 2012). The potential risk of vapor intrusion can also increase in older homes and in less well-constructed mobile homes. Although many homes in this study had characteristics that might increase the risk of vapor intrusion, however, we con-

cluded that the actual risk for vapor intrusion in the areas sampled was low because outdoor levels of hydrogen sulfide were not detected above the California Environmental Protection Agency air quality standard of 30 ppb over one hour and methane was not near levels of explosion risk.

Limitations

We caution against generalizing the air sampling findings to the entire county or cities where measurements were taken. Air sampling in our study provided only a snapshot of hydrogen sulfide levels. The sampling only indicated hydrogen sulfide levels in the immediate sampled areas and at the times when measurements were taken. Geothermal venting in a single location depends on underground geothermal activities; thus it can vary and be difficult to measure consistently (Chiodini, Brombach, Caliro, & Cardellini, 2002; Horwell et al., 2004). Furthermore, after gases are vented into the atmosphere, their dispersion is determined by meteorological factors such as wind speed, mixing depth of wind turbulence, and humidity, creating more variability that is difficult to capture using spot measurements (Horwell et al., 2004; Wright & Diab, 2011). Lack of detection of hydrogen sulfide in one area at

one time does not mean venting does not occur on other days. Consequently, in our stratified analysis we might have misclassified some clusters as having “undetectable hydrogen sulfide levels.” Experiences with geothermal venting by households were self-reported, therefore a degree of bias may be possible. Lastly, because the response was <80% of our target sample size of 210, our sample may not be large enough to reliably project population estimates.

Conclusion

This investigation identified many households with characteristics that could make them more vulnerable to both the exposure and the effects of geothermal venting. But we did not observe any outdoor measurements of hydrogen sulfide above the California Environmental Protection Agency air quality standard of 30 ppb over one hour or methane above the LEL. Households were aware of geothermal venting and some residents expressed concerns. To better inform concerned residents about the risks of geothermal venting, carefully tailored risk communication could be the next step.

Systematic tracking of reports of concerns and complaints from communities throughout Lake County could help LCPHD assess

the need for further air monitoring and investigation in these areas. If reports of concerns and complaints about geothermal gases increase or new geothermal vents are identified, long-term air monitoring could help LCPHD to characterize community exposure over time. 🐼

Acknowledgements: We would like to thank the following people for their contribution to this work: Mr. Doug Gearhart from the Lake County Air Quality Management District for offering practical advice and support for the air sampling; Dr. Jason Wilken from CDPH/CDC for assisting with the survey implementation and reviewing the manuscript; and Dr. Brian Christensen from Air Pollution and Respiratory Health Branch, CDC, for assisting with the air sampling. We would also like to thank the many others who volunteered in the field from LCHSD and CDPH.

Corresponding Author: Cindy H. Chiu, Epidemic Intelligence Service Officer, National Center for Environmental Health, Centers for Disease Control and Prevention, 4770 Buford Highway, NE, Atlanta, GA 30341. E-mail: drcindyhchiu@gmail.com.

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Prevalence of Lead Hazards and Soil Arsenic in U.S. Housing

F. Gary Dewalt, MBA, PhD
David C. Cox, MS, MSc, PhD
Robert O'Haver
Brendon Salatino
Duncan Holmes
QuanTech, Inc.

Peter J. Ashley, DrPH
Eugene A. Pinzer, MS, CIH
Warren Friedman, PhD, CIH
*Office of Lead Hazard Control
and Healthy Homes
U.S. Department of Housing
and Urban Development*

David Marker, PhD
Susan M. Viet, PhD, CIH
Alexa Fraser, PhD
Westat, Inc.

Abstract The American Healthy Homes Survey, June 2005—March 2006, measured levels of lead and arsenic in homes nationwide. Based on a three-stage cluster sample of 1,131 housing units, key statistically weighted estimates of the prevalence of lead-based paint (LBP) and LBP hazards associated with paint, dust, and soil, and arsenic in dust and soil, were as follows: 37.1 million homes (35%) had some LBP; 23.2 million (22%) had one or more LBP hazards; 93% of the homes with LBP were built before 1978. The highest prevalence of LBP and LBP hazards was in the Northeast and Midwest. Over three million homes with children under six years of age had LBP hazards, including 1.1 million low-income households (<\$30,000/yr.). Less than 5% of homes had detectable levels of arsenic in dust (≥ 5 $\mu\text{g}/\text{ft}^2$). Arsenic in soil (for homes with yard soil) averaged 6.6 parts per million (ppm). Many homes had soil arsenic levels of 20 ppm or greater, including 16% of homes with wooden structures in the yard and 8% of homes without such structures.

Introduction

Childhood lead exposure remains a critical environmental health issue in the U.S. A review by the National Toxicology Program found sufficient evidence for reduced IQ and an increased incidence of behavior problems at blood lead levels (BLLs) below 5 $\mu\text{g}/\text{dL}$ (U.S. Department of Health and Human Services [DHHS], 2012). As no safe level of lead exposure for children has been established, the Centers for Disease Control and Prevention (CDC) have adopted a reference value for blood lead in children (currently 5 $\mu\text{g}/\text{dL}$) that is based on the 97.5th

percentile of BLLs in U.S. children aged 1–5 years (CDC, 2013). Reducing mean BLLs in children and reducing the number of U.S. homes with lead-based paint (LBP) hazards are national Healthy People 2020 objectives (DHHS, 2015).

Lead in house dust is the strongest predictor of children's BLLs; ingestion by hand-to-mouth activities in young children is the predominant exposure pathway (Dixon et al., 2009; Lanphear et al., 1998; Lanphear & Roghmann, 1997). Lead from deteriorated or disturbed paint contributes significantly to lead in house dust and soil; lead-contami-

nated soil is also a potential direct exposure source for young children (Gaitens et al., 2009; Lanphear et al., 1996; Mielke & Reagan, 1998).

In 1998–1999, the U.S. Department of Housing and Urban Development (HUD) and the National Institute of Environmental Health Sciences sponsored the National Survey of Lead and Allergens in Housing (NSLAH) (HUD, 2001, 2002). NSLAH included the assessment of homes for the presence of LBP and LBP hazards and the concentrations of common allergens in house dust (Jacobs et al., 2002; Salo et al., 2008). The American Healthy Homes Survey (AHHS) was conducted June 2005 through March 2006 to update the NSLAH and study additional environmental analytes of interest.

AHHS measured levels of lead, LBP hazards, allergens, and endotoxin in homes nationwide, as did NSLAH. AHHS also included analysis for additional environmental contaminants, including arsenic, pesticide residues, and mold (Stout et al., 2009; Vesper et al., 2007). This article includes estimates of the prevalence of LBP and significant lead hazards in paint, dust, and soil, for all housing and for important subpopulations of housing defined by region, age, presence of children under age six, income, housing type, race, housing tenure, government support, and ethnicity. Estimates of arsenic levels in soil are also provided. Because AHHS was designed to ensure a high degree of comparability to NSLAH for lead, differences between AHHS and NSLAH lead estimates are presented.

TABLE 1

Prevalence of LBP^a in the American Healthy Homes Survey by Housing Characteristic

Housing Unit (HU) Characteristic	All HUs ^{b,c,d}	# HUs With LBP ^c			% HUs With LBP			HUs in Sample
		Estimate	Lower 95% CI ^e	Upper 95% CI	Estimate	Lower 95% CI	Upper 95% CI	
Total HUs ^c	106,033	37,058	34,047	40,068	34.90	32.10	37.80	1,131
Region								
Northeast	20,190	10,121	8,722	11,519	50.10	43.30	57.00	196
Midwest	23,994	9,358	7,924	10,791	39.00	33.40	44.60	245
South	38,996	11,003	9,114	12,892	28.20	23.20	33.30	440
West	22,853	6,576	5,345	7,808	28.80	23.80	33.80	250
Construction year								
1978–2005	40,458	2,675	1,458	3,893	6.60	3.60	9.60	476
1960–1977	29,956	7,376	5,761	8,991	24.60	19.50	29.80	306
1940–1959	18,117	11,921	10,645	13,197	65.80	58.60	73.00	187
Before 1940	17,502	15,085	13,932	16,239	86.20	79.70	92.70	162
One or more children under age 6								
All income categories	16,833	5,742	4,237	7,247	34.10	25.20	43.10	207
<\$30,000/yr.	5,781	1,978	1,063	2,895	34.20	19.60	48.90	74
≥\$30,000/yr.	11,052	3,764	2,491	5,036	34.10	23.40	44.70	133
Household income								
<\$30,000/yr.	37,059	14,808	12,632	16,984	40.00	34.20	45.70	401
≥\$30,000/yr.	68,975	22,249	19,461	25,038	32.30	28.70	35.80	730
Housing unit type								
Single family	89,156	33,354	30,699	36,010	37.40	34.40	40.40	950
Multifamily	16,877	3,703	2,104	5,303	21.90	13.50	30.40	181
Race								
White	82,739	26,105	23,449	28,760	31.60	28.50	34.60	868
African-American	13,161	5,957	4,292	7,622	45.30	35.10	55.60	151
Other	10,134	4,996	3,467	6,525	49.30	41.70	56.90	112
Tenure								
Owner occupied	73,627	24,513	21,644	27,381	33.30	29.80	36.80	772
Renter occupied	32,407	12,545	10,466	14,624	38.70	32.80	44.60	359
Government support								
Yes	5,870	1,528	724	2,332	26.00	14.60	37.40	65
No	99,522	35,237	32,276	38,199	35.40	32.60	38.20	1,059
Ethnicity								
Hispanic/Latino	13,175	4,860	3,430	6,290	36.90	28.70	45.10	158
Not Hispanic/Latino	92,858	32,198	28,989	35,406	34.70	31.50	37.80	973

^aLead-based paint (LBP) defined as paint or other surface coating containing lead at or above 1.0 mg/cm².^bHUs include permanently occupied, noninstitutional housing units in which children are permitted to live.^cIn millions.^dAll percentages are calculated with “all HUs” in the left-most column of each row as the denominator.^eCI = confidence interval for the estimated number or percent.

Methods

AHHS was conducted in a nationally representative sample of permanently occupied, noninstitutional housing in which children may live. Vacant housing, seasonal housing, group and senior housing, hotels/motels, and military housing were ineligible for AHHS. Of the estimated 124.4 million U.S. housing units (HUD & U.S. Department of Commerce [U.S. DOC], 2006), the sample frame was the 106 million in which children could live.

Survey Design

The survey design was a three-stage cluster sample of the target population. The first stage consisted of 100 primary sampling units (PSUs—metropolitan statistical areas, single counties, or groups of counties), randomly selected with probability proportional to population according to the 2000 census. The second stage of sampling was to select segments from each PSU with probability proportional to the number of housing units. A segment typically consisted of several city blocks, although it could be much larger in rural areas. The third and final stage of sampling was to select housing units in each segment at random. Ultimately, a sample of 2,224 housing units was drawn, from which 1,131 eligible homes (51%) were recruited and completed the survey. The principal reasons that 49% of sampled homes did not complete the survey were ineligibility (10%), inability to contact a resident (10%), and refusal (23%). Documentation on the details of the design is available (HUD, 2004, 2007).

Field and Laboratory Work

Field operations began in late June 2005 and were completed in March 2006. A two-person team consisted of a trained interviewer and a state-certified LBP inspector/risk assessor. The risk assessor arrived in the PSU five days after the interviewer and began data collection in units already recruited. In each home, the interviewer obtained a signed informed-consent form and then selected four rooms in which sampling was to be conducted: kitchens, common living areas, bedrooms (children's only if present), and all other rooms. If the home had a habitable basement, the largest room in it was also selected. The interviewer administered a questionnaire to a household representative and collected vacuum dust samples for allergen and mold analysis from the

floor of the home, and obtained the entire bag from the resident's vacuum cleaner, if possible. Concurrently, the risk assessor conducted portable X-ray fluorescence (XRF) lead testing in paint and other surface coatings, collected dust wipes for lead and arsenic, soil samples in the yard for lead and arsenic, and floor wipe samples for pesticides in a randomly selected subset of 501 homes (Stout et al., 2009). The soil samples were taken in the main entry, on the foundation/dripline, in the middle of the yard, and in play areas.

Sampling and analysis methods, quality control/quality assurance protocols, and an expanded discussion of the data collected are in HUD (2007, 2011).

Data Analysis

Weighted statistical analysis for AHHS was conducted using WESVAR version 4.2. Survey weights were adjusted for nonresponse and poststratified to match the 2005 American Housing Survey (HUD & U.S. DOC, 2006). The JK(n) version of the Jackknife method was used within WESVAR for variance estimation (Wolter, 2003).

Results

LBP in Housing

An estimated 37.1 million homes (35%) had LBP somewhere in the building, down slightly from the NSLAH estimate of 37.9 million (40%) (Table 1). The significant drop in *percentage* of homes with LBP was due to the large number of lead-free homes built since 1978, when residential LBP use was banned. Of homes built before 1978, 34.4 million (52%) had LBP compared to 35.9 million (54%) in NSLAH, a decrease of 1.5 million in seven years.

The prevalence of LBP increased with the age of the housing, reaching 86% for homes built before 1940. A higher percentage of the housing stock in the Northeast and Midwest had LBP compared to the south and west. Of 16.8 million homes with children under six, 5.7 million (34%) had LBP, about the same incidence of LBP as in all homes. Poorer households had significantly more LBP (40%) than more affluent households (32%), as did single-family homes (37%) compared to multifamily homes (22%), and African-American (45.3%) and other race (49%) households compared to white households (32%). No

significant differences in LBP prevalence were found by housing tenure, ethnicity, or government support of housing.

Significant LBP Hazards in Housing

A home had a *significant LBP hazard* if it contained deteriorated LBP in greater than *de minimis* amounts (Lead Safe Work Practices, 2004), or had dust lead levels above federal thresholds—40 $\mu\text{g}/\text{ft}^2$ for floors, 250 $\mu\text{g}/\text{ft}^2$ for windowsills, or had bare soil lead levels above federal thresholds (9 ft^2 of bare soil with a lead concentration of 1,200 parts per million [ppm] or greater, or 400 ppm for bare soil in an area frequented by a child under six).

An estimated 23.2 million homes (22%) had LBP hazards, also down slightly from the NSLAH estimate of 24.0 million (25%) (Table 2). Older homes had more LBP hazards (67% of homes built before 1940), as did homes in the Northeast and Midwest compared to the south and west. Of the estimated 16.8 million homes with children under the age of six, an estimated 3.6 million (21%) had LBP hazards; of 5.8 million households earning less than \$30,000 per year with children under six, 1.1 million (20%) had LBP hazards. Homes with children did not differ from all homes in their likelihood of having LBP hazards, even when income was taken into account. Few homes had soil lead hazards (an estimated 3.6%) and even fewer in play areas frequented by children under six—only an estimated 0.5%. Poorer households were significantly more likely to have LBP hazards (29%) than more affluent households (18%), as were single-family homes (25%) compared to multifamily homes (7%), and homes not receiving government support of rental payments (22%) compared to those receiving government support (12%). African-American households were more likely (28%) to have LBP hazards than white households (20%). No significant difference in incidence of LBP hazards was found by tenure or ethnicity.

Significant Differences Between AHHS and NSLAH Lead Estimates

The drop in the percentage of homes with LBP from 40% in NSLAH to 34.9% in AHHS (Table 3) was statistically significant, but only because of the large increase in post-1977 homes in AHHS. At the regional level, in the Midwest, both the number and percentage of homes with LBP decreased significantly from NSLAH to AHHS, as did the percentage with signifi-

TABLE 2

Prevalence of Significant LBP Hazards^a in American Healthy Homes Survey by Housing Characteristic

Housing Unit (HU) Characteristic	All HUs ^{b,c,d}	# HUs With Significant LBP Hazards ^c			% HUs With Significant LBP Hazards			HUs in Sample
		Estimate	Lower 95% CI ^e	Upper 95% CI	Estimate	Lower 95% CI	Upper 95% CI	
Total HUs	106,033	23,186	20,532	25,840	21.90	19.40	24.30	1,131
Region								
Northeast	20,190	7,507	6,014	9,001	37.20	29.70	44.70	196
Midwest	23,994	6,398	5,257	7,539	26.70	22.30	31.00	245
South	38,996	6,067	4,454	7,680	15.60	11.50	19.60	440
West	22,853	3,214	2,202	4,225	14.10	9.70	18.40	250
Construction year								
1978–2005	40,458	1,083	453	1,713	2.70	1.10	4.30	476
1960–1977	29,956	3,415	1,899	4,930	11.40	6.50	16.30	306
1940–1959	18,117	6,999	5,391	8,607	38.60	29.70	47.60	187
Before 1940	17,503	11,689	10,425	12,954	66.80	59.60	74.00	162
One or more children under age 6								
All income categories	16,833	3,585	2,205	4,966	21.30	13.10	29.50	207
<\$30,000/yr.	5,781	1,138	510	1,765	19.70	8.80	30.60	74
≥\$30,000/yr.	11,052	2,447	1,330	3,564	22.10	12.60	31.70	133
Household income								
<\$30,000/yr.	37,059	10,635	8,827	12,443	28.70	24.20	33.20	401
≥\$30,000/yr.	68,975	12,551	10,027	15,075	18.20	14.70	21.70	730
Housing unit type								
Single family	89,156	21,942	19,478	24,406	24.60	21.90	27.30	950
Multifamily	16,877	1,244	426	2,062	7.40	2.60	12.10	181
Race								
White	82,739	16,778	14,533	19,022	20.30	17.70	22.80	868
African-American	13,161	3,727	2,455	5,000	28.30	20.60	36.10	151
Other	10,134	2,681	1,863	3,499	26.50	19.80	33.10	112
Tenure								
Owner occupied	73,627	15,036	12,167	17,905	20.40	16.70	24.20	772
Renter occupied	32,407	8,150	6,383	9,916	25.20	19.70	30.60	359
Government support								
Yes	5,870	721	205	1,238	12.30	3.00	21.60	65
No	99,522	22,320	19,590	25,050	22.40	19.80	25.10	1,059
Ethnicity								
Hispanic/Latino	13,175	2,400	1,607	3,194	18.20	12.70	23.70	158
Not Hispanic/Latino	95,858	20,786	18,082	23,490	22.40	19.80	25.00	973

^aSignificant lead-based paint (LBP) hazards defined as deteriorated LBP >20 ft² exterior or 2 ft² interior LBP for large surface area components, or >10 ft² of the total surface area on small interior components; OR dust-lead levels >40 µg/ft² on floors or 250 µg/ft² on windowsills; OR >9 ft² of bare soil with a lead concentration >1,200 parts per million (ppm), or 400 ppm in an area frequented by a child under the age of six years.

^bHUs include permanently occupied, noninstitutional housing units in which children are permitted to live.

^cIn millions.

^dAll percentages are calculated with “all HUs” in the left-most column of each row as the denominator.

^eCI = confidence interval for the estimated number or percent.

cant LBP hazards. The number and percentage of white-owned homes and homes owned by other races (not white or African-American) with LBP also decreased significantly, as did the percentage of white-owned homes with significant LBP hazards. The percentage of multifamily units with significant LBP hazards decreased sharply, from 19% to 7.4%.

AHHS found an estimated 15.3 million homes (14%) with significantly deteriorated LBP, 13.7 million with dust lead hazards (13%), and 3.8 million with soil lead hazards (4%) (Table 4). The comparable numbers from NSLAH were 13.6 million (14%), 15.5 million (16%), and 6.5 million (7%), respectively. The number and percentage of units with soil lead hazards in AHHS and NSLAH are not directly comparable because AHHS collected soil samples only for units where residents had use of an outside area with soil. Even when the number and percentage of units with soil lead hazards in AHHS were adjusted to compare with NSLAH, however, a substantial decrease still occurred in the incidence of soil lead hazards in AHHS (HUD, 2011).

A significant decrease occurred in the number and percentage of homes with both interior and exterior LBP, and in the percentage of homes with very high levels of LBP (≥ 10 mg/cm²) (Table 3). The number and percentage of homes built between 1960 and 1977 with significantly deteriorated LBP, however, showed a significant increase.

Arsenic Findings

AHHS provides the first statistically valid national estimates of the prevalence of arsenic in household dust and soil. Less than 5% of homes had detectable levels of arsenic in dust (detection limit 5 $\mu\text{g}/\text{ft}^2$), but 3,254 of 3,785 soil samples (86%) had detectable levels (detection limit 1 ppm). Table 5 shows estimates of the national mean level as well as differences by region, housing age, and income. For samples below the detection limit, arsenic levels were calculated from raw analytical files provided by the laboratory. The mean level of arsenic in soil, for homes with soil in the yard, was 6.6 ppm. Arsenic levels increased with the age of the housing and were higher in the Northeast and Midwest than in the south and west. In terms of mean levels and regional variation, the arsenic data appear to be broadly consistent with surface soil levels reported by the U.S. Geological Survey (USGS, 2013).

TABLE 3

Statistically Significant Differences ($p = .05$) Between AHHS^a and NSLAH^a

Estimate	AHHS	NSLAH
Percentage of HUs ^a with LBP ^b	34.90%	40%
Number of HUs in the Midwest with LBP	9,358,000	11,748,000
Percentage of HUs in the Midwest with LBP	39.00%	53%
Number of white households with LBP	26,105,000	30,945,000
Percentage of white households with LBP	31.60%	40%
Number of other ^c race households with LBP	4,996,000	1,913,000
Percentage of other race households with LBP	49.30%	29%
Percentage of HUs in the Midwest with significant LBP hazards	26.70%	33%
Percentage of multifamily HUs with significant LBP hazards	7.40%	19%
Percentage of white households with significant LBP hazards	20.30%	25%
Percentage of HUs with interior lead dust hazards	13.00%	16%
Number of HUs with both interior and exterior LBP	16,203,000	20,260,000
Percentage of HUs with both interior and exterior LBP	15.30%	21%
Percentage of HUs with LBP ≥ 10 mg/cm ²	6.00%	14%
Percentage of HUs built 1960–1977—significantly deteriorated LBP	6.10%	2%
Number of HUs built 1960–1977—significantly deteriorated LBP	1,822,000	610,000

^aAHHS = American Healthy Homes Survey; NSLAH = National Survey of Lead and Allergens in Housing; HUs = housing units; HUs include permanently occupied, noninstitutional housing units in which children are permitted to live.
^bLead-based paint (LBP) defined as paint or other surface coating containing lead at or above 1.0 mg/cm².
^cNot white or African-American.

Regional and age differences were much less pronounced for arsenic than for lead. Demographic and socioeconomic variables that were correlated with the incidence of LBP and LBP hazards were generally not important for arsenic, with the exception of household income. Unlike lead, however, high-income households had higher soil arsenic levels than low-income households.

Homes with wooden structures in the yard had significantly higher levels of arsenic in soil (Table 6), even though soil samples for arsenic were not generally taken adjacent to wooden structures (if any)—70% of homes with wooden structures had soil arsenic levels ≥ 5 ppm, while only 49% of homes without wooden structures had such levels; 16% of homes with wooden structures had soil arsenic at 20 ppm or greater, a cleanup level used by several states and by the U.S. Environmental Protection Agency (U.S. EPA) in some Superfund cleanup plans, compared to 8% of homes without wooden structures. Wooden structures were not tested.

Discussion

Lead

Some of the significant differences in LBP prevalence (Table 3) reflect incremental progress in reducing LBP over the seven years between NSLAH and AHHS. Fewer housing units had *both* interior and exterior LBP, perhaps due to common lead hazard control actions such as replacing windows that remove some but not all of the LBP in a home. Fewer units had very high levels of lead in paint (i.e., 10 mg/cm² or greater), perhaps reflecting hazard control actions directed to eliminating exterior LBP, which tends to have the highest levels of lead, as well as demolition of older housing stock. Because of the strong positive association between paint-lead levels and dust-lead levels, this reduction is also expected to be reflected in reductions in dust-lead levels. The significant nationwide drop in the percentage of housing units with LBP is due mainly to the approximately 10 million lead-free homes built between 1998 and 2005. The 1.5 million reduction in the number of pre-1978 homes with LBP (not statistically significant) equates

TABLE 4

Prevalence of Significant LBP Hazards^a in AHHS^b by Type of Hazard With Comparisons to NSLAH^b

Type of Hazard	# HUs ^{c,d}			% HUs		
	Estimate	Lower 95% CI ^e	Upper 95% CI	Estimate	Lower 95% CI	Upper 95% CI
Significantly deteriorated LBP	15,331	12,784	17,879	14.50	12.10	16.80
	<i>13,634</i>	<i>10,928</i>	<i>16,341</i>	14	11	17
Interior lead dust	13,740	11,776	15,704	[13.0]*	11.20	14.80
	<i>15,468</i>	<i>12,982</i>	<i>17,954</i>	16	14	19
Soil lead hazard	3,848	2,235	5,461	3.60	2.10	5.20
	<i>6,460</i>	<i>3,122</i>	<i>9,799</i>	7	3	10
Any LBP hazard	23,186	20,532	25,840	21.90	19.40	24.30
	<i>24,026</i>	<i>21,306</i>	<i>26,746</i>	25	22	28

^aSignificant lead-based paint (LBP) hazards defined as deteriorated LBP in greater than *de minimis* amounts (deterioration >20 ft² of exterior LBP or 2 ft² of interior LBP for large surface area components, or damage >10 ft² of the total surface area of LBP on small interior components); OR has dust-lead levels above the federal threshold for floors or windowsills (40 µg/ft² for floors or 250 µg/ft² for windowsills); OR has bare-soil lead levels above federal thresholds (more than 9 ft² of bare soil with a lead concentration of 1,200 parts per million [ppm] or greater, or 400 ppm for bare soil in an area frequented by a child under the age of 6 years).

^bNational Survey of Lead and Allergens in Housing (NSLAH) values are in italics below the American Healthy Homes Survey (AHHS) values.

^cHUs = housing units; HUs include permanently occupied, noninstitutional housing units in which children are permitted to live.

^dIn millions.

^eCI = confidence interval for the estimated number or percent.

*Statistically significant differences from NSLAH (at the 5 level; $p = .05$) shown bolded in square brackets.

to an annual rate of decrease of 0.6% over the seven years between NSLAH and AHHS, consistent with previous estimates of the annual rate of demolition in housing ranging from 0.6% to 0.96% (Jacobs & Nevin, 2006).

The prevalence of LBP in homes built in 1978 through 2005 after the use of LBP in homes was banned was 6.6%, similar to the 7.0% reported for 1978–1998 in NSLAH. In AHHS, 74% of the XRF readings that were positive for LBP in these units were on ceramic surfaces (1.7% of 1978–2005 homes had XRF readings positive for LBP on nonceramic surfaces; some of these positive readings may reflect measurement error). Floor dust-wipe samples were collected on 42 of the ceramic surfaces with positive readings; 39 were below the detection limit (5 µg/ft²), with the highest lead level being 13.1 µg/ft². This suggests that lead in ceramic tile is encapsulated and does not create elevated levels of lead in dust.

The modest drop in the total number of homes with LBP hazards (0.8 million) reflects larger drops in homes with lead dust hazards (1.7 million) and soil lead hazards (2.6 mil-

lion), offset by an increase in homes with significantly deteriorated LBP (1.7 million). Interestingly, 1.2 million of this last increase was in homes built between 1960 and 1977, perhaps reflecting the aging of this housing stock. These figures suggest that, while the overall number of homes with LBP hazards decreased only modestly in seven years, greater progress occurred in reducing the number of homes with lead hazards in dust and soil. This means reduced overall exposure, dust and soil being the most significant exposure pathways for lead exposure in children, consistent with BLL data showing that children's BLLs declined from 1999 to 2006. Analysis of data from the National Health and Nutrition Examination Survey indicated statistically significant reductions in both the mean BLL of children aged 1–5 and the percentage of children with BLLs ≥5 µg/dL between 1999–2002 and 2007–2010 (CDC, 2013).

The large decrease in the percentage of multifamily units with LBP hazards is noteworthy and likely reflects the influence of HUD's regulations requiring lead hazard control activities

in federally subsidized multifamily housing and enforcement of the Lead Disclosure Rule (24 CFR Part 35, Subpart A) by HUD and U.S. EPA. Through 2013, settlements with large multifamily and other landlords found to have violated the disclosure rule required inspections or lead-hazard control work to be conducted in over 180,000 units.

Dust lead hazards were significantly reduced nationwide, perhaps because of the emphasis of most guidance and regulation related to lead hazard control, which is to conduct interim lead hazard controls to manage LBP and lead-contaminated soil in place, without removing all LBP and contaminated soil. The National Evaluation of HUD's Lead Hazard Control Grant Program showed that interim controls yield substantial reductions in residential dust-lead levels and children's BLLs, lasting for several years (Clark et al., 2011, Wilson et al., 2006). The increase in significantly deteriorated LBP in housing built between 1960 and 1977 could be due to greater relative aging in this group and illustrates the importance of maintaining paint condition.

HUD plans to conduct another national survey this decade to track changes in the prevalence and distribution of LBP hazards and possibly other exposures of concern (e.g., allergens, mold) in U.S. housing. As in the previous surveys, the department will look for opportunities to work with its federal partners to maximize the value of the survey as a targeted national surveillance tool.

Arsenic

Higher levels of soil arsenic found for higher-income households are likely due to more wooden structures such as decks and fences in more expensive homes. Although a definitive determination cannot be made based on the soil sampling protocol used in AHHS, this pattern is likely due to the leaching of inorganic arsenic from wood that was treated with chromated copper arsenate (CCA) or to sawdust left in the soil after construction of wooden structures. CCA was used to treat wood used in outdoor residential settings starting in the 1970s, with its use for this purpose discontinued in 2004 as the result of a voluntary agreement between commercial users and U.S. EPA (US. EPA, 2011).

AHHS results have potentially important implications for regulation of arsenic in states. While no federal regulatory lim-

its exist for arsenic in soil, many states have established limits. Of 19 states reporting residential action levels for soil in a 1998 survey (City of Amherst, 1998), 12 were below the AHHS national mean level of 6.60 ppm arsenic in soil. Only two had an action level > 20 ppm. Of 17 reporting cleanup levels, only one exceeded 20 ppm. AHHS estimated that 16% of homes with wood structures in the yard and 8% of homes without such structures (Table 6) had soil arsenic levels of 20 ppm or greater. Thus, the typical levels of arsenic actually found in soil across the U.S. were higher than many state regulatory limits. The health implications for this are unclear. Arsenic is a known human carcinogen, and risk increases with the extent of exposure. Of greatest concern would be the incidental ingestion of arsenic-contaminated soil and dust by young children (Agency for Toxic Substances and Disease Registry, 2007).

Conclusion

Findings provided both evidence of progress and reasons for caution. Positive trends included significant reductions in the percentage of multifamily housing units with LBP hazards, the proportion of housing units with interior dust-lead hazards, and the proportion of housing units with the highest paint-lead levels. To continue recent trends of reduced children's BLLs, proper maintenance in the 37 million housing units with LBP and efforts to identify and address LBP hazards are necessary. On the federal level, U.S. EPA's Renovation, Repair, and Painting (RRP) rule (40 CFR Part 745, especially Subpart E), is expected to reduce the potential for LBP hazards during home renovation. State and local governments can require rental housing to meet minimum maintenance standards (e.g., Maryland requires pre-1978 rental housing to pass a visual inspection and dust test). Outreach efforts to the housing, maintenance, and construction industries and the general public can inform them of ways to prevent children's exposure to lead.

TABLE 5

American Healthy Housing Survey Mean Soil Arsenic Levels by Housing Characteristic

Characteristic	Soil Arsenic (parts per million)		
	Mean	Lower 95% CI ^a	Upper 95% CI
All occupied housing units	6.60	5.87	7.33
Northeast	8.73	7.30	10.17
Midwest	7.82	6.01	9.63
South	5.32	4.37	6.28
West	5.55	3.89	7.21
1978–2005	5.62	4.59	6.64
1960–1977	6.35	5.24	7.45
1940–1959	7.04	5.55	8.52
Before 1940	8.65	7.48	9.81
Income ≥\$30,000/yr.	7.02	6.14	7.90
Income <\$30,000/yr.	5.77	4.93	6.61

^aCI = confidence interval.

TABLE 6

Maximum Soil Arsenic Levels by Presence or Absence of Wooden Structures in the Yard

Level (parts per million)	% of HUs ^a With Maximum Soil Arsenic > Level	
	Wooden Structures	No Wooden Structures
1	[97]*	92
5	[70]*	49
10	[37]*	21
20	[16]*	8
40	[7]*	3
100	1	1

^aHUs = housing units.
^{*}Statistically significant differences between HUs with wooden structures in the yard and those without such structures (at the 5 level; $p = .05$) shown bolded in square brackets.

The findings on arsenic levels in soil suggest the need for research to better understand the potential health risk to people who come in contact with the soil, especially in yards with wooden structures that were treated with arsenic-containing compounds. 🐼

Corresponding Author: F. Gary Dewalt, Quantech, Inc., 6110 Executive Blvd., Suite 480, Rockville, MD 20852.
 E-mail: fgdewalt@quantech.com.

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A Community-Driven Intervention in Tuftonboro, New Hampshire, Succeeds in Altering Water Testing Behavior

Michael P. Paul, MPH, JD

*Toxic Metals Superfund
Research Program*

*The Audrey and Theodor Geisel School
of Medicine at Dartmouth*

Pierce Rigrod, MRP

*New Hampshire Department
of Environmental Services*

Steve Wingate

Tuftonboro Conservation Commission

Mark E. Borsuk, PhD

*Thayer School of Engineering
Dartmouth College*

Abstract Maximum contaminant levels created by the U.S. Environmental Protection Agency under the Safe Drinking Water Act do not apply to private wells. Rather, the onus is on individual households to undertake regular water testing. Several barriers exist to testing and treating water from private wells, including a lack of awareness about both well water as a potential source of contaminants and government-recommended water testing schedules; a health literacy level that may not be sufficient to interpret complex environmental health messages; the inconvenience of water testing; the financial costs of testing and treatment; and a myriad of available treatment options. The existence of these barriers is problematic because well water can be a source of hazardous contaminants. This article describes an initiative—undertaken by the Tuftonboro (New Hampshire) Conservation Commission, with support from state agencies and a research program at Dartmouth College—to increase water testing rates in a rural region with a relatively high number of wells. The project prompted more water tests at the state laboratory in one day than in the prior six years. This suggests that community-driven, collaborative efforts to overcome practical barriers could be successful at raising testing rates and ultimately improving public health.

Introduction

Approximately one-sixth of U.S. households obtain drinking water from a private well (Kenny et al., 2009). In New Hampshire, more than 40% of the population obtains household water from an unregulated well (Figure 1) (Kenny et al., 2009). Under the Safe Drinking Water Act (SDWA), the U.S.

Environmental Protection Agency (U.S. EPA) regulates public drinking water supplies by establishing maximum contaminant levels (MCLs) and delegating enforcement to states and tribes to ensure water systems conform with the MCLs (Levine, 2012; Tiemann, 2010). The SDWA defines a contaminant as “any physical, chemical, biological, or radio-

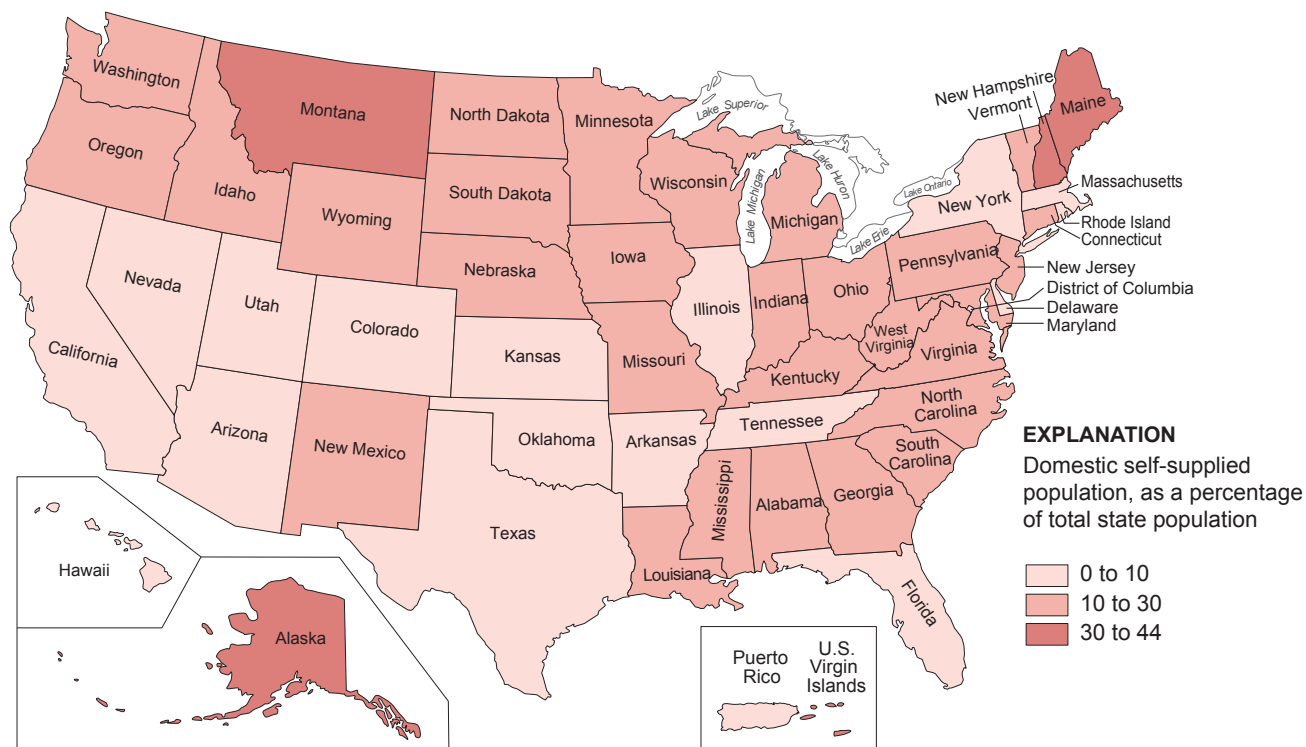
logical substance or matter in water.” Private well water is not tested for compliance with MCLs unless it (1) provides piped water for human consumption to at least 15 service connections (community water systems) or (2) regularly serves at least 25 of the same people for 60 days a year (nontransient, non-community water systems) (Tiemann, 2010; U.S. Environmental Protection Agency [U.S. EPA], 2012a). Therefore, households with wells are responsible for regular water testing to detect contaminants and for applying treatment when necessary.

Potential Human Health Effects of Drinking Water From Private Wells

Untreated water from private wells can be a source of unsafe levels of contaminants (Table 1) (Charrios, 2010; Committee on Environmental Health & Committee on Infectious Diseases [CEHCID], 2009; Walker, Shaw, & Benson, 2006). Ingestion of contaminated water can cause both acute and chronic illness and certain contaminants are particularly hazardous to fetuses, infants, and children (Brender et al., 2013; CEHCID, 2009; Dangleben, Skibola, & Smith, 2013; Farzan, Karagas, & Chen, 2013; Hexemer et al., 2008; Hilborn et al., 2013; Naujokas et al., 2013; Rahman et al., 2010; Reynolds, Mena, & Gerba, 2008; Smith & Steinmaus, 2009). Bacteria, viruses, and parasites cause gastrointestinal illnesses; contaminants, such as radon, arsenic, chromium, and trichloroethyl-

FIGURE 1

Percentage of Total State Population With a Self-Supplied Domestic Water Source



Reproduced from Kenny et al., 2009.

ene are carcinogenic; and studies associate consumption of nitrates with a host of health effects and abnormal fetal development (Ward et al., 2005). Few studies have explored complex mixtures of contaminants and their additive or synergistic effects on health (Ryker & Small, 2008).

In New Hampshire wells, several contaminants are found at levels of concern, including arsenic, radon, and uranium. Low levels of arsenic are likely in nearly 40% of New Hampshire's groundwater (Figure 2) (Ayotte, Cahillaine, Hayes, & Robinson, 2012). Public health officials estimate that approximately one in five New Hampshire wells has arsenic in excess of the U.S. EPA MCL of 0.01 mg/L (Montgomery, Ayotte, Carroll, & Hamlin, 2003). Arsenic is a concern due to both its status as a class 1 carcinogen (Anders et al., 2004) and its place atop of the 2011 Priority List of Hazardous Substances published by

the Agency for Toxic Substances and Disease Registry, which is a ranking of substances based on a combination of their frequency, toxicity, and potential for human exposure at Superfund sites (Agency for Toxic Substances and Disease Registry, 2011). The major concern of ingesting inorganic arsenic is cancer, but dermatological, developmental, neurological, respiratory, cardiovascular, immunological, and endocrine effects are also evident (Hughes, Beck, Chen, Lewis, & Thomas, 2011; Martinez, Vucic, Becker-Santos, Gil, & Lam, 2011; Naujokas et al., 2013; Nuckols et al., 2011; Parvez et al., 2013; Rahman et al., 2010). Evidence is growing that links prenatal and early-life exposure to arsenic with long-term health implications (Farzan et al., 2013) and deleterious effects on the immune system (Dangleben et al., 2013).

Radon is also commonly present in New Hampshire well water. Approximately 50%–

60% of all private drilled wells in New Hampshire produce water with radon concentrations between 300 and 4,000 picocuries per liter (pCi/L) (New Hampshire Department of Environmental Services, 2009). Although the ingestion risk of radon is smaller than the risk associated with inhalation, drinking water with radon increases the risk of developing stomach cancer (Catelino et al., 2006; Hopke et al., 2000). Of the estimated 168 cancer deaths per year due to radon in drinking water, 11% of the deaths are from stomach cancer caused by ingestion (National Research Council, 1999; U.S. EPA, 2012b). Furthermore, radon in water vaporizes during normal usage and contributes to the overall level of radon in indoor air (Collman, Loomis, & Sandler, 1991).

A small number of New Hampshire wells contain uranium above the U.S. EPA MCL (0.03 mg/L). Possible biological effects of

drinking uranium above 0.03 mg/L over a long period include vitamin D and iron homeostasis, bone volume decrease and healing interference, and adverse effects on the kidneys (Canu, Laurent, Pires, Laurier, & Dublineau, 2011). Lower levels of uranium in drinking water have also been associated with high blood pressure (Frisbie, Mitchell, & Sarkar, 2013).

Communicating With Households About Private Wells

Encouraging citizens to monitor their homes is a formidable task (Doyle et al., 1990) and studies indicate that a significant proportion of households are unaware of the need for regular water quality testing (Novokowski, Beatty, Conboy, & Lebedin, 2006). For example, in a rural area of Canada, only 8% of survey respondents had tested their well water at a frequency that met the recommended testing schedule and 20% of households that had tested did not know which tests were performed (Jones et al., 2006). Another study in two rural U.S. counties found that a quarter of respondents with wells had never thought about taking precautions to limit their children's exposure to contaminants, and only one-third of respondents had ever previously tested their water (Postma, Butterfield, Odom-Maryon, Hill, & Butterfield, 2011). At least one study concluded that education, income, age, and homeowner status are all significantly associated with water testing rates (Jones et al., 2005). Treatment rates are also low; a survey in a rural county in Nevada where the media reported extensively about arsenic in drinking water found that only 38% of residents applied treatment (Walker et al., 2006).

Hazard perception is another challenge. No time pressure exists to complete the testing and treatment process and certain contaminants found in well water possess characteristics that lead people to accept the risks associated with drinking well water (Covello, 2008). People may dismiss the risks associated with drinking water because of the following risk characteristics, which have also been identified as reasons people fail to address radon in indoor air (Doyle et al., 1990):

1. The objective probability of the health risk is often below the level at which people understand and respond appropriately;

TABLE 1

Sources, Human Health Benchmarks, and Possible Health Effects of Contaminants Potentially Present in New Hampshire Domestic Well Water^a

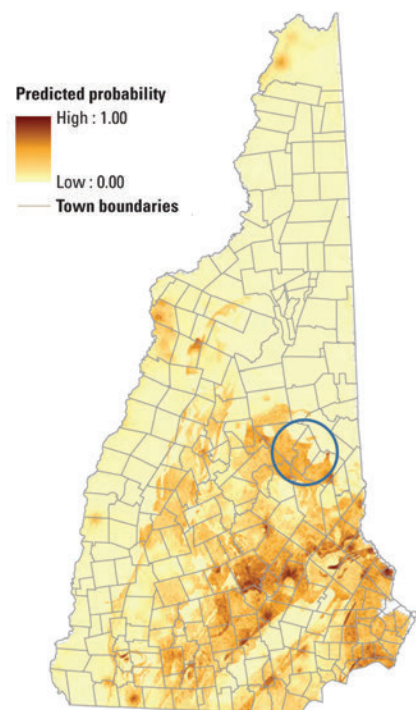
Contaminant	Source	Human Health Benchmark		Possible Health Effects
		Value	Type ^b	
Arsenic	Erosion of natural deposits; runoff from historic pesticide or insecticide application; industrial waste	0.01 mg/L	MCL	Increased risk of several cancers; circulatory problems; endocrine disruption
<i>E. coli</i> ; <i>Legionella</i> ; <i>Giardia</i> ; <i>Cryptosporidium</i>	Human and animal fecal waste; some are naturally present	Goal = zero; No more than 5.0% samples total coliform positive in a month		Gastrointestinal illness (diarrhea, vomiting, cramps); Legionnaires' disease
Fluoride	Naturally in water in a few parts of the U.S.	4.0 mg/L	MCL	Dental fluorosis at high doses; increased risk of bone fractures
Lead	Corrosion of household plumbing; erosion of natural deposits	0.015 mg/L	U.S. EPA action level	Children: developmental delays; possible deficits in attention span and learning abilities Adults: kidney problems; high blood pressure
Manganese	Soil; aquifers; gasoline	0.05 mg/L	Secondary MCL	Neurological effects; manganism; some evidence that shower inhalation can cause toxicity
Nitrate	Fertilizer use; manure; sewage and septic-system effluent; aquifer materials	10 mg/L	MCL	Neural tube defects; central nervous system defects; oral cleft defects; musculoskeletal defects; congenital heart defects; methemoglobinemia; possible promoter of carcinogenesis
Nitrite		1 mg/L		
Radon	Radioactive decay of uranium in aquifer; building materials	2000 pCi/L	NH DES action level	Increased risk of lung cancer for radon in air; increase in risk of stomach cancer for ingested radon
Uranium	Aquifers	0.03 mg/L	MCL	Increased risk of cancer; kidney toxicity
Volatile organics and pesticides (e.g., MtBE)	Dry cleaning and gasoline; leaking storage tanks and pipelines; gasoline spills; air deposition; unidentified sources	0.013 mg/L	NH DES HBSL for MtBE	Compound-specific effects

^aModified and adapted from DeSimone, Hamilton, & Gillom, 2009 and AAP Committee on Environmental Health and Committee on Infectious Diseases, 2009.

^bMCL = maximum contaminant level; U.S. EPA = U.S. Environmental Protection Agency; NH DES = New Hampshire Department of Environmental Services; HBSL = health-based screening level.

FIGURE 2

Probability of Arsenic Concentration in Groundwater From Bedrock Aquifers in New Hampshire Exceeding 0.01 mg/L



As estimated from a U.S. Geological Survey model. Tuftonboro is located inside the blue circle. Adapted from Ayotte et al., 2012.

2. Often no perceptual cues or reminders exist to alert people to the presence of the risk (e.g., arsenic is colorless, odorless, and tasteless in water);
3. Contaminants in well water are often of geological origin, so no villain exists to whom the household can easily assign blame or responsibility;
4. People's experience with the risk is generally benign in the sense that many have lived in their homes years without experiencing any easily attributable health effect;
5. The effect of the risk is far removed from the initial exposure (e.g., arsenic-induced cancer takes many years to develop);
6. Deaths due to contaminant consumption are not dramatic, occur singly, and are impossible to unequivocally relate to consumption; and
7. The risk is not the same for everyone but varies in complex ways depending on sev-

eral dimensions (e.g., location, soil type, well structure).

Additional commonly reported obstacles to water testing and treatment rates include inconvenience, economic costs, inability to interpret test results, and uncertainty over the reliability of treatment companies or performance of systems (Jones et al., 2006; Kreutzwiser, de Loe, & Imgrund, 2010; Kreutzwiser et al., 2011; Montgomery et al., 2003). Self-installation treatment systems are available, but they have startup and maintenance costs, require skills to install, and are typically contaminant specific. Finally, water quality information and test results contain complex terms, labels, and numbers with various confounding units; thus, we suspect that health literacy levels are also an understudied contributor to low treatment rates. Health literacy is "the degree to which individuals have the capacity to obtain, process, and understand basic health information . . . needed to make appropriate health decisions (Ratnan & Parker, 2000)," and it refers to "... understanding and using information to make health decisions (Peerson & Saunders, 2009)." It includes the ability to use quantitative information (Berkman, Davis, & McCormack, 2010). Almost 9 out of 10 U.S. adults have difficulty applying everyday health information (Kutner, Greenberg, Jin, & Paulsen, 2006).

Recent research suggests public health officials must design interventions and materials to address these barriers. In Waterloo, Canada, removing the barriers of cost and inconvenience approximately doubled the background testing rate (Hexemer et al., 2008). A thorough analysis identified complacency and inconvenience as the most significant barriers and confirmed that household knowledge and better information alone were weak bases for predicting higher testing rates (Imgrund, Kreutzwiser, & de Loe, 2011).

Community-Level Interventions and Behavior Change

Community-based participatory research and other forms of community-engaged research encourage involvement of communities in the formation of research and solutions (Brown et al., 2012; O'Fallon & Deary, 2002). Researchers and communi-

ties increasingly report that partnership-driven, community-level interventions are successful in promoting healthy behaviors (Brown et al., 2012; Downs et al., 2010). Partnership-driven efforts build social capital, empower households, and help develop locally appropriate management strategies (Arnold & Fernandez-Gimenez, 2007; Berkes, 2009; Downs et al., 2010). Findings suggest target populations may ignore messages when community leaders do not sufficiently participate in the design of interventions; thus, communication may not clarify the public health hazard and has the potential to expand the gap between perceived and actual risk. High levels of public disinterest and apathy have been reported in many "technocratic" approaches (Covello, 2008; Doyle et al., 1991; Slovic, 1987).

Participatory testing and reporting refers to an approach that enables community members to participate in meaningful and empowering ways in the testing activity and reporting of results (Downs et al., 2010). The work described here was "participatory" in that 1) a local group of volunteers consulted an academic research program and state agency to conceive, design, and implement a water testing program; and 2) the volunteers led an effort to report the results to local leaders and the community with support from the other partners.

Methods

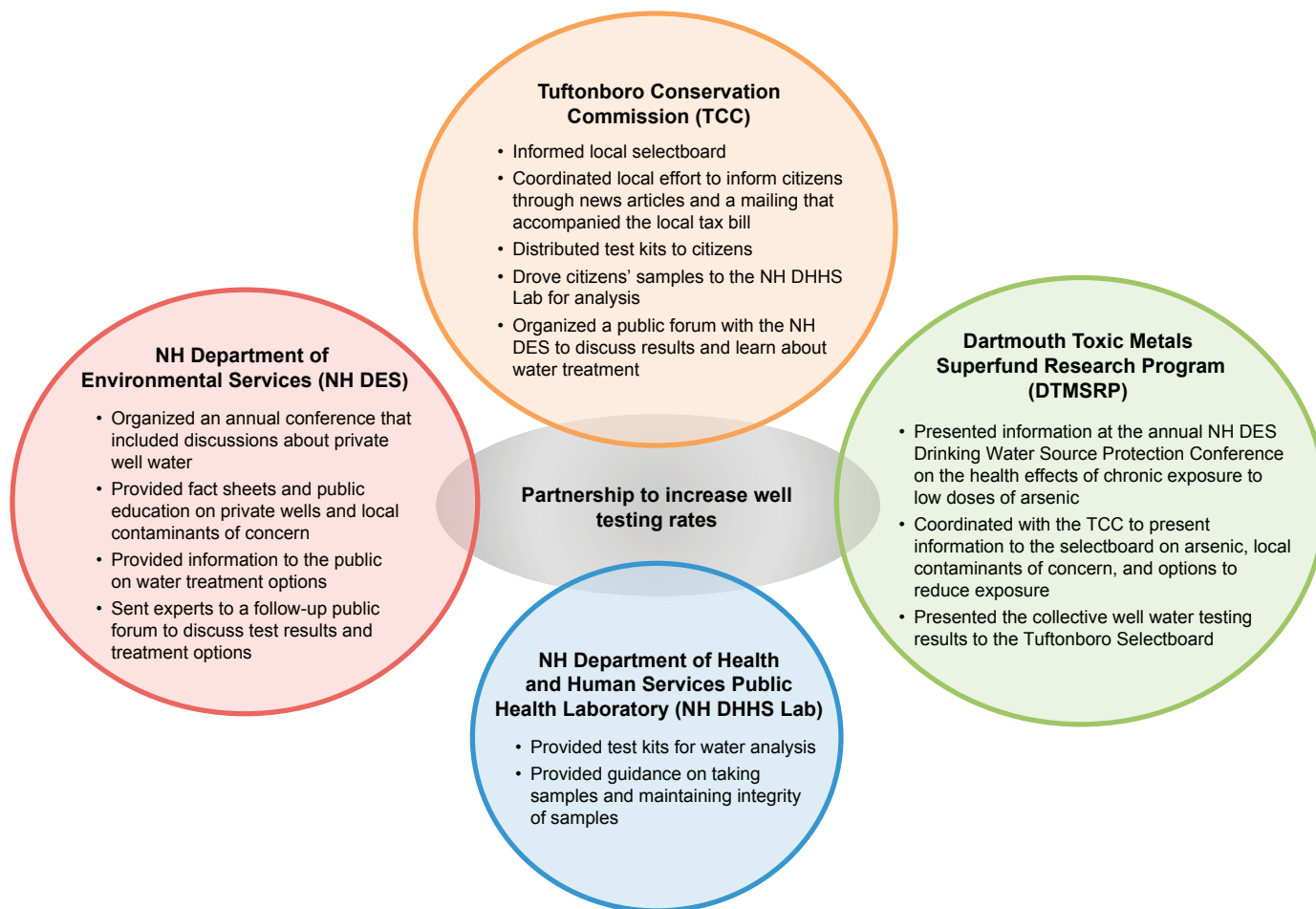
Partnership to Increase Well Water Testing Rates in Tuftonboro, New Hampshire

In 2012, the Tuftonboro Conservation Commission (TCC) initiated an effort to inform local residents about the potential health effects of well water. TCC began by inviting the Dartmouth Toxic Metals Superfund Research Program (DTMSRP) to present to the Tuftonboro Selectboard (Figure 3). A member of DTMSRP presented information about the health effects of contaminants in well water and provided information about protective actions. The selectboard responded with support for an informational campaign. TCC subsequently planned a well water testing service for residents in order to make testing accessible and reduce its overall inconvenience.

Table 2 outlines the timeline of the water testing campaign in 2012. In short, TCC

FIGURE 3

Partners Involved in a Pilot Project to Increase Well Testing Rates in Tuftonboro, New Hampshire



contacted the New Hampshire Department of Health and Human Services Public Health Laboratory (NH DHHS Lab) to obtain water testing kits for distribution to residents. TCC disseminated and publicized information about well water and notified the community about dates TCC would distribute testing kits. After collecting samples, forms, and money, a volunteer delivered the time-sensitive samples to the NH DHHS Lab, which was a 70-minute drive (140 minutes round trip). The volunteer ensured correct transfer of test forms and samples, and TCC coordinated the delivery of results to residents. Residents were provided the option to choose a basic analysis, a standard analysis, a radiological analysis, or individual contaminants. Results were sub-

sequently delivered to residents, and personally identifiable information was removed so the collective results could be presented to the selectboard by a member of DTMSRP. Finally, TCC organized a well water forum in collaboration with the New Hampshire Department of Environmental Services (NH DES) to answer residents' questions about results and treatment. In total, TCC estimated it spent more than 100 man-hours organizing the campaign in 2012. TCC repeated the process in 2013.

Community and Partners Involved

TCC

TCC is composed of four year-round volunteer residents. Conservation commissions

are composed of volunteers who work to study and protect local natural resources. Three members planned and carried out the water testing events, extending the mission of TCC to protect residents from the consequences of contaminants in well water. Tuftonboro is located in Carroll County, New Hampshire. Carroll County has fewer than 50,000 people and Tuftonboro has approximately 2,500, with the number of residents markedly increasing during the summer months. Tuftonboro is a summer vacation spot on the north shore of Lake Winnepesaukee, with a marina and many lakeside homes and rental cottages.

TABLE 2

Timeline of Partnership and Events

Month in 2012	Event ^a
May	Three TCC members attend the NH DES Drinking Water Source Protection Workshop. Dr. Josh Hamilton of DTMSRP presents information on the potential health effects of arsenic in New Hampshire well water.
	TCC researches the issue of contaminants in well water and presents the information at the next TCC meeting. TCC agrees to approach the Tuftonboro Selectboard about organizing a public information program.
	A member of the DTMSRP presents information to the Tuftonboro Selectboard about the potential health effects of common contaminants, a regulatory overview, and information about other local ordinances. The Tuftonboro Selectboard responds with support for an informational campaign. TCC meets to discuss a plan of action.
	TCC contacts several water testing labs to determine the cost of testing and service options.
June	A member of TCC continues to attend selectboard meetings to report progress, receive formal approval, and to ensure the proposed project was covered by the local media.
	TCC produces two articles about arsenic and other pollutants found in New Hampshire wells and the potential health effects. The articles appear in the town newsletter and a local paper. A reporter from the paper also publishes an article about a resident who had discovered an extremely high level of arsenic in their water.
	TCC announces plans to offer a water testing service and produces posters and a supplemental instruction sheet for residents. TCC also posts notices at three post offices and the library.
July	TCC distributes water testing kits at the town transfer station. Members of the TCC set up displays that include handouts from DTMSRP and NH DES. TCC makes three trips to the NH DHHS Lab to pick up test kits because demand exceeds estimations.
	In shifts, members of TCC collect water samples at the town transfer station. TCC checks residents' paperwork and collects money for the cost of water tests. The samples are properly bagged and refrigerated. The next morning two members deliver the samples to the state lab and help technicians organize the samples.
August	As residents receive water test results from the state lab, several members help people interpret reports or refer people to NH DES for technical assistance.
September	TCC begins planning a public forum for residents to include information about interpreting water test results and treatment options.
	TCC prepares a notice to be included with tax bills and a press release to advertise the Well Water Forum.
October	The first collection event in 2012 prompts 122 water samples. A member of DTMSRP presents the collective results of the water tests.
November	NH DES and TCC hold a Well Water Forum where testing and treatment specialists present information on interpreting water tests and respond to questions about water treatment.
	TCC distributes, collects, and delivers additional test kits to the NH DHHS Lab.

^aTCC = Tuftonboro Conservation Commission; NH DES = New Hampshire Department of Environmental Services; DTMSRP = Dartmouth Toxic Metals Superfund Research Program; NH DHHS = New Hampshire Department of Health and Human Services.

DTMSRP

DTMSRP is a research program funded by the National Institute of Environmental Health Sciences. A focus of the program is to investigate the health effects of arsenic in well water, and informing residents about arsenic in well water has been a priority of DTMSRP since its inception. The Research Translation and Community Engagement Cores maintain a Web site with frequently asked questions and water testing information. The Research Translation Core created a 10-minute movie, *In Small Doses: Arsenic*, about arsenic in wells. The cores frequently organize public events to promote water testing, and they have a prominent role in the coordination of the New Hampshire Arsenic Consortium, which is an annual meeting of regional professionals to share information on arsenic in well water.

NH DES

NH DES produces drinking water fact sheets, provides technical assistance about testing and treatment to residents, and conducts outreach to promote testing and treatment. Private well installation and related construction standards are administered by the New Hampshire Water Well Board. The board along with NH DES is primarily responsible for licensing well and pump contractors, maintaining well construction records, and adopting and enforcing standards for the construction of wells and the installation of pumps. NH DES recommends private well users test their water annually for bacteria and nitrates, and every three to five years for a suite of other contaminants. The agency also maintains a list of accredited labs that provide services locally.

NH DHHS Lab

The NH DHHS Lab provides analytical testing services of water, wastes, hazardous materials, soils, and other chemical matrices for all state agencies and citizens. The NH DHHS Lab's mission is to meet clients' needs and requirements, comply with all applicable quality assurance and quality control objectives, and comply with current applicable government standards and regulations. Its policy is to assist clients in understanding and interpreting the relevance of their test results by providing educational material and personal communication.

Results

In total, TCC collected and delivered 285 water samples to the NH DHHS Lab in July 2012 and July 2013 (Figure 4), which was more than triple the number of water samples tested at the same lab in the previous six years (the NH DHHS Lab tested just 83 water samples from Tuftonboro from 2006 to 2012). After the first sample collection event in 2012, the TCC delivered 122 water samples in July and then 37 other samples prompted by follow-up publicity and a Well Water Forum led by NH DES. In 2013, TCC collected and delivered a total of 163 water samples after the sample collection event and then 27 in the following months. Alarming, 28% of water samples exceeded the arsenic MCL and 23% were positive for total coliform bacteria. Of the 79 samples that underwent a radiological analysis, 24 water samples (34%) had greater than 2,000 pCi/L of radon, which is the NH DES recommended action level. The combined results are summarized in Table 3.

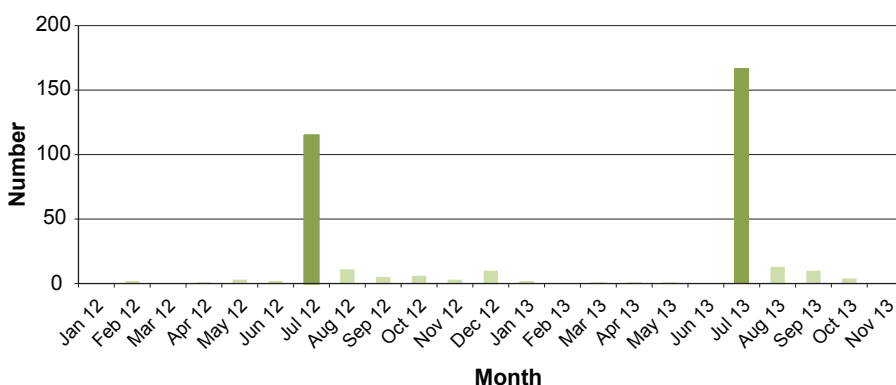
Discussion

We consider the participatory water testing program designed and implemented by TCC to be successful. The program raised awareness about the potential hazards of well water among local community leaders and empowered many residents to test their water. The reporting of results also sprouted other community-led testing initiatives in New Hampshire. Elements that contributed to the success of the program included the following:

- Targeted messages. TCC used local media to significantly raise public awareness, and the efforts to promote the water testing service were well timed.
- Support from the town selectboard. TCC worked together with the town selectboard, keeping the town leaders informed about its actions, and the selectboard supported the TCC's testing service by providing reimbursement to the TCC member who transported the water samples to the NH DHHS Lab. Members of TCC attended selectboard meetings each month to report on progress leading up to the events. The meeting minutes are published and read by town residents.
- Persistence. TCC volunteered a substantial amount of time over the course of two years to plan, inform citizens, and hold events.

FIGURE 4

Number of Well Water Samples Processed by the New Hampshire Department of Health and Human Services Lab from Tuftonboro, Melvin Village, and Mirror Lake in Each Month of 2012–2013



The Tuftonboro Conservation Commission held community water testing events in July 2012 and July 2013. Over the previous six-year period, the state lab processed a total of 83 samples from these three communities.

- Dedicated and compassionate volunteers. Informed members of TCC provided individual assistance to residents on what tests to select, how to draw the samples, and what payment to make.

The actions of TCC addressed factors that have previously been found to influence testing behavior. First, TCC likely changed local attitudes through a public information campaign focused on providing facts and stories about local residents who were dealing with contamination. The publicity may have boosted household knowledge and altered a common misperception that unsafe water must taste or smell abnormally. Second, TCC learned that the inconvenience of water testing may be an important structural constraint, especially in rural regions. TCC made water testing more accessible for people by distributing test kits, driving samples to the lab, and reducing the overall effort needed to obtain and interpret results. This reinforces previous findings that merely providing the public with information is not sufficient to ensure that decisions are consistent with the actual level of risk (Imgrund et al., 2011; Madajewicz et al., 2007; Walker, Shaw, & Benson, 2006).

The overall effectiveness of the program in reducing exposure is difficult to evaluate because we did not measure the rate of treatment and did not formally follow up with households about whether they acted on the test results. This limits our ability to analyze how people interpreted water test results and whether the information they received was actionable. Future programs should contain a mechanism to measure treatment rates, since water testing alone does not reduce exposure to contaminated water. Comments from TCC emphasized the need for clear and simple instructions with test kits and the need for water test results to highlight elevated levels of particular contaminants. We are also unable to definitively state that the water testing program increased the background water testing rate in Tuftonboro because private laboratories in New Hampshire do not release data on the number of samples tested at their facilities. It is possible a significant number of people used private lab services, which could mean 1) more people tested prior to the efforts of TCC, or 2) the number of water tests prompted by the TCC is higher, which would result in a smaller or larger increase of the background water testing rate, respectively.

TABLE 3

Tuftonboro Area Homeowner Survey, June 2012 and June 2013

Parameter	Samples	Limit Type ^a	Limit Value	# Above Limit	%
Total coliform bacteria	258	MCL	0 cts/100/mL ^b	61	23.64
Noncoliform counts	258		>200 cts/100/mL	40	15.50
<i>E. coli</i> bacteria	258	MCL	0 cts/100/mL	14	5.43
Analytical gross alpha	8	MCL	15 pCi/L	0	0.00
Arsenic	275	MCL	0.01 mg/L	77	28.00
Chloride	246	SMCL	250 mg/L	4	1.63
Copper	237	SMCL	1.0 mg/L	1	0.42
Copper-stagnant	232	SMCL	1.0 mg/L	22	9.48
Fluoride	240	MCL	4.0 mg/L	10	4.17
Fluoride SMCL	240	SMCL	2.0 mg/L	33	13.75
Hardness	237		250 mg/L	0	0.00
Iron	237	SMCL	0.3 mg/L	17	7.17
Lead	237	AL	0.015 mg/L	1	0.42
Lead-stagnant	232	AL	0.015 mg/L	23	9.91
Manganese	237	SMCL	0.05 mg/L	20	8.44
Nitrate	246	MCL	10 mg/L	21	8.54
Nitrite	246	MCL	1 mg/L	0	0.00
Radon	79		2000 pCi/L	24	30.38
Sodium	237	SMCL	250 mg/L	1	0.42
Uranium	237	MCL	.030 mg/L	0	0.00
pH	237		pH <6.5	37	15.61
	237		pH >8.5	8	3.38
Volatile organic compounds	3	MCL	varies with compound	0	0.00
Alkalinity	2			0	0.00

^aMCL = maximum contaminant level for public water systems; SMCL = secondary maximum contaminant level for public water systems; AL = action level for public water systems.

^bPRESENT is unacceptable.

Conclusion

Water from private wells is largely unmonitored and private well users are often unaware of the potential presence of contaminants. In the absence of protective laws, convincing households to follow recommended testing schedules is necessary to protect public health. Participatory programs that reduce the barriers to testing and treatment can help certain communities increase the likelihood of protective behaviors. The pilot program described here was successful in raising local awareness and prompting residents to test their water. Further programs and research should explore the other testing and treatment constraints. 🏠

Acknowledgements: DTMSRP is supported by funds from National Institute of Health Grant Number P42ES07373. The authors are solely responsible for this content; it does not represent the official views of the National Institute of Environmental Health Sciences or the National Institutes of Health.

Corresponding Author: Mark E. Borsuk, Associate Professor of Engineering, Thayer School of Engineering, Dartmouth College, 14 Engineering Drive, Hanover, NH 03755-8000. E-mail: mark.borsuk@dartmouth.edu.

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► DIRECT FROM CDC ENVIRONMENTAL HEALTH SERVICES BRANCH



Raquel I.
Sabogal, MSPH



Brian Hubbard,
MPH

Improving State and Local Capacity to Assess and Manage Risks Associated With Private Wells and Other Drinking Water Systems Not Covered by the Safe Drinking Water Act

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 a column from the Environmental Health Services Branch (EHSB) of the Centers for Disease Control and Prevention (CDC) in every issue of the *Journal*.

In these columns, EHSB and guest authors share insights and information about environmental health programs, trends, issues, and resources. The conclusions in this article are those of the author(s) and do not necessarily represent the views of CDC.

Raquel Sabogal is an epidemiologist and Brian Hubbard is a health scientist. They are both on the safe water team at EHSB. They are currently managing cooperative agreements that support state and local agencies' water programs.

Eleven percent of U.S. households (~35 million people) use private drinking water systems that are not covered by the U.S. Environmental Protection Agency's Safe Drinking Water Act (SDWA) (U.S. Census Bureau, n.d.). These drinking water systems are primarily private wells but can also include springs, cisterns, and hauled water systems. Limited federal guidance and no established uniform standards or approach exist for monitoring the water quality from these water systems. Where state testing requirements do exist, testing is usually infrequent (e.g., wells must be tested as part of a real estate transaction, new construction, or equipment change). Most private well programs are voluntary and require strong outreach activities to encourage well owners to monitor the safety of their drinking water and accept water program ser-

vices offered by the local health department.

To address the need of state, tribal, local, and territorial (STLT) health departments, the Centers for Disease Control and Prevention (CDC) released a funding opportunity announcement in 2013 that built on previous CDC safe drinking water efforts to address drinking water contamination. The 2013–2015 funding initiative supported 11 grantees (nine state and two county health departments) to improve state and local capacity to assess and manage risks associated with drinking water systems not covered by SDWA.

Although CDC funding primarily directed grantees to identify and collect data to define drinking water exposures and then develop interventions, grantees engaged in many additional essential public health services (Table 1). Grantees developed community

partnerships to facilitate private well data collection and data sharing, sought external technical assistance to conduct data analysis, and worked on community outreach and education interventions.

STLT health departments vary considerably in capacity, partnerships, policy environment, programmatic focus, efficiency, and effectiveness. Program variability makes it important to provide support to all components of a drinking water program to make them successful and sustainable. The 10 essential environmental public health services (EPPHS) and accompanying toolkits offer a framework and activities that STLT public health agencies can use to improve the capacity of drinking water programs. The Environmental Public Health Performance Standards (EnvPHPS) assessment toolkit (www.cdc.gov/nceh/ehs/envphps/assessment_toolkit.htm) is an additional resource for assessing performance of public health programs. Figure 1 shows the 10 EPPHS as they align with the core functions of public health.

To understand the diversity of STLT programmatic efforts, CDC used the 10 EPPHS and EnvPHPS to align first-year outcomes from the 11 grantees by each of the 10 EPPHS (Table 2). Since data collection and characterization of exposures were goals of the cooperative agreement, most grantees addressed the first two essential services associated with the assessment function. Specifically, grantees collected private well drinking water quality data and created and organized inventories of private well databases. When conducting interventions, however, many grantees developed educational and outreach materials with drink-

TABLE 1

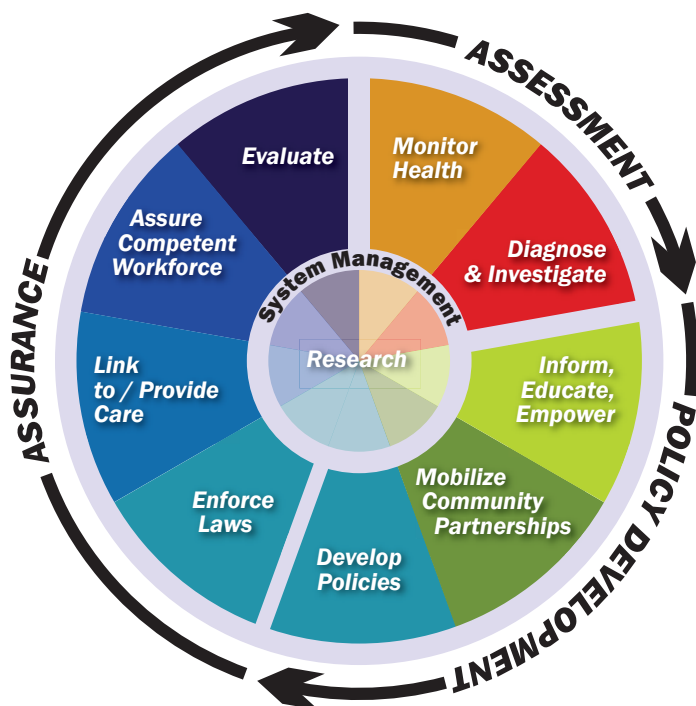
Ten Essential Environmental Public Health Services

ES1. Monitor environmental and health status to identify and solve community environmental public health problems	ES6. Enforce laws and regulations that protect environmental public health and ensure safety
ES2. Diagnose and investigate environmental public health problems and health hazards in the community	ES7. Link people to needed environmental public health services and assure the provision of environmental public health services when otherwise unavailable
ES3. Inform, educate, and empower people about environmental public health issues	ES8. Assure a competent environmental public health workforce
ES4. Mobilize community partnerships and actions to identify and solve environmental health problems	ES9. Evaluate effectiveness, accessibility, and quality of personal and population-based environmental public health services
ES5. Develop policies and plans that support individual and community environmental public health efforts	ES10. Research for new insights and innovative solutions to environmental public health problems

Source: www.cdc.gov/nceh/ehs/home/healthservice.htm.

FIGURE 1

Core Functions of Public Health




This figure shows how the ten essential environmental health services align with the three core functions of public health (assessment, policy development, and assurance). For more information about these core functions, visit www.cdc.gov/nceh/ehs/ephli/core_ess.htm.

ing water messaging to meet the specific needs of target populations (ES3). For example, the New Hampshire Department of Environmental Services created an online application that provides individualized water treatment guidance to private well users based on water testing results for 15 parameters. Other grantees developed messaging using both traditional and social media channels for dissemination. Grantees also developed new external partnerships to obtain private well data and to help them with data analysis (ES4), thereby strengthening the core function of policy development.

Under the core function of assurance, two grantees revised state and local regulations to reduce drinking water exposure risks (ES6). Duval County, Florida, developed and passed a local ordinance to secure funds to extend municipal water lines to communities that were permanently grouting and abandoning private wells. New Hampshire passed a revised bill requiring buyers to acknowledge arsenic well-testing results before a real estate transaction. Some grantees improved the capacity of their workforces by using GIS mapping and geo-referencing techniques to share risk map areas for private wells on their web portals (ES8). All grantees received CDC technical assistance to improve logic models and evaluation plans—required components of the cooperative agreement (ES9).

CDC is continuing to support and promote performance management and quality improvement activities using the 10 EEPHS under a new cooperative agreement, Environmental Health Services Support for Public Health Drinking Water Programs to Reduce Drinking Water Exposures, 2015–2020. The goals of this funding initiative are to increase safe drinking water program efficiency and effectiveness and improve programmatic response to all issues related to safe drinking water, especially those that focus on drinking water systems not covered by the SDWA.

Programs can benefit by using the 10 EEPHS and accompanying toolkits as resources to improve programmatic capacity. Conducting performance improvement activities will also help public health departments meet accreditation standards. The ultimate goals of CDC's new funding initiative are to reduce exposures to contaminated drinking water and improve performance of safe drinking water programs. 

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TABLE 2

Ten Essential Environmental Public Health Services Addressed by Grantees, End of Year One

Grantee	Core Functions									
	Assessment		Policy Development			Assurance				
	ES1	ES2	ES3	ES4	ES5	ES6	ES7	ES8	ES9	ES10
Cerro Gordo County, IA	X	X		X				X	X	
Connecticut	X	X	X	X			X		X	
Duval County, FL	X	X		X		X			X	
Florida Department of Health	X	X	X	X			X		X	
Louisiana	X	X	X						X	
Maine	X	X	X	X			X	X	X	
New Hampshire	X	X	X	X		X	X		X	X
New Mexico	X	X	X					X	X	X
New York	X	X	X					X	X	
Ohio	X	X		X				X	X	
Oregon	X	X	X	X				X	X	

Corresponding Author: Raquel I. Sabogal, Division of Emergency and Environmental Health Services, National Center for Environmental Health, Centers for Disease Control

and Prevention, 4770 Buford Highway, NE, MS F-58, Atlanta, GA 30341-3717.
E-mail: rsabogal@cdc.gov.

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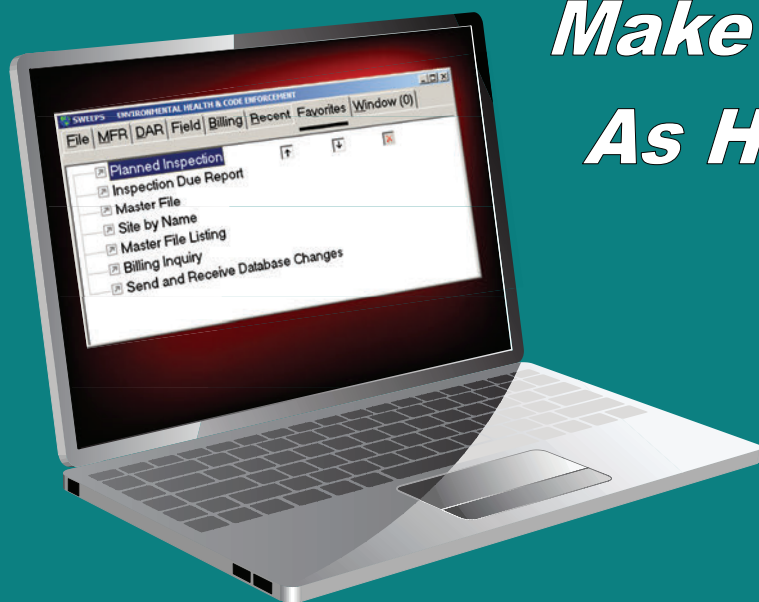
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► DIRECT FROM CDC ENVIRONMENTAL PUBLIC HEALTH TRACKING NETWORK



Heather Strosnider, MPH

Striving to Achieve the Mission of CDC's National Environmental Public Health Tracking Program

Editor's Note: As part of our continuing effort to highlight innovative approaches and tools to improve the health and environment of communities, the *Journal* is pleased to publish a bimonthly column from the Centers for Disease Control and Prevention's (CDC's) Environmental Public Health Tracking Network (Tracking Network). The Tracking Network is a system of integrated health, exposure, and hazard information and data from a variety of national, state, and city sources. The Tracking Network brings together data concerning health and environmental problems with the goal of providing information to help improve where we live, work, and play.

Environmental causes of chronic diseases are hard to identify. Measuring amounts of hazardous substances in our environment in a standard way, tracing the spread of these over time and area, seeing how they show up in human tissues, and understanding how they may cause illness is critical. The Tracking Network is a tool that can help connect these efforts. Through these columns, readers will learn about the program and the resources, tools, and information available from CDC's Tracking Network.

The conclusions of this article are those of the author(s) and do not necessarily represent the views of CDC.

Heather Strosnider has served as an epidemiologist for CDC's Environmental Health Tracking Branch since 2006. Her primary responsibilities are to develop environmental health indicators and measures, identify appropriate analytic and data visualization methods, and monitor the impact of the environment on health in order to guide public health action and policy.

The Centers for Disease Control and Prevention's (CDC's) National Environmental Public Health Tracking Program (Tracking Program) was established in 2002 with the mission "to provide information from a nationwide network of integrated health and environmental data that drives

actions to improve the health of communities (CDC, 2005)." To tackle this mission, CDC first brought together environmental public health professionals and experts from local, state, and national agencies; from academia; and from nongovernmental organizations. The group set the mission into motion

by identifying the relevant and necessary information, network architecture, data, and actions. In 2006, I joined CDC's Tracking Program as an epidemiologist, just in time to assist in laying the groundwork for the National Environmental Public Health Tracking Network (Tracking Network). Over the years, we've continued to collaborate with partners to enhance the network, including its data and information, to support public health actions. Approaching my 10th anniversary with the Tracking Program, I'd like to reflect on the progress we've made towards achieving our mission and the opportunities we have to improve.

First, "a nationwide network." In 2009, the Tracking Program launched the Tracking Network, a web-based surveillance system that now exists in 25 states and New York City (<http://ephtracking.cdc.gov/showStateTracking.action>) and at the national level (<http://ephtracking.cdc.gov>). It provides access to data and information for communities, environmental public health agencies, health care providers, and researchers. At each level, the network consists of centralized data repositories, gateways for transporting data between levels, secure portals, public portals, and a variety of technical services like data management, geocoding, metadata creation, and report generation.

While the Tracking Program and its network aren't nationwide, we have supported pilot and capacity building projects in 34 additional state and local health departments. This was done through an Association of State and Territorial Health Officials (ASTHO) fellowship program. And over 70% of the data on Tracking Network's National Public Por-

tal covers the U.S. population beyond the 25 funded states and New York City.

The network is more than just the technical infrastructure. It's also the people. The Tracking Program supports over 200 environmental public health practitioners at the state and local level. This people network has built capacity in state and local agencies in disciplines such as data science, informatics, surveillance, geospatial information science, spatial analysis, hazard and exposure assessments, and risk communication.

Next, **"integrated health and environmental data."** The Tracking Network provides access to health, exposure, hazard, and population data; it puts data at the fingertips of public health professionals, nongovernmental organizations, and communities. With our partners, we've identified priority environmental health issues, reviewed the state of the science, determined surveillance needs, developed data standards, and integrated available, relevant data into the network.

Currently, data are available for 18 environmental health issues on the Tracking Network's National Public Portal. Additional data are available on state and local portals to address specific state and local needs. While integrating data into the network, we've addressed important data gaps by supporting existing systems like birth defects surveillance, developing modeled grid-level fine particulate matter and ozone concentration data with the U.S. Environmental Protection Agency, identifying key data elements to support new surveillance for radon in homes and private well water, and improving the utility of hospitalization data by refining our protocols for data extraction and case definitions.

Then, **"provide information."** We have turned terabytes of data into useful, "bite-sized" information by combining our understanding of the environmental public health question with our knowledge about how data are collected. With our partners, we've developed key content for each environmental health issue in the network to explain what we know and don't know about the connections between health and environmental hazards. We've developed and implemented risk communication messages so that users better understand the associated risks and what steps they can take to protect the health and safety of their families and themselves.

Recognizing that different users have different needs, the Tracking Program presents the data in multiple formats. For example, we recently added a new feature on Tracking Network's National Public Portal called "Info by Location." This tool provides quick and easy access to snapshots of county-level data and information covering multiple environmental health issues. In addition, the Tracking Program and its partners have contributed to over 200 peer-reviewed publications and numerous health department reports to describe and inform important environmental public health issues (<http://ephtracking.cdc.gov/showScientificPublications.action>).

Finally, **"drives actions to improve the health of communities."** We drive actions by first using the data in the network to detect and monitor trends, identify populations at risk, examine the relationship between hazards and disease, assess potential disease clusters, identify sources of exposure to hazards, evaluate proposed interventions or policies, and more. Then with our partners, we use the information we've generated to inform, improve, and evaluate public health actions, including programs, interventions, and policies. So far, we've documented that the Tracking Program's data and information have informed over 300 public health actions and likely many additional contributions have gone unreported (Qualters, Strosnider, & Bell, 2014). Some examples (www.cdc.gov/nceh/tracking/successstories.htm) where we have supported and informed decision making include the following:

- The addition of arsenic as a required contaminant for private well water testing in Oregon.
- The adoption of a policy to phase out the use of residual oil for heating in New York City.
- The targeting of small water systems vulnerable to drought in California.
- The implementation of policy requiring carbon monoxide detectors in new construction and rental properties in Maine.
- The deployment of an interactive map of cooling centers in Missouri.
- The development of an intervention to prevent the effects of wildfire air pollution in New Mexico.

In my 10 years with the Tracking Program, I've been fortunate to witness and be part of the tremendous progress we've made towards

accomplishing our mission. Looking forward, we find ourselves faced with significant challenges as well as great opportunities. As a program with a strong informatics focus, it's incumbent on us to stay current with the technology we employ. Across the network as a whole, it's important to evaluate the technology and processes we use to ensure we are as efficient and effective as possible to maximize use of existing resources. It's imperative that we continue to address data gaps by supporting new data collection or modeling for issues such as developmental disabilities, private well water quality, and radon. To provide more local and timely data, it's essential that we tackle the science and privacy issues surrounding small numbers and take advantage of new data streams like electronic health records. Finally, it's critical that we evaluate the utility of the information we provide to ensure we are providing the right information to the right people for the right action. We have built an extensive people and data network which presents a great opportunity to drive actions to prevent or reduce the effect of the environment on health. In collaboration with our many partners, we will use our network to continue progress towards achieving our mission of ultimately improving the health of communities. 🐾

Corresponding Author: Heather Strosnider, Epidemiologist, Environmental Health Tracking Branch, Division of Environmental Hazards and Health Effects, National Center for Environmental Health, Centers for Disease Control and Prevention, 4770 Buford Highway, NE, MS F-52, Atlanta, GA 30341. E-mail: hks9@cdc.gov.

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The Association of Environmental Health Academic Programs (AEHAP), in partnership with NSF International, is offering a paid internship project to students from National Environmental Health Science and Protection Accreditation Council (EHAC)-accredited programs. The NSF International Scholarship Program is a great opportunity for an undergraduate student to gain valuable experience in the environmental health field. The NSF Scholar will be selected by AEHAP and will spend 8–10 weeks (March–May 2016) working on a research project identified by NSF International.

Project Description

The applicant shall work with a professor from their degree program who will serve as a mentor/supervisor and agree to providing a host location from which to do the research. The research project involves administering a survey of the 50 states to determine how they have responded to a specific health code or standard designated by NSF International.

Application deadline: January 15, 2016

For more details and information on how to apply please go to www.aehap.org/nsf-paid-summer-internship-opportunity-for-students

For more information, contact info@aeahp.org or call 206-522-5272.



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EH CALENDAR

UPCOMING NEHA CONFERENCE

June 13–16, 2016: NEHA 2016 Annual Educational Conference & Exhibition and HUD Healthy Homes Conference, San Antonio, TX. For more information, visit www.neha.org/aec.

NEHA AFFILIATE AND REGIONAL LISTINGS

California

March 21–25, 2016: 65th Annual Educational Symposium, hosted by the California Environmental Health Association, Oakland, CA. For more information, visit www.ceha.org.

Idaho

March 16–17, 2016: Annual Education Conference, hosted by the Idaho Environmental Health Association, Boise, ID. For more information, visit www.ieha.wildapricot.org.

Kentucky

February 16–18, 2016: KAMFES 2016, hosted by the Kentucky Association of Milk, Food, & Environmental Sanitarians, Florence, KY. For more information, visit www.kamfes.com.

Michigan

March 15–18, 2016: Annual Education Conference, hosted by the Michigan Environmental Health Association, Bay City, MI. For more information, visit www.meha.net/AEC.

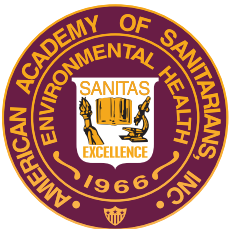
Minnesota

January 28, 2016: Winter Conference, hosted by the Minnesota Environmental Health Association, St. Paul, MN. For more information, visit www.mehaonline.org.

Ohio

April 18–20, 2016: Annual Education Conference, hosted by the Ohio Environmental Health Association, Columbus, OH. For more information, visit www.ohioeha.org/annual-education-conference.aspx.

DAVIS CALVIN WAGNER SANITARIAN AWARD



The American Academy of Sanitarians (AAS) announces the annual Davis Calvin Wagner Award. The award will be presented by AAS during the National Environmental Health Association's 2016 Annual Educational Conference & Exhibition. The award consists of a plaque and a \$500 honorarium.

Nominations for this award are open to all AAS diplomates who:

1. Exhibit resourcefulness and dedication in promoting the improvement of the public's health through the application of environmental and public health practices.
2. Demonstrate professionalism, administrative and technical skill, and competence in applying such skills to raise the level of environmental health.
3. Continue to improve through involvement in continuing education type programs to keep abreast of new developments in environmental and public health.
4. Are of such excellence to merit AAS recognition.

NOMINATIONS MUST BE RECEIVED BY APRIL 15, 2016.

Nomination packages should be sent electronically to shep1578@gmail.com. If desired, three hard copies of the nomination document may be submitted to

American Academy of Sanitarians
c/o Craig A. Shepherd
1271 Statesville Road
Watertown, TN 37184

For more information about the award nomination, eligibility, and evaluation process and previous recipients of the award, please visit sanitarians.org/Awards.

STUDENTS

Don't Miss This Opportunity!

Applications for the 2016 National Environmental Health Association/American Academy of Sanitarians (NEHA/AAS) Scholarship Program are now available.

Last year, \$5,000 was awarded to four students who demonstrated the highest levels of achievement in their respective environmental public health degree programs. If you would like an application or information about the NEHA/AAS Scholarship, do one of the following before the deadline:

VISIT

www.neha.org/professional-development/students/scholarship.

Application and qualification information is available to download from NEHA's scholarship Web page.

CONTACT

Cindy Dimmitt
with a request for
an application and information.
E-mail: cdimmitt@neha.org
Phone: 303.756.9090, ext. 309
Write: NEHA/AAS Scholarship
720 S. Colorado Blvd.,
Ste.1000-N
Denver, CO 80246-1926

Deadline: February 1, 2016

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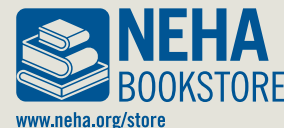
It's never too late to #BeASpartan

Did You Know?

You can learn more about all of the credentials NEHA offers directly from our credentialing coordinator. View the recorded webinar at www.neha.org/credentialing-webinar for an overview and the process to attain a NEHA credential, including the REHS/RS. Q&A from attendees during the live webinar is also included.

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!



Healthy & Safe Homes: Research, Practice, & Policy

Edited by Rebecca L. Morley, MSPP, Angela D. Mickalide, PhD, CHES, and Karin A. Mack, PhD (2011)



This book marks an exciting advance in the effort to ensure that people across all socioeconomic levels have access to healthy and affordable housing. It provides practical tools and information to make the connection between health and housing conditions relatable to everyone. The book brings together perspectives from noted scientists, public health experts, housing advocates, and policy leaders to fully explain the problem of substandard

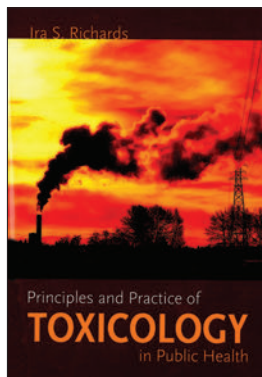
housing that plagues our nation and offers holistic, strategic, and long-term solutions to fix it. Study reference for NEHA's Healthy Homes Specialist credential exam.

225 pages / Paperback / Catalog #1111

Member: \$52 / Nonmember: \$55

Principles and Practice of Toxicology in Public Health

Ira S. Richards (2008)



In four sections, this book offers an introduction to the field of toxicology, as well as the basics of toxicology principles, systemic toxicity, and toxicology practice. It offers thorough coverage of the basic principles of toxicology without being too technical or specialized. The text uses reader-friendly language making it accessible to professionals from a variety of backgrounds including environmental health, industrial

hygiene, engineering, and more. Finally, it includes a section on the application of toxicology in the field.

464 pages / Paperback / Catalog #800

Member: \$107 / Nonmember: \$112

Control of Communicable Diseases Manual (20th Edition)

Edited by David L. Heymann, MD (2015)



NEW! The *Control of Communicable Diseases Manual (CCDM)* is revised and republished every several years to provide the most current information and recommendations for communicable-disease prevention. The CCDM is designed to be an authoritative reference for public health workers in official and voluntary health agencies. The 20th edition sticks to the tried and tested structure of previous editions. Chapters have been updated by international experts. New disease

variants have been included and some chapters have been fundamentally reworked. This edition is a timely update to a milestone reference work that ensures the relevance and usefulness to every public health professional around the world. The CCDM is a study reference for NEHA's REHS/RS, CP-FS, and CEHT exams.

729 pages / Paperback / Catalog #573

Member: \$53 / Nonmember: \$59

Health, Sustainability, and the Built Environment

DAK Kopec (2009)



With the emergence of sick building syndrome in the 1970s and the emphasis on LEED standards today, many are becoming interested in the topics of health and sustainability. *Health, Sustainability, and the Built Environment* examines the concept of sustainability as it pertains to sustaining human health. By analyzing the many ways that humans interact with the built

environment, the text teaches readers how to identify both the positive and negative effects designs can have on the health of occupants. The book is separated into three parts: Introduction to Environmental Health, the Built Environment and Health Threats, and Creating Healthy Environments.

340 pages / Hardback / Catalog #1088

Member: \$99 / Nonmember: \$110



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JEH QUIZ

FEATURED ARTICLE QUIZ #3

Prevalence of Lead Hazards and Soil Arsenic in U.S. Housing

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 a convenient tool for self-assessment and 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 at www.neha.org/publications/journal-environmental-health (click on the December 2015 issue in the left menu),
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, 2015 (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.

Home phone

Work phone

E-mail

JEH Quiz #1 Answers July/August 2015

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

→ Quiz deadline: March 1, 2016

1. According to the American Healthy Homes Survey (AHHS), over ___ million homes with children under the age of six had lead-based paint (LBP) hazards.
 - a. one
 - b. three
 - c. five
 - d. eight
2. The highest prevalence of LBP and LBP hazards, according to AHHS, was in the
 - a. Northeast.
 - b. south.
 - c. Midwest.
 - d. a and c.
 - e. all of the above.
3. The current reference value for blood lead in children adopted by the Centers for Disease Control and Prevention is
 - a. 1 µg/dL.
 - b. 2.5 µg/dL.
 - c. 5 µg/dL.
 - d. 10 µg/dL.
4. AHHS measured levels of
 - a. lead and LBP hazards.
 - b. allergens and endotoxins.
 - c. arsenic.
 - d. pesticide residues and mold.
 - e. all of the above.
5. The AHHS design was a ___ cluster sample of the target population.
 - a. one-stage
 - b. two-stage
 - c. three-stage
 - d. four-stage
6. From the sample of housing units drawn for AHHS, ___ were recruited and completed the survey.
 - a. 10%
 - b. 23%
 - c. 49%
 - d. 51%
7. According to AHHS, an estimated ___ homes had LBP somewhere in the building.
 - a. 23.2 million
 - b. 35 million
 - c. 37.1 million
 - d. 39.1 million
8. An estimated ___ homes had LBP hazards, according to AHHS.
 - a. 16.8 million
 - b. 23.2 million
 - c. 35 million
 - d. 37.1 million
9. According to AHHS, of the estimated 16.8 million homes with children under the age of six, an estimated ___ had LBP hazards.
 - a. 11%
 - b. 16%
 - c. 21%
 - d. 26%
10. The drop in the percentage of homes with LBP from 40% in the National Survey of Lead and Allergens in Housing to 34.9% in AHHS was statistically significant.
 - a. True.
 - b. False.
11. According to AHHS, arsenic levels ___ with the age of the housing.
 - a. decreased
 - b. increased
12. More homes had detectable levels of arsenic in household dust compared to outdoor soil, according to AHHS.
 - a. True.
 - b. False.

Thank You

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**American Public
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Did You Know?

NEHA is growing! Additional staff members at NEHA were hired to help design and deliver food safety training courses. Through a cooperative agreement with the Food and Drug Administration, these trainings will help state, local, territorial, and tribal food safety agencies prepare to implement the Food Safety Modernization Act and fully develop an integrated food safety system (IFSS). NEHA will also research training needs and develop new courses based on needs assessments for IFSS food and feed inspectors and regulators.

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The NEHA Endowment Foundation was established to enable NEHA to do more for the environmental health profession than its annual budget might allow. Special projects and programs supported by the foundation will be carried out for the sole purpose of advancing the profession and its practitioners.

Individuals who have contributed to the foundation are listed below by club category. These listings are based on what people have actually donated to the foundation—not what they have pledged. Names will be published under the appropriate category for one year; additional contributions will move individuals to a different category in the following year(s). For each of the categories, there are a number of ways NEHA recognizes and thanks contributors to the foundation. If you are interested in contributing to the Endowment Foundation, please fill out the pledge card or call NEHA at 303.756.9090. You can also donate online at www.neha.org/donate.

Thank you.

DELEGATE CLUB (\$25–\$99)

Name in the Journal for one year and endowment pin.

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Sandra Long, REHS, RS

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Ned Therien, MPH

Olympia, WA

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(\$100–\$499)

Letter from the NEHA president, name in the Journal for one year, and endowment pin.

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Alicia Collins, REHS

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Name in AEC program book, name submitted in drawing for a free one-year NEHA membership, name in the Journal for one year, and endowment pin.

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ship, name in the Journal for one year, and endowment pin.

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Metairie, LA

George A. Morris, RS

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Vince Radke, MPH, REHS, CP-FS, DAAS, CPH

Atlanta, GA

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Indian Head Park, IL

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South Riding, VA

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(\$5,000–\$100,000)

Name in AEC program book, special invitation to the AEC President's Reception, name in the Journal for one year, and endowment pin.

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I pledge to be a NEHA Endowment Foundation Contributor in the following category:

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☐ **You have my permission to disclose the fact and amount (by category) of my contribution and pledge.**

☐ Sustaining Members Club (\$1,000)

☐ Endowment Trustee Society (\$25,000)

I plan to make annual contributions to attain the club level of _____ over the next _____ years.

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Allegheny County Health Department
www.county.allegheny.pa.us

American Academy of Sanitarians (AAS)
www.sanitarrians.org

American Chemistry Council
www.americanchemistry.com

Arlington County Public Health Division
www.arlingtonva.us

Ashland-Boyd County Health
www.abchdkentucky.com

Association of Environmental Health Academic Programs
www.aehap.org

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

Building Performance Center, a Department of The Opportunity Council
www.buildingperformancecenter.org

Cabell-Huntington Health Department
www.cabellhealth.org

Chesapeake Health Department
www.vdh.state.va.us/lhd/chesapeake

City of Houston Environmental Health
www.houstontx.gov/health/environmental-health

City of Milwaukee Health Department, Consumer Environmental Health
http://city.milwaukee.gov/Health

City of Phoenix, Neighborhood Services Department
www.phoenix.gov/nsd

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

Coconino County Public Health
www.coconino.az.gov

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

Custom Data Processing, Inc.
www.cdpehs.com

DEH Child Care
www.denvergov.org/DEH

Digital Health Department, Inc.
www.dhdinspections.com

Diversey, Inc.
www.diversey.com

Douglas County Health Department
www.douglascountyhealth.com

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www.dupagehealth.org

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

Ecolab
www.ecolab.com

EcoSure
charlesa.arnold@ecolab.com

Erie County Department of Health
www2.erie.gov/health

Florida Department of Health in Sarasota County
http://sarasota.floridahealth.gov

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Kent County Health Department
www.accesskent.com/Health/health_department.htm

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Multnomah County Environmental Health
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National Environmental Health Science and Protection Accreditation Council
www.ehacoffice.org

National Registry of Food Safety Professionals
www.nrfsp.com

National Restaurant Association
www.restaurant.org

National Swimming Pool Foundation
www.nspf.org

New Mexico Environment Department
www.nmenv.state.nm.us

New York City Department of Health & Mental Hygiene
www.nyc.gov/health

North Bay Parry Sound District Health Unit
www.myhealthunit.ca

NSF International
www.nsf.org

Omaha Healthy Kids Alliance
www.omahahealthykids.org

Oneida Indian Tribe of Wisconsin
www.oneidanation.org

Orkin
www.orkincommercial.com

Ozark River Hygienic Hand-Wash Station
www.ozarkriver.com

PinnacleHealth Lead and Healthy Homes Program
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Presby Environmental, Inc.
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Pride Community Services
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Prometric
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QuanTEM Food Safety Laboratories
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Racine City Department of Health
www.cityofracine.org/Health

Seattle & King County Public Health
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StateFoodSafety.com
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The Steritech Group, Inc.
www.steritech.com

Tri-County Health Department
www.tchd.org

Underwriters Laboratories, Inc.
www.ul.com

Waco-McLennan County Public Health District
www.waco-texas.com/cms-healthdepartment

Washington County Environmental Health (Oregon)
www.co.washington.or.us/HHS/EnvironmentalHealth

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Michigan State University, Online Master of Science in Food Safety
www.online.foodsafety.msu.edu

The University of Findlay
www.findlay.edu

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University of Vermont Continuing and Distance Education
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University of Wisconsin-Oshkosh, Lifelong Learning & Community Engagement
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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.



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carolyn.harvey@eku.edu

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ddyjack@neha.org

Regional Vice Presidents

Region 1—Ned Therien, MPH, Olympia, WA.
nedinoly@juno.com
Alaska, Idaho, Oregon, and Washington.
Term expires 2017.

Region 2—Keith Allen, MPA, REHS/RS, Program Supervisor, City of Long Beach Health Dept., Bureau of Environmental Health, Long Beach, CA.
keith.allen@longbeach.gov
Arizona, California, Hawaii, and Nevada.
Term expires 2018.

Region 3—Roy Kroeger, REHS, Environmental Health Supervisor, Cheyenne/Laramie County Health Department, Cheyenne, WY.
roykrogers@laramiecounty.com
Colorado, Montana, Utah, Wyoming, and members residing outside of the U.S. (except members of the U.S. armed forces).
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keith.johnson@custerhealth.com
Iowa, Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin.
Term expires 2016.

Region 5—Sandra Long, REHS, RS, Inspection Services Supervisor, City of Plano Health Department, Plano, TX.
sandra@plano.gov
Arkansas, Kansas, Louisiana, Missouri, New Mexico, Oklahoma, and Texas.
Term expires 2017.

Region 6—Lynne Madison, RS, Environmental Health Division Director, Western UP Health Department, Hancock, MI.
lmadison@hline.org
Illinois, Indiana, Kentucky, Michigan, and Ohio. Term expires 2016.

Region 7—Tim Hatch, MPA, REHS, Environmental Programs, Planning, and Logistics Director, Center for Emergency Preparedness, Alabama Department of Public Health, Montgomery, AL.
tim.hatch@adph.state.al.us
Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, and Tennessee. Term expires 2017.

Region 8—LCDR James Speckhart, MS, USPHS, Health and Safety Officer, FDA, CDRH-Health and Safety Office, Silver Spring, MD.
jamesmspeckhart@gmail.com
Delaware, Maryland, Pennsylvania, Virginia, Washington, DC, West Virginia, and members of the U.S. armed forces residing outside of the U.S. Term expires 2018.

Region 9—Edward L. Briggs, MPH, MS, REHS, Director of Health, Town of Ridgefield Department of Health, Ridgefield, CT.
eb.health@ridgefieldct.org
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. Term expires 2016.

Affiliate Presidents

Alabama—Haskey Bryant, MPH, MPA, Environmental Health Specialist, Jefferson County Dept. of Health, Birmingham, AL.
haskey.bryant@jcdh.org

Alaska—Christopher Fish, Anchorage, AK.
fish.christopher@gmail.com

Arizona—Michelle Chester, RS/REHS, Training Officer, Maricopa County

Environmental Services, Phoenix, AZ.
mchester@mail.maricopa.gov

Arkansas—Jeff Jackson, Camden, AR.
jeff.jackson@arkansas.gov

Business & Industry—Shelly Wallingford, MS, REHS, Retail Quality Assurance Manager, Starbucks, Denver, CO.
swalling@starbucks.com

California—Matthew Reighter, MPH, REHS, Environmental Health Specialist, County of Orange, Santa Ana, CA.
president@ceha.org

Colorado—Alexandra Hawley, Colorado Dept. of Public Health and Environment, Denver, CO.
alex.hawley@state.co.us

Connecticut—Stephen Civitelli, RS, Town of Wallingford, Wallingford, CT.
wlfdsan@yahoo.com

Florida—Garry Schneider, Orlando, FL.
gschneider@cfl.rr.com

Georgia—Maggie Rickenbaker, Agriculture Compliance Specialist, Georgia Dept. of Agriculture, Savannah, GA.
maggie.rickenbaker@agr.georgia.gov

Hawaii—John Nakashima, Sanitarian IV, Food Safety Education Program, Hawaii Dept. of Health, Hilo, HI.
john.nakashima@doh.hawaii.gov

Idaho—Patrick Guzzle, MA, MPH, REHS, Food Protection Program Manager, Idaho Dept. of Health and Welfare, Boise, ID.
guzzlep@dhw.idaho.gov

Illinois—Lenore Killam, Clinical Instructor, University of Illinois Springfield, Springfield, IL.
lkill2@is.edu

Indiana—Denise Wright, Training Officer, Indiana State Dept. of Health, Indianapolis, IN.
dhwright@isdh.in.gov

Iowa—James Hodina, MS, QEP, Manager, Environmental Public Health, Linn County Public Health, Cedar Rapids, IA.
james.hodina@linncounty.org

Jamaica—Steve Morris, Chief Public Health Inspector, Ministry of Health, St. Catherine, Jamaica.
president@japhi.org.jm

Kansas—Ann Mayo, MS, RS, Elmdale, KS.
Indiangrass1@gmail.com

Kentucky—D. Gary Brown, DrPH, CIH, RS, DAAS, Professor and Graduate Program Coordinator, Eastern Kentucky University, KY.
gary.brown@eku.edu

Louisiana—Bill Schramm, Louisiana Dept. of Environmental Quality, Baton Rouge, LA.
bill.schramm@la.gov

Maryland—James Lewis, Westminster, MD.
jlewis@mde.state.md.us

Massachusetts—Alan Perry, REHS/RS, Health Agent, City of Attleboro, Attleboro, MA.
healthagent@cityofattleboro.us

Michigan—Christine Daley, Environmental Health Supervisor, Chippewa County Health Dept., Sault Ste.

Marie, MI.
cdaley@meha.net

Minnesota—Sadie Pulk, MA, REHS, Process Analyst, Target Corporation, Minneapolis, MN.
sadie.pulk@target.com

Mississippi—Patrick Grace, MSEH, Public Health Environmentalist, Mississippi State Dept. of Health, Cleveland, MS.
patrick.grace@msdh.state.ms.us

Missouri—Chelsea Chambers, cmchambe@gocolumbiamo.com

Montana—Erik Leigh, RS, Public Health Sanitarian, State of Montana DPHHS, Helena, MT.
leigh@mt.gov

National Capitol Area—Shannon McKeon, Environmental Health Specialist, Fairfax, VA.
smckeon@ncaeha.com

Nebraska—Allen Brown, REHS, Environmental Health Inspector, Douglas County, Omaha, NE.
allen.brown@douglascounty-ne.gov

Nevada—Tamara Giannini, Environmental Health Supervisor, Southern Nevada Health District, Las Vegas, NV.
giannini@snhdmail.org

New Jersey—Robert Uhrlik, Senior REHS, South Brunswick Township Health Dept., Township of South Brunswick, NJ.
ruhrlik@sbtj.net

New Mexico—Esme Donato, Environmental Health Scientist, Bernalillo County, Albuquerque, NM.
edonato@berncogov

New York—Contact Region 9 Vice President Edward L. Briggs.
eb.health@ridgefieldct.org

North Carolina—Lillian Henderson, REHS, Davidson County Health Dept., Lexington, NC.
lillian.henderson@davidsoncountync.gov

North Dakota—Jane Kangas, Environmental Scientist II, North Dakota Dept. of Health, Fargo, ND.
jkangas@nd.gov

Northern New England Environmental Health Association—Co-president Brian Lockard, Health Officer, Town of Salem Health Dept., Salem, NH.
blockard@ci.salem.nh.us

Co-president Thomas Sloan, RS, Agricultural Specialist, New Hampshire Dept. of Agriculture, Concord, NH.
tsloan@agr.state.nh.us

Ohio—Jerry Bingham, RS, Supervisor, Toledo-Lucas County Health Dept., Toledo, OH.
binghamj@co.lucas.oh.us

Oklahoma—James Splawn, RPS, RPES, Sanitarian, Tulsa City-County Health Dept., Tulsa, OK.
tsplawn@tulsa-health.org

Oregon—William Emminger, Corvallis, OR.
bill.emminger@co.benton.or.us

Past Presidents—Alicia Collins, REHS, Lilburn, GA.
enriqueza@comcast.net

Pennsylvania—TBD

Rhode Island—Dottie LeBeau, CP-FS, Food Safety Consultant and Educator, Dottie LeBeau Group, Hope, RI. deejaylebeau@verizon.net

Saudi Arabia—Zubair M. Azizkhan, Environmental Health Manager, SCDHEC-BEHS Enforcement Section, Columbia, SC. kinneyte@dhec.sc.gov

South Carolina—Timothy Kinney, Environmental Health Manager, SCDHEC-BEHS Enforcement Section, Columbia, SC. kinneyte@dhec.sc.gov

South Dakota—John Osburn, Pierre, SD. john.osburn@state.sd.us

Tennessee—Larry Manis, Loudon County Health Dept., Loudon, TN. larry.manis@tn.gov

Texas—Joanna Meyer, RS, Regional QA Manager, MBM, Ft. Worth, TX. jmeyer@mbmfoodservice.com

Uniformed Services—MAJ Joseph Hout, MSPH, PhD, REHS, CPH, Industrial Hygiene Chief, Academy of the Health Sciences, Ft. Sam Houston, TX. joseph.j.hout.mil@mail.mil

Utah—Michelle Cooke, LEHS, Program Manager, Weber-Morgan Health Dept., Ogden, UT. mcooke@co.weber.ut.us

Virginia—Mark Cranford, REHS, CP-FS, Environmental Health Specialist, Virginia Dept. of Health, Charlottesville, VA. mark.cranford@vdh.virginia.gov

Washington—Michael Baker, MS, PhD, Dept. of Environmental Health Director, Whitman County Public Health, Pullman, WA. michael.baker@whitmancounty.net

West Virginia—Ronald Dellinger, REHS/RS, WVDHHR/BPH/OEHS/PHS, Beckley, WV. jarod.r.dellinger@wv.gov

Wisconsin—Laura Temke, REHS, CP-FS, HHS, Environmentalist, City of West Allis Health Dept., West Allis, WI. ltemke@westalliswi.gov

Wyoming—Tiffany Gaertner, REHS, CP-FS, EHS II, Cheyenne-Laramie County Health Dept., Cheyenne, WY. tgaertner@laramiecounty.com

NEHA Historian

Dick Pantages, NEHA Past President, Fremont, CA. dickpantages@comcast.net

Technical Advisors

Air Quality—David Gilkey, PhD, Associate Professor, Colorado State University, Ft. Collins, CO. dgilkey@colostate.edu

Aquatic Health/Recreational Health—Tracynda Davis, MPH, President, Davis Strategic Consulting, LLC, Colorado Springs, CO. tracynda@gmail.com

Aquatic Health/Recreational Health—CDR Jasen Kunz, MPH, REHS, USPHS, CDC/NCEH, Sugar Hill, GA. izk00@cdc.gov

Children's Environmental Health—Anna Jeng, MS, ScD, Associate Professor and Graduate Program Director, Old Dominion University, Norfolk, VA. hjeng@odu.edu

Climate Change—Leon Vinci, DHA, RS, Founder & CEO, Health Promotion Consultants, Roanoke, VA. lfv6@aol.com

Drinking Water/Environmental Water Quality—Sharon Smith, REHS/RS, Sanitarian Supervisor, Minnesota Dept. of Health, Underwood, MN. sharon.l.smith@state.mn.us

Emergency Preparedness and Response—Marcy Barnett, MA, MS, REHS, Emergency Preparedness Liaison, California Dept. of Public Health, Center for Environmental Health, Sacramento, CA. marcy.barnett@cdph.ca.gov

Emergency Preparedness and Response—Martin Kalis, Public Health Advisor, CDC, Atlanta, GA. mkalis@cdc.gov

Food (including Safety and Defense)—Eric Bradley, MPH, REHS, CP-FS, DAAS, Environmental Health Coordinator, Scott County Health Dept., Davenport, IA. eric.bradley@scottcountyiaowa.com

Food (including Safety and Defense)—John Marcello, CP-FS, REHS, Regional Retail Food Specialist, FDA, Tempe, AZ. john.marcello@fda.hhs.gov

General Environmental Health—Tara Gurge, Environmental Health Agent, Needham Health Dept., Needham, MA. tgurge@needhamma.gov

General Environmental Health—ML Tanner, HHS, Former Program Manager, Swansea, SC. mlacesmom@gmail.com

Hazardous Materials/Toxic Substances—Sarah Keyes, MS, Health, Safety, and Environmental Manager, Peter Cremer North America, LP, Cold Spring, KY. skeyes@petercremer.com

Hazardous Materials/Toxic Substances—Crispin Pierce, PhD, Assistant Professor, University of Wisconsin-Eau Claire, Eau Claire, WI. piercech@uwec.edu

Hazardous Materials/Toxic Substances—Stew Whitney, Waste Program Supervisor, Ottawa County Health Dept., Holland, MI. swhitney@miottawa.org

Healthy Communities/Built Environment—Sandra Whitehead, MPA, PhD, Director of Healthy Community Design, NACCHO, Washington, DC. whitehead.sandra.1@gmail.com

Healthy Homes and Housing—Judeth Luong, Program Manager, City of Long Beach Health Dept., Fountain Valley, CA. Judeth.Luong@longbeach.gov

Healthy Homes and Housing—Ruth Ann Norton, President & CEO, Green & Healthy Homes Initiative, Baltimore, MD. ranorton@ghhi.org

Informatics and Technology—Darryl Booth, MPA, President/General Manager Environmental Health, Accela, Fresno, CA. dbooth@accela.com

Injury Prevention—Alan Dellapenna, RS, Branch Head, Injury and Violence Prevention Branch, North Carolina Division of Public Health, Raleigh, NC. alan.dellapenna@dhhs.nc.gov

Institutions—Robert W. Powitz, MPH, PhD, RS, CP-FS, DLAAAS, Principal Consultant, R.W. Powitz & Associates, PC, Old Saybrook, CT. powitz@sanitarian.com

International Environmental Health—Sylvanus Thompson, PhD, CPHI(C), Associate Director, Toronto Public Health, Toronto, ON, Canada. sthomp@toronto.ca

Land Use Planning and Design—Robert Washam, MPH, RS, Jensen Beach, FL. b_washam@hotmail.com

Occupational Health/Safety—Tracy Zontek, PhD, Assistant Professor, Environmental Health Program, Western Carolina University, Cullowhee, NC. zontek@email.wcu.edu

Onsite Wastewater—Joelle Wirth, RS, Program Manager II, Environmental Quality Division, Coconino County Health Dept., Flagstaff, AZ. jwirth@coconino.az.gov

Onsite Wastewater—Denise Wright, Training Officer, Indiana State Dept. of Health, Indianapolis, IN. dhwright@isdh.in.gov

Radiation/Radon—Bob Uhrlik, Senior REHS, South Brunswick Township, Monmouth Junction, NJ. ruhrlik@sbtjnj.net

Risk Assessment—Jason Marion, PhD, Assistant Professor, Eastern Kentucky University, Richmond, KY. jason.marion@eku.edu

Risk Assessment—Kari Sasportas, MPH, REHS/RS, Environmental Health Specialist, Cambridge Public Health Dept., Cambridge, MA. ksasportas@challiance.org

Schools—Stephan Ruckman, Environmental Health Manager, Worthington City Schools, Dublin, OH. mpohsu@yahoo.com

Sustainability—Tim Murphy, PhD, RESH/RS, DAAS, Associate Professor and Dept. Chair, The University of Findlay, Findlay, OH. murphy@findlay.edu

Vector Control/Zoonotic Disease Control—Zia Siddiqi, PhD, BCE, Director of Quality Systems, Orkin/Rollins Pest Control, Atlanta, GA. zsiddiqi@rollins.com

Workforce Development, Management, and Leadership—CAPT Michael Her-ring, MPH, REHS, USPHS (ret.), Surf City, NC. captmike@hotmail.com

Workforce Development, Management, and Leadership—George Nakamura, MPA, REHS, RS, CP-FS, DAAS, CEO, Nakamura Leasing, Sunny Vale, CA. gmlnaka@comcast.net

NEHA Staff: (303) 756-9090

Rance Baker, Program Administrator, NEHA Entrepreneurial Zone (EZ), ext. 306. rbaker@neha.org

Trisha Bramwell, Sales and Training Support, NEHA EZ, ext. 340. tbramwell@neha.org

Ellen Cornelius, Project Specialist, Research and Development (R&D), ext. 307. ecornelius@neha.org

Ginny Coyle, Project Coordinator, R&D, ext. 346. gcoyle@neha.org

Vanessa DeArman, Project Coordinator, R&D, ext. 311. vdearman@neha.org

Cindy Dimmitt, Member Services/Accounts Receivable, AEC Registration Coordinator, ext. 309. cdimmitt@neha.org

Elizabeth Donoghue-Armstrong, Copy Editor, *Journal of Environmental Health*, nehasmtp@gmail.com

David Dyjack, Executive Director, ext. 301. ddjack@neha.org

Eric File, Learning Content Producer, NEHA EZ, ext. 344. efife@neha.org

Soni Fink, Strategic Sales Coordinator, ext. 314. sfink@neha.org

Michael Gallagher, Operations and Logistics Planner, NEHA EZ, ext. 343. mgallagher@neha.org

Laura Gallaher, Education Coordinator, ext. 313. lgallaher@neha.org

TJay Gerber, Credentialing Coordinator, ext. 328. tgerber@neha.org

Arwa Hurley, Website and Digital Media Specialist, ext. 327. ahurley@neha.org

Dawn Jordan, Member Services, Human Resources, and Office Manager, ext. 312. djordan@neha.org

Erik Kosnar, Learning Content Production Assistant, NEHA EZ, ext. 318. ekosnar@neha.org

Elizabeth Landeen, Assistant Manager, R&D, (702) 802-3924. elandeen@neha.org

Matt Lieber, Marketing and Communications Assistant, ext. 338. mlieber@neha.org

Bobby Medina, Credentialing Dept. Customer Service Coordinator, ext. 310. bmedina@neha.org

Marissa Mills, Project Specialist, R&D, ext. 304. mmills@neha.org

Eileen Neison, Credentialing Specialist, ext. 339. eneison@neha.org

Carol Newlin, Credentialing Specialist, ext. 337. cnewlin@neha.org

Solly Poprish, CDC Public Health Associate Program Intern, ext. 335. spoprish@neha.org

Barry Porter, Financial Coordinator, ext. 308. bporter@neha.org

Kristen Ruby-Cisneros, Managing Editor, *Journal of Environmental Health*, ext. 341. kruby@neha.org

Rachel Sausser, Member Services/Accounts Receivable, ext. 300. rsausser@neha.org

Clare Sinacori, Marketing and Communications Manager, ext. 319. csinacori@neha.org

Christl Tate, Project Coordinator, R&D, ext. 305. ctate@neha.org

Sharon Unkart, Instructional Designer, NEHA EZ, ext. 317. sdunkart@neha.org



2016

ACCEPTING NOMINATIONS NOW

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 the 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.

Nominations are due in the NEHA office by **March 15, 2016.**



Visit www.neha.org/walter-s-mangold-award for application criteria.

NEHA SABBATICAL EXCHANGE PROGRAM
TO ENGLAND OR CANADA

NEHA offers wide-ranging opportunities for professional growth and the exchange of valuable information on the international level through its longtime Sabbatical Exchange Program.

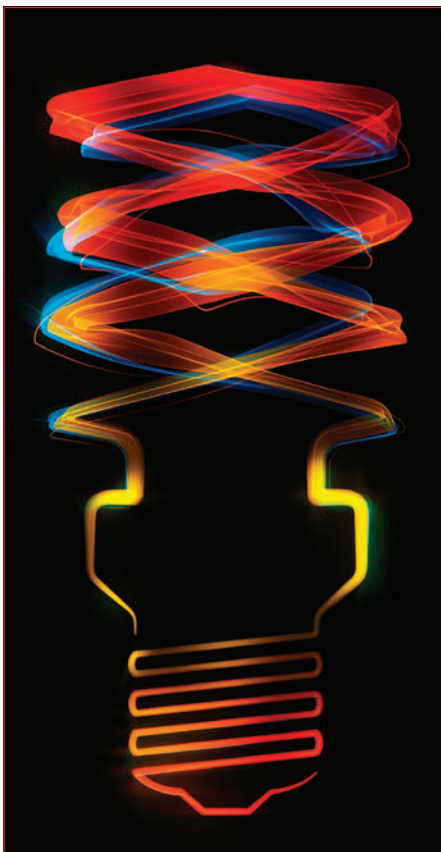
The sabbatical may be taken in England, in cooperation with the Chartered Institute of Environmental Health, or in Canada, in cooperation with the Canadian Institute of Public Health Inspectors. The sabbatical can be from two to four weeks, as determined by the recipient. If selected, the sabbatical ambassador receives up to **\$4,000** as a stipend, depending on the length of the sabbatical, and up to \$1,000 for roundtrip transportation.

The application deadline is March 1, 2016.

Winners will be announced at the NEHA 2016 Annual Educational Conference (AEC) & Exhibition in San Antonio, Texas, in June 2016. Recipients will complete the sabbatical between August 1, 2016, and June 1, 2017. The sabbatical ambassador will give a required report of their experience at the 2017 AEC in Grand Rapids, Michigan.

To access the online application, visit www.neha.org/sabbatical-exchange-program.





2016 NEHA Innovation Award

This award recognizes a NEHA member or organization for creating a new idea, practice, or product that has had a positive impact on environmental health and the quality of life. Innovative change that promotes or improves environmental health protection is the foundation of this award.

This annual award recognizes those who have made an innovative contribution to the field, as well as encourages others to search for creative solutions. Take this opportunity to submit a nomination to highlight the innovations being put into practice in the field of environmental health!

Nominations are due in the NEHA office by March 15, 2016.

For more information, please visit
www.neha.org/environmental-health-innovation-award.



2016 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 works of your colleagues!

**Nominations are due in the NEHA office by
March 15, 2016.**

For more information, please visit
www.neha.org/joe-beck-educational-contribution-award.



President's Message

continued from page 7

What Can NEHA Affiliates and Individual Members Do to Support NEHA's International Work?

There is an increasing number of international opportunities for NEHA members and affiliates. Here are a few:

- Volunteer to be a NEHA Ambassador. NEHA is looking for ambassadors to the Middle East, Asia, Mexico and Central America, and South America. For more information e-mail me at NEHA.Prez@comcast.net.
- If you have gently used environmental health books, equipment, or laptops that are not too outdated, you can donate these to GEHP. You can contact them at GEHP@comcast.net.

- Apply for an international sabbatical exchange in the United Kingdom or Canada. Details on how to apply can be found at www.neha.org/sabbatical-exchange-program.
- Volunteer for a short-term mission with one of the many humanitarian organizations doing work in the developing world. Several places to search for opportunities can be found at
 - » www.idealists.org/info/Volunteer/Resources/Travel,
 - » www.goodnet.org/articles/397,
 - » www.habitat.org/getinv/volunteer_programs.aspx,
 - » www.water.cc, or
 - » www.missionfinder.org.
 A volunteer experience in the developing world will give you new insights on environmental health.

- Beginning in 2016, NEHA will encourage its affiliates to pair themselves with an environmental health association in the developing world. NEHA believes that even small investments in information sharing, training, mentoring, or donation of used books or equipment can have a major impact in these developing countries. We also believe that these relationships will enrich the practice of environmental health practitioners here in the U.S.

Environmental health has no borders. NEHA recognizes that and is increasingly connecting environmental health practitioners in the U.S. with their peers across the globe. As Walt Disney said, "It's a small world after all." 🐘

Bob Custard

NEHA.Prez@comcast.net

DirecTalk

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promises to bring dividends to our member-centered organization. None of us is as smart as all of us, and we are creating the internal conditions where the best ideas float, independent of who offered up the gem. Our aim over time is for you to trust our capabilities, and more importantly, to trust our organizational character. If we can achieve that, then nothing else matters. If we can't, then nothing else matters. I mean it.

Relationships and trust are built on four basic factors: the proximity of the key players, the frequency of their interaction, the duration of their time together, and finally,

the intensity of the processes. As we travel our professional journey together I will keep these factors in mind as we recognize that our success as an organization is primarily predicated on your success as individual practitioners, as we strengthen the systems that ensure a safe and healthy environment.

I am struck that we have many battles ahead of us. Dr. Katherine Kirkland, executive director of the Association of Occupational and Environmental Clinics, spoke to our staff a couple of months ago in Denver. She reflected on the impending budget battle on Capitol Hill, with increasingly common terms "sequester," "continuing resolution," and other evidence of political gridlock in full

evidence. Sadly, it is becoming increasingly evident that these battles will be with us for the duration of our working lifetimes. We will need to consider the four trust factors I mentioned earlier to cultivate relationships with the influencers on Capitol Hill. This will not be an inexpensive or easy proposition in our journey to success. It is nonetheless necessary.

Speaking of journey, the conductor just announced our impending arrival into Coimbra. With that, I bid you a blessed holiday season. Carpe diem. 🐘

Dave

ddyjack@neha.org
Twitter: @DTDyjack

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Join Us in

San Antonio

NEHA 2016 AEC & HUD Healthy Homes Conference

June 13-16, 2016*

The National Environmental Health Association (NEHA) and the U.S. Department of Housing and Urban Development (HUD), Office of Lead Hazard Control and Healthy Homes are excited to partner in 2016 for our annual conference!

Registration

Online Registration Is Now Available

neha.org/aec/register

Reservations

Hotel Reservations Are Now Available

neha.org/aec/hotel

Exhibitors

Exhibitors

Be sure to reserve your space in our Exhibition! Booth space is limited so don't miss being part of this year's conference.

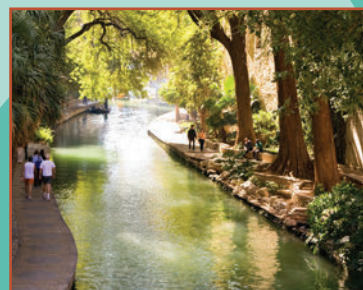
Exhibit Booth Purchase

neha.org/aec/exhibition

* Note the **NEW date this year** as we are holding the event in June instead of July.



Charreada-Mexican-Rodeo-Charras,
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NEHA 2016 AEC and
HUD Healthy Homes Conference

SAN ANTONIO, TX ★ JUNE 13-16, 2016



NEHA 2016 AEC and HUD Healthy Homes Conference

► **DirectTalk** MUSINGS FROM THE 10TH FLOOR

David Dyjack, DrPH, CIH

Tabula Rasa, Solarium Argentums, and Carpe Diem, Baby

I'm on the intercity train from Lisbon, my favorite city in the planet, headed to Coimbra, the site of the International Federation of Environmental Health (IFEH) conference. No, this is not the fastest train, and there are frequent stops along the way, with many beautiful little towns such as Vila Franca de Xira, where I happen to be at the moment. Trips like this provide an opportunity to reflect and put things in perspective, a privilege too good to pass up for purposes of this column.

At the time of this writing, I've been on the job at NEHA for almost five months, and have listened and learned. On most days I feel like I have returned to the University of Utah Rocky Mountain Center for Occupational and Environmental Health, trying to keep up with the second year graduate students. Which leads me to tabula rasa, Latin for "clean slate," the fresh approach I employed when I entered grad school. Likewise, we are taking a clean and new approach to everything your association is doing. Let me explain, starting with our Annual Educational Conference (AEC) & Exhibition.

For the 2016 AEC we are partnering with the U.S. Department of Housing and Urban Development (HUD) in San Antonio. This translates to approximately 400 additional attendees, perhaps more, and many learning and networking opportunities with our colleagues who are vested in the built environment. The conference will begin late on a Monday afternoon, which will allow you to spend the weekend with your families before departing for the conference. In the same

*We are taking a
clean and new
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association is doing.*

spirit, we will end the conference on Thursday around 1:00, which should get you home the same evening.

The conference itself will be laser focused on education and networking, with much less emphasis on association pomp and circumstance. The opening session will be anchored by a keynote and panel session with an "A-list" of participants. Individual sessions will largely forgo the historic "talking heads" as we introduce more interactive high-energy workshops. Some examples are debates, ignite sessions, and sessions developed by millennials. Also expect less stuff to lug around as we explore going largely paperless through deployment of our conference application (i.e., mobile app).

We also recognize that you travel to conferences to build and enhance your professional network. There will be ample and extended coffee breaks built into the program to achieve your aim. We plan to sunset the traditional banquet on the last day and introduce a social

event the night before the conference ends so everyone can participate. There are abundant eateries at every possible price point within walking distance of the conference events. You can be assured we will take this approach for AECs from this point forward.

We will also be more student friendly at the AEC. We have extended the student abstract submission process until May 2016 to accommodate student paper and poster submissions. Also effective in 2016, there will be a stand-alone AEC student poster session. We are also doing away with the caste system where students have limited access to events—the student registration rate will treat them as full professionals to include all activities. This is not your grandparents' NEHA.

Our changes are not limited to the AEC. We have embarked on the planning process to bring our credentialing into the paperless era. That's right, digitizing everything so there are no more copies to send through snail mail. The same is true for our internal accounting processes; we are reviewing how we can do our work sustainably without compromising on quality or accountability. We desire to walk the environmental health and sustainability talk.

Solarium argentums refers to the Roman practice of paying its soldiers in bars of salt, because it was prized and essential to health. In the same manner, I consider it a strategic imperative to uncover and liberate latent talent among our three dozen employees. We are rapidly moving into an era where an engaged, enabled, and empowered workforce

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When you're ready to apply principles of environmental health

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