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# Environmental Health

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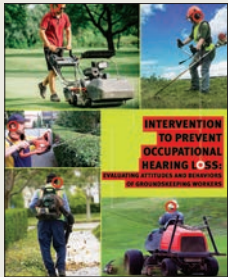
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**ABOUT THE COVER**



This month we feature an article that focuses on occupational safety and health. The article, “Effectiveness of a Multifaceted

Occupational Noise and Hearing Loss Intervention Among Landscaping and Groundskeeping Workers,” evaluates attitudes and behavior of wearing hearing protection devices among groundskeeping workers and tests the effectiveness of educational training on worker knowledge. While workers recognize the importance of wearing hearing protection devices, actual use is inconsistent. The findings of this article make the case for regular trainings provided by employers, as well as the promotion of hearing protection device usage.

See page 8.

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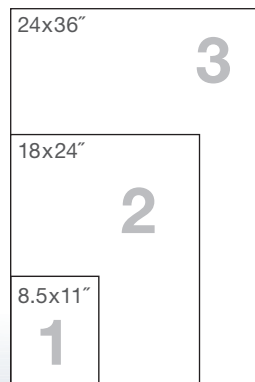


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## ▶ PRESIDENT'S MESSAGE



Adam London,  
MPA, RS, DAAS

## The Science of a Strange Profession

As you have probably noticed, environmental health is an unusual profession. I have often told my team that working in this field is a little bit like being on the *X-Files*. Environmental health agencies across the world seem to attract the most mind bending and inexplicable situations. To make matters more challenging, environmental health professionals are often faced with problems that other agencies and professions do not know how to handle. These problems frequently present real and significant threats to the health and safety of our communities. And while they are not supernatural, the monsters that we face—usually in the form of adverse exposure to biological or chemical agents—are no less destructive than the creatures of science fiction.

I can immediately think of three such instances during the past year when the environmental health team at my agency was called upon to address problems far outside of the programmatic responsibilities of their regularly assigned duties. In the first instance, we were notified that an old groundwater contamination site related to a long-abandoned dry cleaning operation was possibly creating vapors that could harm the occupants of nearby homes and business. The subsequent investigation revealed a disturbingly high concentration of perchloroethylene vapors in nearby structures. Our environmental health professionals were part of a cross-disciplinary team that assessed risk, developed a plan forward, and evaluated results. We now understand that this type of vapor intrusion is another pathway through which historic industrial pollution is going

*Our profession  
is firmly rooted  
in science and in  
our ability to apply  
that science for  
society's benefit.*

to affect human health. This issue is going to be with us for a long time and will necessitate the ongoing professional development of environmental health professionals.

In the second instance, we learned that a pet store specializing in exotic birds was experiencing an avian outbreak of psittacosis. This zoonotic disease is caused by a bacterium that can infect humans, causing pneumonia and other sequelae. Once again, this issue was completely foreign to our team. Our environmental health professionals were nevertheless able to quickly apply concepts of infection control and sanitation protocols to the situation to prevent further transmission among the birds and to humans.

Finally, like so many of you, we were looked upon to provide accurate and actionable information about Zika virus to people in our community. The scientific expertise that our profession has developed regarding mosquito-borne diseases has been priceless.

In each of these examples, the ability to apply the basic principles of environmental health, in combination with the ability to operationalize new scientific information into public health action, has been truly remarkable. This characteristic of our profession sets us apart as a unique and irreplaceable part of our national security.

Environmental health is a knowledge based profession. Ultimately, the most important product of our work is communities with a diminished burden of illness and injury. The primary tools of our craft are our minds, social skills, and a network of resources. It is important, as with any other craft, to sharpen and care for the tools that we rely upon. The fact that you are reading the *Journal of Environmental Health* suggests that you embrace the importance of continuing education. Thank you for your dedication to become a better version of yourself. I believe that it is critically important to our profession, and more importantly to public health, that we elevate our collective performance. Membership with the National Environmental Health Association (NEHA) is a powerful way to access the sort of information, networking, and skill building resources necessary to strengthen our tools. This month I challenge you to find a colleague who is not a member and share with them the many ways that you benefit from participation in NEHA.

I recently had the pleasure of working with a regional public health training collaborative out of the University of Illinois at Chicago to better understand the training needs of our profession. This project employed an active learning approach with approximately 50

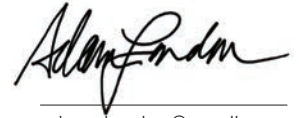
of our colleagues from leadership positions in local health departments in the Midwest. The study concluded that while some of the issues varied from state to state, there was a consensus about many things, including the need for better leadership training curricula, improved systems of data sharing, and timely toolkits for new and emerging issues.

Another study organized by the Centers for Disease Control and Prevention, in partnership with Baylor University and NEHA, seeks to identify further training needs. This study is called UNCOVER EH (Understand-

ing the Needs, Challenges, Opportunities, Vision, and Emerging Roles in Environmental Health, [www.neha.org/uncover-eh](http://www.neha.org/uncover-eh)). I urge you to participate in the surveying they will be conducting.

Studies such as these help organizations like ours better understand what kinds of trainings and resources you need to be ready for both the usual and unusual problems that our profession is expected to solve. I began this column comparing the ways in which environmental health sometimes feels like science fiction. The reality, however, is that our profession is firmly rooted

in science and in our ability to apply that science for society's benefit. On behalf of NEHA's staff and board of directors, I assure you that this association is committed to bringing you quality content in this *Journal* and in all our training products. Without further ado, please enjoy this issue! Hopefully it helps prepare you for some future mystery. 🐞



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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.

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## Effectiveness of a Multifaceted Occupational Noise and Hearing Loss Intervention Among Landscaping and Groundskeeping Workers

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**Abstract** Landscaping and groundskeeping workers are exposed to excessive amounts of loud noise from powered lawn equipment and tools that can lead to adverse health effects, including noise-induced hearing loss. The main objectives of this project were to evaluate attitudes and behavior of wearing hearing protection devices (HPDs) and to test the effectiveness of knowledge following an educational training among these workers. This was a cross-sectional intervention study. Bivariate analysis was conducted to evaluate worker perceptions about the importance and frequency of wearing HPDs. Pre- and post-tests were distributed to workers to evaluate significant differences in learned knowledge following a multifaceted noise and hearing loss training. Although nearly all workers recognized the importance of wearing either earplugs or earmuffs, actual use for wearing HPDs was approximately only half of the time when working around loud noise. Following the training intervention, there was a significant increase between mean pre- and post-test scores. Targeted trainings can be effective for increasing worker knowledge about the effects of noise, hearing loss, and hearing protection. Sustained efforts, however, must be made by employers to ensure that regular trainings are routinely provided and that the use of HPDs are promoted in the workplace.

### Introduction

In 2014, the U.S. Department of Labor reported nearly 1 million full-time groundskeeping workers in the U.S. (North American Classification System, NAICS-37-3011). This number is likely an underestimate, however, because it does not include part-time workers who perform landscaping duties for payment in addition to their regular job. In the past decade, the number of Hispanic workers in groundskeeping has dramatically increased, with the highest number of full-time workers in this occupa-

tion located in California, Florida, and Texas (U.S. Department of Labor, 2014).

Groundskeeping workers are exposed to excessive amounts of occupational noise as a result of working with powered lawn maintenance equipment such as riding and push lawn mowers, chain saws, hedge and edge trimmers, and other related tools (Centers for Disease Control and Prevention [CDC], 2006, 2011; Hammig, Childers, & Jones, 2009). In general, the health literature links noise exposures expected to occur among landscapers and groundskeepers with that

of similar occupations, including agriculture (McBride, Firth, & Herbison, 2003; Williams et al., 2015) and construction (Neitzel, Seixas, Camp, & Yost, 1999; Seixas, Ren, Neitzel, Camp, & Yost, 2001). The equipment and tools used differ significantly between these industries, while also presenting unique noise exposure opportunities. A recent paper recognized the service industry (which includes landscaping and grounds maintenance), as one of the highest-ranking sectors for worker exposure to occupational noise (Masterson, Deddens, Themann, Bertke, & Calvert, 2015).

Federal law (29 CFR 1910.132, Subpart-I) requires employers to protect worker hearing whenever noise exposures are at or above an 8-hour time-weighted average (TWA) of 85 A-weighted decibels (dBA) or, equivalently, a dose of 50%, referred to as the action level (U.S. Department of Labor, n.d.). When the action threshold level is exceeded, Occupational Safety and Health Administration (OSHA) regulations mandate employers to administer a continuing, effective hearing conservation program that includes minimum requirements to protect worker hearing. These requirements include 1) a monitoring program to evaluate noise levels and worker exposure to noise; 2) an audiometric testing program of employees exposed at or above the OSHA action level of 85 dBA; 3) providing hearing protection devices (HPDs) at no cost to employees exposed at or above the OSHA action level of 85 dBA; 4) employee training and education to workers on the effects of noise, HPDs, and purpose of audiometric testing; and 5) recordkeeping of noise exposure measurements and audiometric testing of employees.



Failure to meet these regulatory components may result in enforcement and/or fines, but more importantly contribute to work-related health effects, including noise-induced hearing loss (NIHL). Sound levels above 90 dB can be harmful enough to cause hearing loss, particularly if the exposure lasts for an extended time period (National Institute on Deafness and Other Communication Disorders, 2017). Until recently, noise exposure levels among landscapers and groundskeeping workers were not well characterized. In the parent study of this project, Balanay and coauthors (2015) demonstrated that noise exposure among a sample of groundskeepers far exceeded the action level set by the OSHA standard.

A current evaluation is needed to fill the gap in the literature to evaluate how groundskeepers perceive their risk to noise and their associated behavior for protecting their hearing when working around loud equipment. The primary objectives of this project are to 1) evaluate perceptions and personal behavior of wearing HPDs and 2) test the effectiveness (either increase or decrease) of worker knowledge following a multifaceted educational training on noise, hearing protection, and health impacts of hearing loss. The results of this project offer insight for environmental health and safety professionals by providing a better understanding of worker competency levels and suggestions for improving hearing conservation programs to reduce noise exposure in the occupational environment.

## Methods

### Participants

This study was a cross-sectional intervention among workers ( $N = 97$ ) performing landscaping and groundskeeping duties at three public universities in North Carolina. Environmental health and safety officers and grounds supervisors at universities in North Carolina were randomly contacted either by telephone or by e-mail and asked to participate in the study. Prior to actual data collection, meetings were held between the investigators and safety officers and supervisors to discuss the goals and logistics of the project. Supervisors from each university assisted with identifying employees with duties exclusive to landscaping and grounds

maintenance work. Criteria for eligible participants included being 18 years or older and actively working full time (40 hr per week) performing landscaping and/or ground maintenance-type duties.

### Data Collection

Data were collected May 2014–June 2015. The East Carolina University Institutional Review Board reviewed and approved the study protocol prior to any data collection. All participants were given specific instructions on how to complete the survey and pre-tests, and were under no obligation to participate. Workers who agreed to participate in the study gave signed informed consent.

Each university was visited on several occasions throughout the study period. During each initial visit, a demographic, work, and noise exposure history questionnaire was distributed and completed by participants in group settings. To increase worker comprehension of the survey, trained investigators read each question out loud to participants. Following the survey, each participant was given an 18-question pre-test to complete. Several landscapers reviewed the pre-test and pilot tested it prior to distribution. Approximately 4–6 weeks after the initial visit, the investigators returned to each university and provided a comprehensive, multifaceted noise and hearing loss training for workers. The training intervention consisted of three parts: a lecture-style presentation on noise and hearing loss; an instructional video (Comprehensive Loss Management, Inc., 2009); and a hands-on demonstration of proper insertion of earplugs and discussion on HPDs. Informational material endorsed by the National Institute for Occupational Safety and Health (NIOSH) on NIHL was distributed to workers at the close of each session. The trainings were conducted in English and Spanish.

Instructors for the training included a certified industrial hygienist (CIH), a registered environmental health professional (REHS/RS), and graduate level public health and environmental health students. The training video was approximately 15 min in length with content covering the fundamental principles and concepts of noise exposure, the effects of hearing loss, and the importance of wearing HPDs. Following the training, workers completed a post-test containing the same 18 questions as the initial pre-test.

The survey questionnaire, pre-, and post-tests were translated into Spanish by Spanish-speaking individuals familiar with the dialect used predominantly in North Carolina. Group interviews, which took approximately 15–20 min to complete, were conducted in English and in Spanish, depending on the respondent's preference. Non-English, Spanish-speaking individuals were provided with surveys in a separate private room with a trained, bilingual interviewer. All interviewers were certified on human subject protection and ethics. Each participant was given a \$10 store gift card for participating.

### Measures

The survey instrument, pre-, and post-tests were taken from previous pre-tested questionnaires developed by others, modified by the investigators, and pilot tested by workers prior to distribution. The questionnaire included descriptive items eliciting information on personal and work characteristics including age, gender, ethnicity, marital status, hobbies, work-related injuries, job, and medical history. Work-related questions included number of years working at current job as groundskeeper/landscaper (1–5 years; >5 years) and time working in landscaping and groundskeeping prior to working in current job (<1 year; >1 year). Participants were asked if they currently worked part-time in addition to their normal university job (performing groundskeeping or landscaping duties for compensation). Additional questions included yes/no responses regarding whether they had experienced work-related injuries in the past 12 months, had a history of hearing loss in the family, had trouble hearing in a group setting, or ever had a hearing test. Remaining questions included yes/no responses to using the following types of powered equipment at work within the past week: riding mower, push mower, weed eater, leaf blower, chain saw, and other power tools. Categorical responses to the importance of wearing HPDs were collapsed and reported on Likert-type scales as important or extremely important (1), neither important nor unimportant (2), and not important or very unimportant (3). The frequency of wearing HPDs was reported as never/rarely (1), half the time (2), and always/most of the time (3).

Participants were also given seven questions that asked about their perception of hearing loss and hearing protection. Responses were coded on a Likert-type scale as agree (1), neither agree or disagree (2), and disagree (3) to questions on hearing loss being a part of growing old, unavoidable, reversible, and treatable. Other perception questions asked were related to hearing protection and included wearing hearing protection prevents someone from getting attention, being uncomfortable, and interfering with work. The content for the 18 questions in the pre- and post-tests included areas related to noise, hearing protection, and factors that contribute to NIHL. The response to each question was coded as true or false.

**Data Analysis**

Frequency counts and percentages were computed for each of the above measures. Mean and standard deviations were calculated for age. Cronbach's alpha ( $\alpha$ ) for the 18-item NIHL test scale and the 7-item noise perception evaluation were 0.71 and 0.77, respectively. Dichotomous responses (true/false) of pre- and post-tests were recoded as correct (1) or incorrect (0). Chi-square test was used to assess associations between age (grouped as 0 = 18–39 and 1 = 40 and older), race, and grouping variables, including importance and behavior of wearing HPDs. A paired samples *t*-test was used to assess differences between total pre-test and post-test scores. A McNemar's test was used to evaluate statistically significant differences between individual pre- and post-test questions. Statistical associations were considered significant at the  $p < .05$  level. All analyses were conducted using SPSS version 20.

**Results**

The study included 97 participants, with 99% being male and 1% being female. Personal, work characteristics, job, and medical history are reported in Table 1. Overall, the majority of workers were 40–59 years (55.7%), male (99%), white (56.7%), and married (64.9%), with a high school diploma or higher (76.1%). For job history and activities, the majority of participants had worked in groundskeeping/landscaping prior to their current job (69.1%), and worked more than 5 years in their current landscaping job (58.8%). Over 30% of respondents worked part-time outside of their normal university job performing landscaping or

TABLE 1

**Personal and Work Characteristics and Medical History Among Groundskeeping Workers in North Carolina, 2015**

Personal Characteristic	# (%)
<b>Age (year)</b>	
Mean (SD)	44 (12.7)
18–25	7 (7.2)
26–39	26 (26.8)
40–59	54 (55.7)
≥60	10 (10.3)
<b>Gender</b>	
Male	96 (99.0)
Female	1 (1.0)
<b>Ethnicity</b>	
White (not Hispanic)	55 (56.7)
Black (not Hispanic)	22 (22.7)
Hispanic or Latino	15 (16.1)
Other	1 (1.1)
High school diploma or GED	75 (80.6)
<b>Marital status</b>	
Married	63 (64.9)
Single, never married	24 (24.7)
Single, divorced	6 (6.2)
Separated	3 (3.1)
<b>Hobbies involving loud noise</b>	
Hunt or skeet shoot	16 (16.5)
Power tools	44 (45.4)
Chain saws (outside of work)	29 (29.9)
Ride ATVs, motorcycles	21 (21.6)
Listen to loud music	30 (30.9)
<i>SD</i> = standard deviation.	

Personal Characteristic	# (%)
<b>Job activities and job history</b>	
<b>Landscaping work history</b>	
Length of time in current job as landscaper	69 (71.1)
1–5 years	39 (40.2)
>5 years	57 (58.8)
<b>Number of years working in landscaping prior to this job</b>	
<1 year	1 (1.0)
>1 year	67 (69.1)
Currently working as groundskeeper outside of university job	30 (30.9)
Ever served in the military	12 (12.4)
If yes, were you exposed to excessive noise?	6 (6.2)
Ever exposed to loud noises at previous jobs	31 (32.0)
<b>Medical history</b>	
Work-related injuries/illness within the past 12 months	49 (50.5)
<b>Ever had any of the following:</b>	
Middle ear infection	21 (21.6)
Ear surgery	7 (7.2)
ringing in ear	38 (39.2)
Measles	20 (20.6)
Mumps	18 (18.6)
Scarlet fever	1 (1.0)
Head trauma	8 (8.2)
Hearing loss in the family	17 (17.5)
Trouble hearing in a group setting	14 (14.4)
Ever had a hearing test	84 (86.6)
If yes, were the results normal?	66 (68.0)

groundskeeping work. The majority of workers (50.5%) had experienced a work-related injury within the past 12 months, 39.2% had ringing in the ear, and 68.0% reported ever having a hearing test.

Figure 1 shows the most commonly used landscaping power tool workers reported

using within the last week: leaf blower (94%), weed trimmer (85%), push mower (79%), other tools (75%), chain saw (74%), and riding lawn mower (72%). Workers similarly ranked the importance of wearing both earplugs (91.8%) and earmuffs (84.5%) as extremely important (Table 2). The fre-

FIGURE 1

**Types of Power Equipment and Percentage of Use Within the Past Week Among Groundskeeping Workers in North Carolina, 2015**

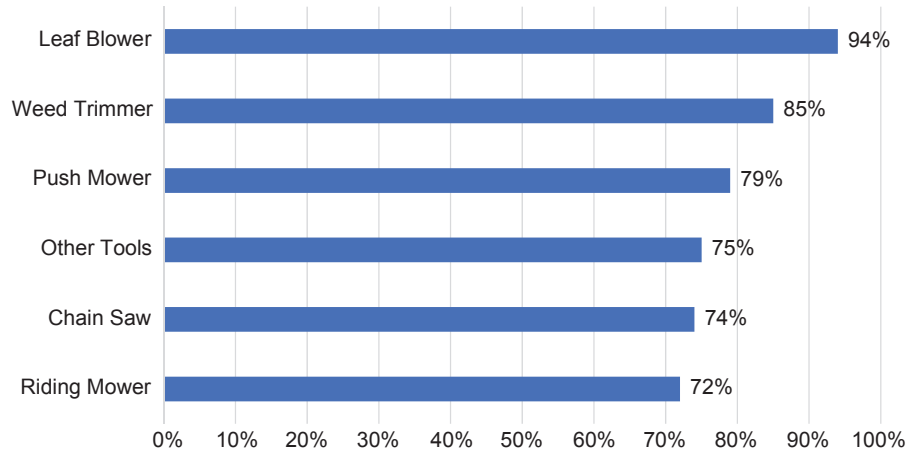


TABLE 2

**Importance of Wearing Hearing Protection Devices Among Groundskeeping Workers in North Carolina, 2015**

Hearing Protection Device	Important or Extremely Important # (%)	Neither Important nor Unimportant # (%)	Not Important or Very Unimportant # (%)
Earplugs	89 (91.8)	1 (1.0)	NR
Earmuffs	82 (84.5)	4 (4.1)	1 (1.1)

NR = none reported.

TABLE 3

**Frequency of Wearing Hearing Protection Devices Among Groundskeeping Workers in North Carolina, 2015**

Hearing Protection Device	Never/Rarely # (%)	Half the Time # (%)	Always/Most of the Time # (%)
Earmuffs (n = 88)	41 (42.3)	2 (2.1)	45 (46.4)
Earplugs (n = 92)	20 (20.6)	5.0 (5.2)	67 (69.1)

quency of wearing earplugs by groundskeepers within the last week was greater than earmuffs, yet only 69.1% of workers wore them always or most of the time when working around loud noise (Table 3). As shown in Table 4, over one half (57.7%) of workers

perceived hearing loss as normal and related to growing old. Nearly one third of participants (33.0%) felt that hearing loss due to noise was reversible and could be treated, and over one third (35.1%) felt that wearing hearing protection was uncomfortable.

In the Chi-square test analysis, there were no observed statistically significant differences between age, race/ethnicity, and other variables (data not shown). Among workers who completed both pre- and post-tests (57/97 = 59%), results indicated a significant increase from mean pre-test scores (mean = 64.2, standard deviation [SD] = 14.3), compared with mean post-test scores (mean = 71.4, SD = 14.3). Overall, in paired samples t-test analysis, a significant difference was observed between pre- and post-test scores (mean = 11.66, SD = 2.60; mean = 12.93;  $t(56) = -2.90, p = .005$ ) (data not shown).

As shown in Table 5, statistically significant differences were identified between six pre- and post-test questions: Q3) sound being over 95 dB ( $p = .001$ ); Q6) hearing loss by noise being permanent ( $p = .001$ ); Q12) not hearing normal conversation at a distance of 12 ft ( $p = .001$ ); Q13) earplugs blocking noise from reaching the inner ear ( $p = .022$ ); and Q18) hearing aids will bring back the hearing that you have lost ( $p = .001$ ).

**Discussion**

Data from this study demonstrated that landscaping and groundskeeping workers are aware of the importance of using HPDs to prevent hearing loss, yet their actual behavior or use of HPDs varied. Given such a significant number of landscaping and groundskeeping workers in the U.S. and the occupational hazards involved with their work duties, there is a paucity of published studies related to this group. From our literature search, the limited number of studies we identified focused either on worker fatalities or nonfatal worker injuries (Buckley, Sestito, & Hunting, 2008; Pegula, 2005). Similarly, occupational studies we identified that involved evaluations of worker perceptions, interventions, and hearing protection behavior concentrated primarily on industries in agriculture (McCullagh, 2011), mining (Joy & Middendorf, 2007; McBride, 2004; McBride et al., 2003), manufacturing (Brühl & Ivarsson, 1994), music (Barlow & Castilla-Sanchez, 2012; Bray, Szymański, & Mills, 2004), construction (Neitzel et al., 1999; Neitzel, Stover, & Seixas, 2011; Seixas et al., 2001), or the military (Mrena, Ylikoski, Kiukaanniemi, Mäkitie, & Savolainen, 2008; Paäkönen & Lehtomäki, 2005). These studies often reported mixed results.

A combination of training techniques proved effective at increasing test scores of worker knowledge on noise and factors related to NIHL among certain questions. Overall, the test scores generally were low, but the improvement of the mean post-test score following the intervention is encouraging and adds support for continuous worker education and training on noise and hearing protection. Although no discernible patterns in the post-test scores stood out, we found that the most significant improvements from individual post-test questions related to workers having increased knowledge of ambient noise levels and wearing HPDs (Q3 and Q12). In addition, increased scores on questions Q6 (hearing loss by noise was not permanent) and Q18 (that hearing aids would bring back hearing that has been lost) were also encouraging. These “misconceptions” were evidenced in noise and hearing loss in the initial perception survey that showed a large majority of workers felt hearing loss was normal and part of growing old (57.7%) and was unavoidable when working in a noisy job (43.3%). As demonstrated, perceptions of noise and actual sound levels among these workers are areas that need to be emphasized to workers to dispel myths and encourage use of HPDs.

In bivariate analysis, we did not find any statistical associations between personal and work characteristics with perception or importance of HPDs. In a separate analysis, however, when we compared test scores by race/ethnicity, we found significant improvements between pre-test and post-test scores among Whites and Blacks, but not among Hispanics. Among Whites, we saw an increase of mean scores from 55.4 to 70.2; among Blacks, scores improved from 69.1 to 74.8. For workers reporting as Hispanic, however, a mean decrease from 65.5 to 61.5 between pre- and post-test scores was identified. Despite the questions being read out loud and the training materials being translated into Spanish, worker scores did not improve. This finding is concerning, and we attribute the lack of improvement primarily to functional illiteracy in the workplace.

From a safety and health perspective, workers who cannot comprehend the risks associated with exposure to loud noise are unknowingly more vulnerable and susceptible to harm. A large majority of immigrant

TABLE 4

**Perceptions of Noise, Hearing Protection, and Hearing Loss Among Groundskeeping Workers in North Carolina, 2015**

Perception	Agree # (%)	Neither Agree nor Disagree # (%)	Disagree # (%)
Hearing loss is normal and is part of growing old	56 (57.7)	21 (31.6)	17 (17.5)
If you work a noisy job, hearing loss is unavoidable	42 (43.3)	14 (14.4)	37 (38.1)
Hearing loss due to noise is reversible and can be treated	32 (33.0)	19 (19.6)	41 (42.3)
Wearing hearing protection prevents you from hearing someone trying to get your attention	54 (55.7)	4 (4.1)	34 (35.1)
Cotton is as effective as ear plugs in hearing protection	14 (14.4)	16 (16.5)	65 (67.0)
Wearing hearing protection is uncomfortable	34 (35.1)	20 (20.6)	41 (42.3)
Wearing hearing protection interferes with your work	25 (25.8)	7 (7.2)	62 (63.9)
<i>Note.</i> Not all participants responded and totals may not add up to 100%.			

Hispanics in the U.S. have been increasingly entering the landscaping and groundskeeping workforce. In fact, The Bureau of Labor Statistics reported in 2014 that Hispanics and/or Latinos represented over 43% of the total employed in the landscaping industry (U.S. Department of Labor, 2015). These often lower paying jobs provide good entry-level work opportunities for an overwhelmingly majority of immigrant Hispanic workers, yet many Latinos entering the workforce in the U.S. face considerable hardships including language barriers, literacy issues, and fear of losing employment if they complain (Johnson & Ostendorf, 2010). The high fatalities and injuries among this underrepresented workgroup in landscaping and groundskeeping occupations (Buckley et al., 2008; CDC, 2011) warrants further investigation.

Protection from excessive noise in the occupational setting requires efforts by both the employer and employee. Employers must be committed to making safety a priority in the workplace and workers must be motivated to protect themselves from harm. As shown in Figure 2, the hierarchy of control model can be applied to landscaping and groundskeeping as a proper framework for reducing worker exposure to noise. Although not always feasible in all applications, the elimination and

substitution methods to reduce exposure to excessive noise can include having a worker use nonpower equipment or substituting with less hazardous equipment.

An engineering control could include making physical changes to power lawn equipment to prevent or reduce noise exposure such as providing a cab enclosure to lawn tractor equipment. For employers, administrative decisions could include policy changes to influence increased awareness to workers. Another viable option is to purchase or select equipment that produces less noise. The NIOSH “Buy Quiet” program is an excellent example of a prevention initiative that encourages companies to select low-noise tools and machinery in an effort to reduce worker exposure to noise (NIOSH, 2014).

Although recognized as the least effective option, the use of HPDs is the most portable method for personal protection. Previous studies that have evaluated the use of HPDs in other industries, including agriculture, mining, and construction, generally report low use of HPDs (Neitzel et al., 1999; Pääkkönen & Lehtomäki, 2005; Williams et al., 2015). Most workers often cite reasons including being uncomfortable and inability to hear equipment (Masterson et al., 2015; McBride et al., 2003).

TABLE 5

**Pre- and Post-Test Scores of Noise and Hearing Loss Among Groundskeeping Workers in North Carolina, 2015**

Measures	Pre-Test				Post-Test				p-Value
	Incorrect		Correct		Incorrect		Correct		
	#	%	#	%	#	%	#	%	
Q1. Noise is defined as any sound except conversation.	26	48.1	28	51.9	30	52.6	27	47.4	.832
Q2. Sound levels are measured in decibels, like temperature is measured in degrees.	5	8.8	52	91.2	4	7.0	53	93.0	1.00
Q3. The sound level of normal conversation is over 95 dB.	20	35.1	34	59.6	3	5.3	53	93.0	.001
Q4. The two major types of noise in the workplace are continuous and steady.	37	64.9	17	29.8	45	78.9	12	21.1	.238
Q5. Hearing loss is caused by noise breaking the three small bones in the middle ear.	27	47.4	27	47.4	23	40.4	33	57.9	.523
Q6. Hearing loss caused by noise is permanent.	19	33.3	36	63.2	6	10.5	50	87.7	.001
Q7. Constant ringing or humming in the ears (known as tinnitus) can be a warning sign of hearing loss.	7	12.3	48	84.2	1	1.8	54	94.7	.070
Q8. Damage to your nerve cells can occur at an average level of 85 dB for 8 hr.	7	12.3	50	87.7	9	15.8	48	84.2	.791
Q9. Higher-frequency noise can cause more damage to the hair cells in the inner ear.	15	26.3	40	70.2	11	19.3	46	80.7	.481
Q10. The only factor that matters in noise exposure is the level of noise in decibels.	26	45.6	30	52.6	24	42.1	33	57.9	.678
Q11. Eventually, you can get used to any continual and steady noise.	24	42.1	33	57.9	17	29.8	39	68.4	.286
Q12. As a general rule, if you cannot hear a normal conversation at a distance of 12 ft, you need to wear hearing protection.	37	64.9	19	33.3	18	31.6	38	66.7	.001
Q13. Earplugs fit into your ear canals, blocking excessive noise from reaching the inner ear and causing damage to the hair cells and auditory nerves.	15	26.3	42	73.7	6	10.5	51	89.5	.022
Q14. The Occupational Safety and Health Administration standard requires hearing protection for employees exposed to noise levels at or above 85 dBA in an 8-hr time-weighted average.	3	5.3	52	91.2	5	9.1	50	90.9	.727
Q15. The baseline audiogram serves as a comparison for future audiograms, helping to determine hearing improvement or loss.	6	10.5	50	87.7	11	19.3	46	80.7	.227
Q16. Hearing loss might not be noticed for 10–30 years.	24	42.1	32	56.1	18	31.6	39	68.4	.286
Q17. Hearing loss is not preventable.	11	19.3	46	80.7	11	19.3	46	80.7	1.00
Q18. Hearing aids will bring back the hearing that you have lost.	28	49.1	29	50.9	7	12.3	50	87.7	.001

Note. Adapted from *Hearing conservation: What...?! CLMI Safety Training*, 2012.

### Strengths and Limitations

This research helps fill a gap in the literature by providing evidence on behavior, perceptions, and knowledge of noise and related health effects among this understudied workgroup. Results from this study can serve as a basis for contributing to the effectiveness of hearing conservation programs in the workplace. As a pilot study, these results should be interpreted in light of its limitations. The study is limited by

self-reporting bias; also, many of the workers who took the pre-test were not available to take the post-test, which reduced the participant subsample size for the analysis. The study sites were localized to include a few North Carolina institutions, which might limit its generalizability to workers at other universities and those who perform landscaping in commercial, governmental, or other settings.

### Conclusion

The decision to reduce noise and hearing loss in the workplace stems from a combination of individual behavior and concentrated efforts on management to protect workers. Reducing noise exposure to workers can and should be achieved through safety awareness and improved efforts to establish a positive work safety culture. Focusing on health and safety, including hearing loss and exposure to noise, among underrepresented workers in

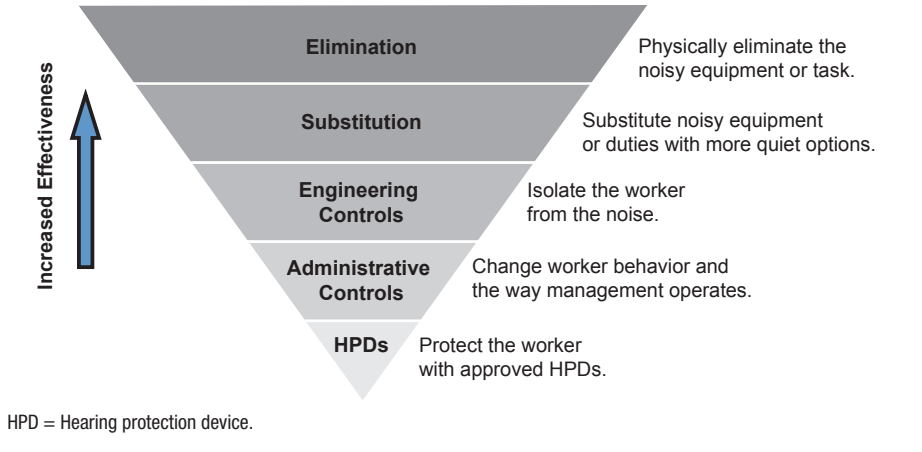
groundskeeping and landscaping is an area that needs increased attention. 🎧

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FIGURE 2

**Hierarchy of Controls to Reduce Noise Exposures Among Groundskeeping Workers**



**References**

Balanay, J.A., Kearney, G.D., & Mannarino, A.J. (2016). Noise exposure assessment among groundskeepers in a university setting: A pilot study. *Journal of Occupational and Environmental Hygiene*, 13(3), 193–202.

Barlow, C., & Castilla-Sanchez, F. (2012). Occupational noise exposure and regulatory adherence in music venues in the United Kingdom. *Noise & Health*, 14(57), 86–90.

Bray, A., Szymański, M., & Mills, R. (2004). Noise induced hearing loss in dance music disc jockeys and an examination of sound levels in nightclubs. *The Journal of Laryngology and Otology*, 118(2), 123–128.

Brühl, P., & Ivarsson, A. (1994). Noise-exposed male sheet-metal workers using hearing protectors. A longitudinal study of hearing threshold shifts covering fifteen years. *Scandinavian Audiology*, 23(2), 123–128.

Buckley, J.P., Sestito, J.P., & Hunting, K.L. (2008). Fatalities in the landscape and horticultural services industry, 1992–2001. *American Journal of Industrial Medicine*, 51(9), 701–713.

Centers for Disease Control and Prevention. (2006). Worker illness related to ground application of pesticide—Kern County, California, 2005. *Morbidity and Mortality Weekly Report*, 55(17), 486–488.

Centers for Disease Control and Prevention. (2011). Fatal injuries among grounds maintenance workers: United States, 2003–2008. *Morbidity and Mortality Weekly Report*, 60(17), 542–546.

Comprehensive Loss Management, Inc. (2009). *Hearing conservation: What...?!* [Video]. Retrieved from <https://www.clmi-training.com/training-library/hearing-conservation-what>

Hammig, B., Childers, E., & Jones, C. (2009). Injuries associated with the use of riding mowers in the United States, 2002–2007. *Journal of Safety Research*, 40(5), 371–375.

Johnson, S., & Ostendorf, J. (2010). Hispanic employees in the workplace: Higher rate of fatalities. *American Association of Occupational Health Nurses*, 58(1), 11–16.

Joy, G.J., & Middendorf, P.J. (2007). Noise exposure and hearing conservation in U.S. coal mines—A surveillance report. *Journal of Occupational and Environmental Hygiene*, 4(1), 26–35.

Masterson, E.A., Deddens, J.A., Themann, C.L., Bertke, S., & Calvert, G.M. (2015). Trends in worker hearing loss by industry sector, 1981–2010. *American Journal of Industrial Medicine*, 58(4), 392–401.

McBride, D.I. (2004). Noise-induced hearing loss and hearing conservation in mining. *Occupational Medicine*, 54(5), 290–296.

McBride, D.I., Firth, H.M., & Herbison, G.P. (2003). Noise exposure and hearing loss in agriculture: A survey of farmers and farm workers in the Southland region of New Zealand. *Journal of Occupational and Environmental Medicine*, 45(12), 1281–1288.

McCullagh, M.C. (2011). Effects of a low intensity intervention to increase hearing protector use among noise-exposed workers. *American Journal of Industrial Medicine*, 54(3), 210–215.

Mrena, R., Ylikoski, J., Kiukaanniemi, H., Mäkitie, A.A., & Savolainen, S. (2008). The effect of improved hearing protection regulations in the prevention of military noise-induced hearing loss. *Acta Oto-Laryngologica*, 128(9), 997–1003.

National Institute for Occupational Safety and Health. (2014). *Buy quiet: Components of a buy quiet program*. Retrieved from <http://www.cdc.gov/niosh/topics/buyquiet/component.html>

National Institute on Deafness and Other Communication Disorders. (2017). *Noise-induced hearing loss*. Retrieved from <https://www.nidcd.nih.gov/health/noise-induced-hearing-loss>

## References

- Neitzel, R., Seixas, N.S., Camp, J., & Yost, M. (1999). An assessment of occupational noise exposures in four construction trades. *American Industrial Hygiene Association Journal*, 60(6), 807–817.
- Neitzel, R.L., Stover, B., & Seixas, N.S. (2011). Longitudinal assessment of noise exposure in a cohort of construction workers. *The Annals of Occupational Hygiene*, 55(8), 906–916.
- Pääkkönen, R., & Lehtomäki, K. (2005). Protection efficiency of hearing protectors against military noise from handheld weapons and vehicles. *Noise & Health*, 7(26), 11–20.
- Pegula, S.M. (2005). *Occupational injuries among groundskeepers, 1992–2002*. Washington, DC: U.S. Bureau of Labor Statistics. Retrieved from <https://www.bls.gov/opub/mlr/cwc/occupational-injuries-among-groundskeepers-1992-2002.pdf>
- Seixas, N.S., Ren, K., Neitzel, R., Camp, J., & Yost, M. (2001). Noise exposure among construction electricians. *American Industrial Hygiene Association Journal*, 62(5), 615–621.
- U.S. Department of Labor, Bureau of Labor Statistics. (2014). *Occupational employment statistics*. Retrieved from [http://www.bls.gov/oes/current/naics5\\_561730.htm](http://www.bls.gov/oes/current/naics5_561730.htm)
- U.S. Department of Labor, Bureau of Labor Statistics. (2015). *Labor force statistics from the current population survey, 2014*. Retrieved from <http://www.bls.gov/cps/cpsaat18.htm>
- U.S. Department of Labor, Occupational Safety and Health Administration, Occupational Noise Exposure. 29 C.F.R. 1910.95 (c)(1) (2). (n.d.). Retrieved from [https://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=standards&p\\_id=9735](https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=9735)
- Williams, W., Brumby, S., Calvano, A., Hatherell, T., Mason, H., Mercer-Grant, C., & Hogan, A. (2015). Farmers' work-day noise exposure. *The Australian Journal of Rural Health*, 23(2), 67–73.

## Did You Know?

The Occupational Safety and Health Administration has a website of occupational noise exposure resources that can be found at [www.osha.gov/SLTC/noisehearingconservation/otherresources.html](http://www.osha.gov/SLTC/noisehearingconservation/otherresources.html).

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# Household Radon Gas Occurrences and Geographic Distribution in Western Michigan

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**Abstract** Pseudorandomized cluster sampling was used to select households from an initial pool of households geographically clustered in two Michigan counties, Ottawa and Kent. In Ottawa County and Kent County, 17.6% of 346 households sampled were above the U.S. Environmental Protection Agency (U.S. EPA) action level for radon (4 pCi/L). In Ottawa County, approximately 22.9% ( $N = 131$ ) of sampled households exceeded U.S. EPA limits, and in Kent County, approximately 14.4% ( $N = 215$ ) had indoor radon concentrations greater than U.S. EPA limits. Elevated indoor radon levels are broadly correlative with two bedrock formations, the Marshall and Michigan Formations, and areas where these two bedrock formations are overlain by glacial outwash and postglacial alluvium. More detailed mapping using GIS can help educate and motivate homeowners. This information will inform homeowners of radon risk and allow them to implement preventive measures in cooperation with local health departments and other stakeholders.

## Background

Michigan's geology consists of marine sedimentary rocks that have been deformed into a structural basin. Six bedrock formations occur in Kent County and Ottawa County (Table 1). All of these bedrock formations are overlain by Quaternary and postglacial sedimentary units of variable thickness, composition, and age. This study evaluates in-home radon levels for 346 homes using a computer mapping tool ArcGIS 10.1 to determine whether elevated radon levels correlate with mapped Quaternary and bedrock geologic units. Indoor radon levels were measured in Ottawa and Kent counties in western Michigan.

Previous investigations of indoor radon concentrations have found elevated radon levels in some Michigan counties: Ottawa County

was mapped by the U.S. Geological Survey in 1993 as having low geologic radon potential ( $<2$  pCi/L), while most of Kent County was mapped as having moderate geologic radon potential (2–4 pCi/L) (Schumann, 1993). The present study combines new radon measurements with geologic data using ArcGIS 10.1 to better understand the relationship between surface/subsurface geology and household radon gas concentrations.

Radon is an odorless, tasteless, invisible, carcinogenic, and radioactive gas that affects the health of homeowners across the country. Radon is a daughter element of uranium. Unlike other components of the uranium decay chain, however, radon gas is able to migrate through soil and therefore contaminate both soil and water (Ginevan, 1988).

As Samet and Eradze (2000) described it, "In homes, the principal source is soil gas, which penetrates through cracks or sumps in basements or around a concrete slab." Radon can also be present in the groundwater and the use of radon-contaminated well water can result in elevated radon gas levels due to gas released from the water (Teichman, 1988).

Radon occurs in igneous rocks that contain uranium and in clastic sedimentary rocks derived from uranium-bearing rocks (Gundersen et al., 1992; Harrell, Belsito, & Kumar, 1991; Peake, 1988). Roughly one third of the U.S. has geologic materials that might result in elevated radon levels. Radon typically is associated with fractured igneous and meta-igneous rocks, clay-rich glacial deposits, marine shale, carbonate soils, and uranium-bearing river and marine sediments (Gundersen et al., 1992).

While many people in the U.S. are aware of the dangers of cigarette smoke inhalation, many are unaware that radon gas is a naturally occurring cancer-causing element that kills thousands of people annually (U.S. Environmental Protection Agency [U.S. EPA], 2003). Radon is the second leading cause of lung cancer in the U.S. and claims approximately 21,000 lives annually, roughly two thirds the number of people who died in automobile accidents in the U.S. in 2013 (National Center for Statistics and Analysis, 2014; U.S. EPA, 2003). According to one study, radon "is responsible for about 2% of all deaths from cancer in Europe" (Darby et al., 2005).

Despite the real risk, radon is a threat that receives little attention from our society and most residents, even in areas with elevated radon risk (Clifford, Hevey, & Menezes, 2012). Several studies have demonstrated



TABLE 1

**Bedrock Formations in Kent and Ottawa Counties**

Formation	Area (Acres)	Area (Hectares)	% Area
Bayport Limestone	105,708	42,779	11.4
Coldwater Shale	85,921	34,771	9.3
Marshall Formation	225,992	91,456	24.4
Michigan Formation	263,408	106,598	28.4
Red Beds	138,206	55,930	14.9
Saginaw Formation	107,399	43,463	11.6
Grand total	926,634	374,997	100.0

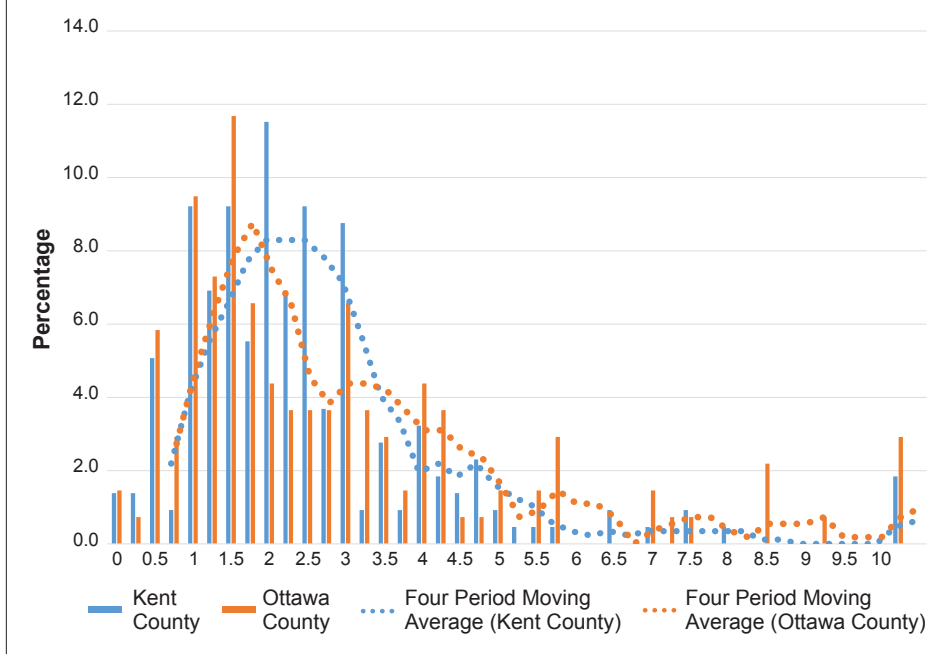
TABLE 2

**Radon Levels in Kent and Ottawa Counties**

County	N	>4 pCi/L	% Action Level	Average Radon Level (pCi/L)	Maximum Radon Level (pCi/L)	SD (pCi/L)
Kent	215	31	14.4	2.49	20.3	2.31
Ottawa	131	30	22.9	2.99	21.9	3.06
Grand total	346	61	17.6	2.68	21.9	2.63

SD = standard deviation.

FIGURE 1

**Histogram of Radon Levels by County**

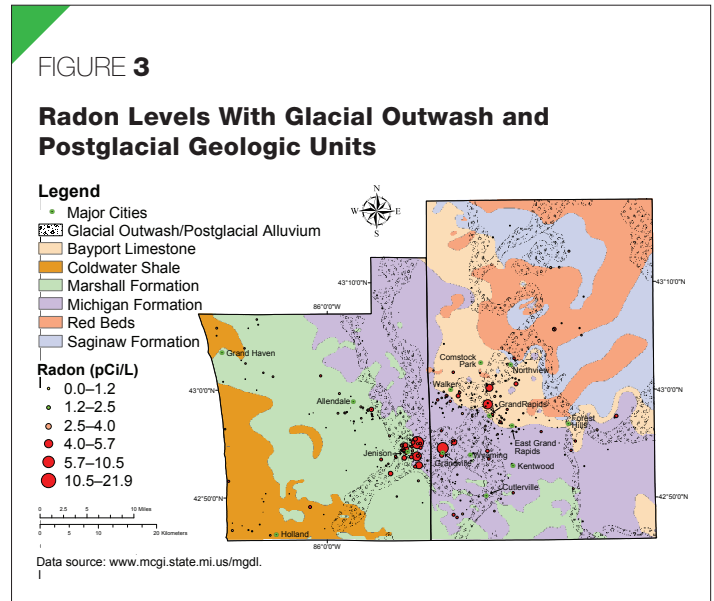
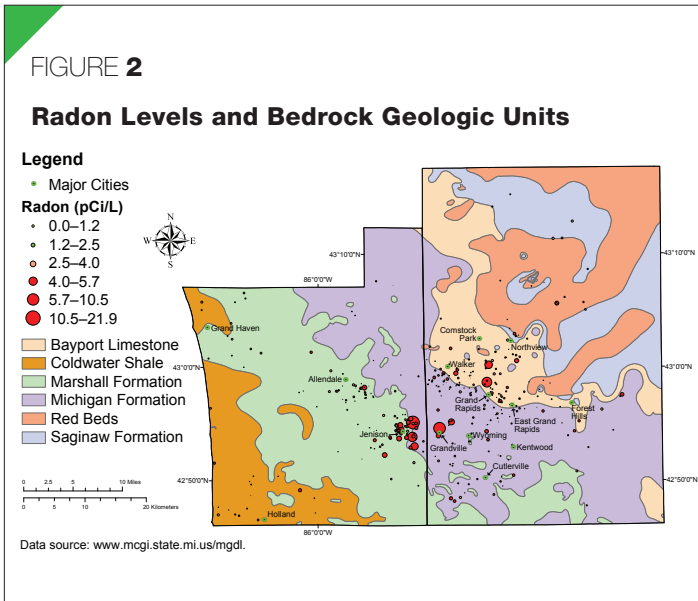
the effectiveness of mitigation strategies, yet thousands of homes across the country with dangerous radon levels remain unmitigated due to a lack of awareness and resources to address the problem (Denman & Phillips, 1998; Henschel, 1994). Several radon mitigation systems are summarized on the U.S. Environmental Protection Agency's (U.S. EPA) website. In general, the cost of these treatments ranges from \$800–\$2,500 depending on the characteristics of the house and choice of radon reduction methods. The average cost of a radon reduction system is about \$1,200 (U.S. EPA, 2017).

Several recent studies have explored the influence of geologic units on measured radon level. In Pennsylvania, elevated radon levels were associated with geologic units, well water, community attributes, weather, and unconventional natural gas development (Casey et al., 2015). A recent study in Kentucky found elevated radon levels were associated with limestone, shale, siltstone, or dolostone (Hahn et al., 2015). In Michigan, there is an added layer of complexity because most of the bedrock geologic units are overlain by Quaternary glacial deposits. These surface deposits likely attenuate radon levels associated with bedrock units, but they might also serve to focus radon in some areas with more porous or permeable overlying sediments.

**Methods**

This study was a faculty–student collaborative research project conducted in Ottawa County and Kent County, Michigan, during fall 2008 through winter 2010. Each researcher used a digital radon-testing device and household survey to collect household radon data. A total of 346 households within Kent and Ottawa counties were included in the analysis for this study.

Pseudorandomized cluster sampling was used to select which households would be included (Lavrakas, 2008). The initial pool of households was geographically clustered in two Michigan counties, Ottawa and Kent. These locations were chosen because they were accessible to students within the time allocated for the project. Beginning in November 2008, Grand Valley State University (GVSU) students contacted potential study participants through informational flyers; community presentations at schools, churches, housing associations, and health



fares; word of mouth; and through radio and newspapers outlets. Interested homeowners contacted GVSU by phone or e-mail to indicate their interest in participating in the study. A list of prospective households was compiled and these households were contacted in the order received until March 2010. Once a household was identified that was willing to participate, a pair of GVSU student researchers was assigned to make arrangements for radon measurements. The student researchers, who were anthropology students, were provided packets with informed consent forms, surveys for the participants, a flyer on the radon study, and a radon report card (IRB #127641-4). After data were collected, data were compiled into a database and checked for errors. Geographic coordinates were determined using Google Earth and home addresses so that homes could be mapped in ArcGIS 10.1.

Each researcher was provided a digital radon-testing device (Safety Siren Pro series) that tests indoor radon levels. This device has been used in other studies in North America and Asia (Griffin & Tarr, 2013; Valdez-Valbuena et al., 2007). In addition, they were given audio-recording devices and water collection bottles to collect data and water samples. The radon device was installed in a basement or below-ground closed room. The households ensured that the room was closed 12 hr before the device was set for the test. The test was left to run for 48 hr. At the completion of 48 hr, the researcher would return

to the participant's home, record the radon level of the home, inform the participants, and obtain signatures on both the survey and the radon report card. The radon report card was given to the household for their records.

### Results and Discussion

In Ottawa and Kent counties, 17.6% of 346 households sampled were above the U.S. EPA action level (4 pCi/L). In Ottawa County, approximately 22.9% ( $N = 131$ ) of sampled households exceeded U.S. EPA limits, and in Kent County, approximately 14.4% ( $N = 215$ ) had indoor radon concentrations greater than U.S. EPA limits (Table 2). The distribution of indoor radon gas in both Ottawa and Kent counties had similar frequency distributions (Figure 1).

Elevated indoor radon levels are broadly correlative with a shale-bearing bedrock formation called the Michigan Formation (average of 2.68 pCi/L) and a sandstone unit called the Marshall Formation (2.96 pCi/L) (Figures 2 and 3). When these two formations are overlain by glacial outwash, average household radon levels are even greater. The radon levels in Marshall Formation overlain by glacial outwash sand and gravel and postglacial alluvium is 4.61 pCi/L, while the radon levels in Michigan Formation overlain by glacial outwash sand and gravel and postglacial alluvium is 3.81 pCi/L (Table 3).

Radon level maps are available for most of the U.S., but the resolution of these maps is often inadequate to be of use for the typi-

cal homeowner in evaluating their radon exposure risk. Detailed spatial distribution maps, like those generated for this study and made available as a layer in programs such as Google Earth or Google Maps, would make these data more accessible to the average homeowner (Figure 4).

### Conclusion

Over 50% of the surface area of Ottawa and Kent counties is underlain by the Marshall and Michigan Formations. Average radon levels in homes built above these two geologic units are higher than average radon levels in homes built above other geologic units. Average radon levels were even greater when these two bedrock units were overlain by glacial outwash and postglacial alluvium. It is possible that the bedrock units are the source of observed radon and the overlying glacial units serve as a more porous medium through which groundwater and radon can travel. Additional studies of radon levels in the source rocks and overlying sediments are needed to test this preliminary hypothesis. The study data suggest two geologic formations are sources of radon gas and that these bedrock sources, when overlain by glacial outwash, allow higher radon levels to accumulate in homes. More detailed mapping using GIS can help educate and motivate homeowners to test their radon levels and implement mitigation measures when appropriate. Local health departments, nongovernmental organizations, and social institutions such as churches, housing associations, and schools

TABLE 3

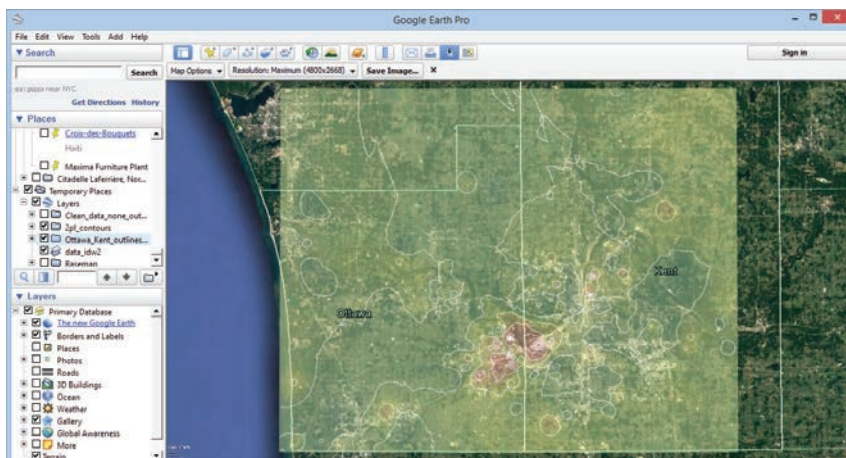
**Distribution of Radon by Geologic Units**

Bedrock and Quaternary Geologic Units	Average Radon Level (pCi/L)	# of Samples
Bayport Limestone	2.63	76
End moraines of fine-textured till	2.29	35
End moraines of medium-textured till	3.21	11
Fine-textured glacial till	1.60	1
Glacial outwash sand and gravel and postglacial alluvium	2.87	28
Medium-textured glacial till	2.10	1
Coldwater Shale	1.98	22
Dune sand	3.12	6
Lacustrine sand and gravel	1.51	14
Water	1.80	2
Marshall Formation	2.96	99
Dune sand	2.20	1
End moraines of fine-textured till	1.93	6
Fine-textured glacial till	1.73	18
Glacial outwash sand and gravel and postglacial alluvium	4.61	34
Lacustrine sand and gravel	2.29	40

Bedrock and Quaternary Geologic Units	Average Radon Level (pCi/L)	# of Samples
Michigan Formation	2.68	125
End moraines of fine-textured till	1.79	23
End moraines of medium-textured till	2.20	43
Fine-textured glacial till	1.45	10
Glacial outwash sand and gravel and postglacial alluvium	3.81	46
Lacustrine sand and gravel	0.50	1
Medium-textured glacial till	4.35	2
Red Beds	2.23	12
End moraines of fine-textured till	1.37	3
End moraines of medium-textured till	3.12	6
Glacial outwash sand and gravel and postglacial alluvium	1.30	3
Saginaw Formation	2.53	12
End moraines of medium-textured till	2.37	7
Glacial outwash sand and gravel and postglacial alluvium	2.97	3
Medium-textured glacial till	2.40	2
All samples	2.68	346

FIGURE 4

**Generalized GIS Map of Radon in Ottawa and Kent Counties**



can be partners to convey neighborhood-level radon data through printed maps and publicize available web-based data resources. 🌐

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References continued from page 19

- Casey, J.A., Ogburn, E.L., Rasmussen, S.G., Irving, J.K., Pollak, J., Locke, P.A., & Schwartz, B.S. (2015). Predictors of indoor radon concentrations in Pennsylvania, 1989–2013. *Environmental Health Perspectives*, 123(11), 1130–1137.
- Clifford, S., Hevey, D., & Menezes, G. (2012). An investigation into the knowledge and attitudes towards radon testing among residents in a high radon area. *Journal of Radiological Protection*, 32(4), N141–N147.
- Darby, S., Hill, D., Auvinen, A., Barros-Dios, J.M., Baysson, H., Bochicchio, F., . . . Doll, R. (2005). Radon in homes and risk of lung cancer: Collaborative analysis of individual data from 13 European case-control studies. *BMJ*, 330(7485), 223.
- Denman, A.R., & Phillips, P.S. (1998). A review of the cost effectiveness of radon mitigation in domestic properties in Northamptonshire. *Journal of Radiological Protection*, 18(2), 119–129.
- Ginevan, M.E. (1988). Radon as an indoor air pollutant. *Statistical Science*, 3(3), 371–373.
- Griffin, R.H., & Tarr, N.G. (2013). Optical image sensors and their application in radon detection. *Proceedings of SPIE*, 8915. Retrieved from <http://dx.doi.org/10.1117/12.2033635>
- Gundersen, L.C.S., Schumann, R.R., Otton, J.K., Dubiel, R.F., Owen, D.E., & Dickinson, K.A. (1992). Geology of radon in the United States. In A.E. Gates & L.C.S. Gundersen (Eds.), *Geological Society of America special papers*, (Vol. 271, pp. 1–16). McLean, VA: GeoScienceWorld.
- Hahn, E.J., Gokun, Y., Andrews, W.M., Jr., Overfield, B.L., Robertson, H., Wiggins, A., & Rayens, M.K. (2015). Radon potential, geologic formations, and lung cancer risk. *Preventive Medicine Reports*, 2, 342–346.
- Harrell, J.A., Belsito, M.E., & Kumar, A. (1991). Radon hazards associated with outcrops of Ohio shale in Ohio. *Environmental Geology and Water Sciences*, 18(1), 17–26.
- Henschel, D. (1994). Analysis of radon mitigation techniques used in existing U.S. houses. *Radiation Protection Dosimetry*, 56(1–4), 21–27.
- Lavrakas, P.J. (Ed.). (2008). *Encyclopedia of survey research methods*. Thousand Oaks, CA: SAGE Publications, Inc.
- National Center for Statistics and Analysis. (2014). *2013 motor vehicle crashes: Overview* (Traffic Safety Facts Research Note. Report No. DOT HS 812 101). Washington, DC: National Highway Traffic Safety Administration. Retrieved from <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812101>
- Peake, R.T. (1988). Radon and geology in the United States. *Radiation Protection Dosimetry*, 24(1–4), 173–178.
- Samet, J.M., & Eradze, G.R. (2000). Radon and lung cancer risk: Taking stock at the millenium. *Environmental Health Perspectives*, 108(Suppl. 4), 635–641.
- Schumann, R.R. (Ed.). (1993). *Geologic radon potential of EPA Region 5: Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin* (Open-file report 93-292-E). Reston, VA: U.S. Geological Survey. Retrieved from <https://pubs.er.usgs.gov/publication/ofr93292E>
- Teichman, K.Y. (1988). A little exposure to radon. *Statistical Science*, 3(3), 374–376.
- Valdez-Valbuena, M., Dayag, J., Kimmayong, M., Laborera, K., Montefalco, M.M., Piasan, M., & Sicmaten, E.S. (2007). A Philippine-based study on radon: The greatest source of ionizing radiation (construction material, ventilation and altitude as modifying factors). *Australasian Physical & Engineering Sciences in Medicine*, 30(4), 496–497.
- U.S. Environmental Protection Agency. (2003). *EPA assessment of risks from radon in homes* (Report No. EPA 402-R-03-003). Washington, DC: Office of Radiation and Indoor Air, U.S. Environmental Protection Agency. Retrieved from <https://www.epa.gov/sites/production/files/2015-05/documents/402-r-03-003.pdf>
- U.S. Environmental Protection Agency. (2017). *Radon*. Retrieved from <https://www.epa.gov/radon>



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# Measuring Arsenic Exposure Among Residents of Hernando County, Florida, 2012–2013

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**Abstract** Private wells throughout central Florida have arsenic levels above the maximum contaminant level (MCL) of 10 µg/L. We conducted a biomonitoring project of residents with wells above the MCL (higher risk) and below 8 µg/L (lower risk) to determine the relative importance of dietary and water sources of arsenic. Urinary arsenic did not differ by risk status, though higher-risk residents were more likely to use bottled or filtered well water as their primary source for drinking, cooking, and brushing teeth. Higher income, home ownership, and more servings of fish, seafood, white rice, and wine were associated with higher urinary arsenic levels. Similar relationships were seen when excluding individuals who consumed fish or seafood within 3 days of sampling. Provision of filters and bottled water to higher-risk households provided protection from arsenic exposure through well water. Diet and lifestyle factors, however, contributed to higher urinary arsenic levels among participants, regardless of household risk status.

## Introduction

Arsenic is a ubiquitous element found in soil and rock; it can occur in organic and inorganic forms. Both types occur naturally, but human activity can contribute to arsenic levels: organic arsenic can be found in food sources such as seafood, as additives in animal feed, or in agricultural pesticides. Sources of inorganic arsenic include wood preservatives and some agricultural pesticides (historically). Inorganic arsenic is a known carcinogen when ingested over many years, while organic arsenic is thought to be much less harmful to human health (Agency for Toxic Substances and Disease Registry, 2007; U.S. Environmental Protection Agency [U.S. EPA], 2007). U.S. EPA has established the maximum contaminant level (MCL) for total arsenic at 10 µg/L based on the potential

health effects associated with exposure (U.S. EPA, 2007).

Arsenic contamination has been identified in groundwater in some Florida counties, and is likely related to historic use of arsenic compounds in cattle dip vats or herbicides, although arsenic naturally occurs in some areas. In contract with the Florida Department of Environmental Protection (DEP), the Florida Department of Health (DOH) conducts private well testing to determine arsenic levels in residential drinking water. Private wells in many central Florida counties have total arsenic levels above the MCL.

The overall objective of this biomonitoring project was to determine if differences exist in urinary arsenic levels between people residing in homes with well water arsenic levels above the MCL (10 µg/L) and those

with levels below 8 µg/L. The results of this analysis have been published previously (Jordan, DuClos, Kintziger, Gray, & Bonometti, 2015). A secondary objective, and the focus of this analysis, was to determine the relative importance of dietary and water sources on total arsenic in our study population.

## Methods

### Study Design

In 2012–2013, DOH conducted a biomonitoring study to determine urinary arsenic levels among residents of Hernando County, Florida, a place known to have wells with arsenic above the MCL. All study participants resided in a home whose primary source of water was a private well. Participants were classified by risk status. High risk was defined as a household with well water arsenic levels above the MCL (10 µg/L) without a point-of-entry (POE) filter or connection to a public water system, and typically having either a point-of-use (POU) filter or bottled water provided by DEP. Low risk was defined as a household with well water arsenic levels below a conservative level of 8 µg/L and not connected to public water. This conservative threshold was used because arsenic levels in groundwater vary over time. This study was submitted to the DOH institutional review board and determined to be nonresearch as an extension of public health surveillance activities.

### Sampling Design

DOH obtained a list of private wells sampled by DEP in Hernando County, Florida, that provided arsenic levels and the DEP action taken for that well. Per the Florida Safe

TABLE 1

### Demographic Characteristics of Participants by Risk Status, Hernando County Arsenic Biomonitoring Project, Florida, 2012–2013

		Overall		Risk Status				Chi-Square <i>p</i> -Value
				Lower Risk (<8 µg/L)		Higher Risk (>10 µg/L)		
Variable	Level	#	%*	#	%*	#	%*	
Case status	Total	350	100.00	170	49.05	180	50.95	
Gender	Female	180	50.86	87	50.28	93	51.47	.7399
	Male	170	49.14	83	49.72	87	48.53	
Age (year), continuous	Mean (SE)	53.74	(2.98)	57.33	(5.60)	50.00	(1.88)	.2168**
Age (year), categorical	0–17	48	13.71	23	13.78	25	13.64	.4171
	18–64	179	51.79	82	47.95	97	55.79	
	≥65	123	34.49	65	38.27	58	30.57	
Race/ethnicity	White	317	90.17	157	92.18	160	88.08	.5851
	Hispanic	26	7.96	10	6.15	16	9.84	
	Other	7	1.87	3	1.68	4	2.07	
Education or school attendance	Child (still in school)	49	14.00	24	14.34	25	13.64	.9112
	High school education or less	86	24.60	43	25.51	43	23.66	
	Some college or college graduate	215	61.40	103	60.15	112	62.69	
Annual household income	Unemployed/retired	6	1.65	4	2.23	2	1.04	.7836
	<\$35,000	48	13.89	21	12.29	27	15.54	
	\$35,000–\$74,999	167	48.14	86	50.84	81	45.34	
	≥\$75,000	129	36.33	59	34.64	70	38.08	
BMI category	Underweight	10	2.66	4	2.23	6	3.11	.2999
	Normal weight	140	38.74	74	42.46	66	34.89	
	Overweight/obese	200	58.59	92	55.31	108	62.00	
ZIP code	34601	100	28.26	32	19.55	68	37.31	<.0001
	34602	182	51.30	81	45.81	101	56.99	
	34604	36	10.57	28	16.76	8	4.15	
	Other	32	9.87	29	17.88	3	1.55	
Own or rent home	Other	7	1.90	4	2.23	3	1.55	.7791
	Rent	6	1.59	2	1.12	4	2.07	
	Own	337	96.51	164	96.65	173	96.37	
Years in current home	Mean (SE)	12.66	(0.65)	12.98	(1.04)	12.33	(0.78)	.6165**

SE = standard error. BMI = body mass index.

\*Weighted percentages, means, and SE reported.

\*\*The *t*-test *p*-value reported for continuous variables.

Water Restoration Program, actions by arsenic level are:

- 0–7.99 µg/L: no remediation/action taken;
- 8.00–10.49 µg/L: routine monitoring;
- 10.50–49.99 µg/L: kitchen sink or POU filter offered/installed, connected to public water, or bottled water; and

- ≥50.00 µg/L: POE filter provided or connected to public water (where economically feasible).

For this study, households with a POE filter or those connected to public water were excluded from sampling.

At sampling, 789 wells were classified as low risk and 312 wells as high risk. We sent recruitment letters to 100% of high-risk households and a simple random sample of 311 (39%) low-risk households. Multiple individuals from each household were encouraged to participate. In total, 360 resi-

TABLE 2

**Potential Exposures to Arsenic During 3-Day Period Prior to Survey by Risk Status, Hernando County Arsenic Biomonitoring Project, Florida, 2012–2013**

Variable	Level	Overall		Risk Status				Chi-Square p-Value
				Lower Risk (<8 µg/L)		Higher Risk (>10 µg/L)		
		#	%*	#	%*	#	%*	
Drinking water	Bottled water	176	51.20	63	37.43	113	64.51	<.0001
	Filtered well water	75	20.58	13	7.82	62	32.90	
	Unfiltered well water	99	28.22	94	54.75	5	2.59	
Cooking water	Bottled water	97	28.54	6	3.91	91	52.33	<.0001
	Filtered well water	74	20.42	11	6.70	63	33.68	
	Unfiltered well water	179	51.04	153	89.39	26	13.99	
Bathing or showering	Filtered well water	4	1.59	1	0.56	3	2.59	.1689
	Unfiltered well water	346	98.41	169	99.44	177	97.41	
Brushing teeth	Bottled water	8	2.11	0	0.00	8	4.15	<.0001**
	Filtered well water	8	2.65	1	0.56	7	4.66	
	Unfiltered well water	334	95.25	169	99.44	165	91.19	
Wash fruits and vegetables	No	20	5.37	9	5.03	11	5.70	.8512
	Yes	330	94.63	161	94.97	169	94.30	
Insecticide or herbicide use	No	258	73.97	127	75.98	131	72.02	.5754
	Yes	92	26.03	43	24.02	49	27.98	
Own a swimming pool	No	206	59.04	90	54.19	116	63.73	.2620
	Yes	144	40.96	80	45.81	64	36.27	
Homeopathic treatments or vitamins	No	149	41.67	65	37.15	84	46.03	.2024
	Yes	201	58.33	105	62.85	96	53.97	
Any tobacco use or exposure	No	264	75.33	134	78.21	130	72.54	.4834
	Yes	86	24.67	36	21.79	50	27.46	

\*Weighted percentages reported.

\*\*Due to small cell sizes, Rao–Scott chi-square analysis was not possible and regular chi-square analysis was conducted using individual weights only.

dents from 166 households participated (188 individuals from 86 high-risk and 172 individuals from 79 low-risk households). The overall household response rate was 29.5% (30.5% for high-risk and 28.1% for low-risk households). Children were included with a parent’s permission. If children were unable to complete the survey alone, it was completed by or with assistance from a parent.

**Data Collection**

We used a survey to collect information on home water use, dietary exposures, pes-

ticide and herbicide use, other potential arsenic sources, demographic information, tobacco and alcohol use, and occupational risk (survey can be viewed at [www.neha.org/jeh/supplemental](http://www.neha.org/jeh/supplemental)). Study personnel scheduled a sampling visit. One week prior, participants received a package with study documentation, informed consent documents, specimen containers, and detailed instructions on collecting and storing urine samples. Participants were instructed to abstain from consuming fish and seafood during the 3 days prior to the visit. During

the visit, study personnel administered the survey and collected informed consent documents, urine samples, and water samples from the kitchen faucet and one other location in the home.

**Sample Testing**

All collected samples were shipped to the Bureau of Public Health Laboratories in Jacksonville for testing. For water samples, total arsenic was obtained using an ELAN 6000 inductively coupled plasma mass spectrometer (ICP/MS) and the U.S. EPA 200.8



TABLE 3

**Consumption of Potential Exposures to Arsenic During 3-Day Period Prior to Survey by Risk Status, Hernando County Arsenic Biomonitoring Project, Florida, 2012–2013**

Variable	Overall		Lower Risk (<8 µg/L)		Higher Risk (>10 µg/L)		t-Test p-Value
	Mean*	SE*	Mean*	SE*	Mean*	SE*	
Main water sources (3 days prior to survey)							
8 oz glasses of filtered tap water (servings)	4.32	0.60	1.66	0.75	7.08	0.93	<.0001
8 oz glasses of unfiltered tap water (servings)	6.61	0.57	12.07	1.17	0.95	0.25	<.0001
8 oz glasses of tap water outside of home (servings)	2.88	0.28	2.69	0.42	3.06	0.36	.5020
8 oz glasses of bottled or vended water (servings)	10.12	0.72	7.47	1.08	12.87	0.97	.0003
Total 8 oz glasses of water (servings)	23.93	0.86	23.89	1.29	23.97	1.14	.9665
Used swimming pool (times)	0.50	0.12	0.71	0.21	0.23	0.07	.0272
Main dietary sources (3 days prior to survey)							
Chicken (oz)	3.30	0.19	3.66	0.27	2.91	0.27	.0513
Brown rice or other cooked whole grains (servings)	0.19	0.04	0.20	0.05	0.19	0.06	.8484
White rice (servings)	0.42	0.07	0.46	0.11	0.39	0.08	.6050
Fruit: fresh, frozen, canned (servings)	2.63	0.18	2.92	0.29	2.33	0.18	.0892
Fruits or vegetables grown at home (servings)	0.20	0.04	0.24	0.06	0.15	0.05	.2321
Glasses of 100% pure fruit juice (servings)	1.95	0.21	1.84	0.23	2.07	0.37	.5885
Wine (servings)	0.77	0.13	1.01	0.20	0.53	0.16	.0651
Beer (servings)	1.09	0.16	1.27	0.26	0.90	0.19	.2525
Seafood dietary sources** (3 days prior to survey)							
Fish, including tuna (oz; overall for all participants)	0.40	0.08	0.43	0.13	0.36	0.10	.6971
Fish, including tuna (oz; consumed by <i>n</i> = 39)	3.46	0.41	3.37	0.65	3.59	0.39	.7725
Seafood (oz; overall for all participants)	0.16	0.05	0.21	0.08	0.11	0.05	.3054
Seafood (oz; consumed by <i>n</i> = 16)	3.63	0.83	3.70	1.21	3.50	0.74	.8906

SE = standard error.

\*Weighted means and SEs reported.

\*\*Participants were asked to abstain from consuming fish and seafood in the 3-day period prior to study visit because of the large impact of these items on total urinary arsenic levels. Not all participants abstained, according to self-reported dietary history.

method (U.S. EPA, 1994). Arsenic was measured at the mass-to-charge ratio (*m/z*) 75, using yttrium *m/z* 89 as an internal standard. We applied a correction equation to correct for the isobaric  $^{40}\text{Ar}^{35}\text{Cl}^+$  and  $^{40}\text{Ca}^{35}\text{Cl}^+$  interferences. We calibrated the instrument using a National Institute of Standards and Technology (NIST) traceable arsenic standard between 1–100 µg/L. For urine, total arsenic was obtained using an ELAN DRCII ICP/MS and a modified Centers for Disease Control and Prevention (CDC) method (CDC, 2012), which used oxygen (research

grade, >99.999%) in the dynamic reaction cell of the ICP/MS for removal of isobaric interferences. Arsenic was measured at *m/z* 91 ( $^{75}\text{As}^{16}\text{O}^+$ ), using iridium *m/z* 193 as an internal standard. We calibrated the DRCII between 10–4,000 µg/L using a NIST traceable arsenic standard. The precision of the arsenic measurement for the quality control low mean was 11.54 µg/L with a standard deviation of 0.47 µg/L. Additionally, a sub-aliquot of each urine specimen was sent to Quest Diagnostics to determine urinary creatinine levels. We accounted for urine

dilution by adjusting arsenic levels for creatinine. All participants were provided test results within 4–6 weeks of collection.

### Statistical Analysis

We converted height (in.) and weight (pounds) to metric (m and kg) to calculate body mass index (BMI) (kg/m<sup>2</sup>) in adults. For individuals under 20 years, we calculated BMI percentiles using CDC growth charts (Kuczmarski et al., 2002). Individuals were classified as underweight, normal weight, or overweight/obese based on BMI

TABLE 4

**Predictors of Creatinine-Adjusted Urinary Arsenic Levels (µg/g), Hernando County Arsenic Biomonitoring Project, Florida, 2012–2013**

Categorical Variables	Level	Unadjusted Models		Adjusted Model	
		Least Square	F-Test	Least Square	F-Test
		Geometric Means*	p-Value	Geometric Means*	p-Value
Risk status	Higher risk	7.68	.4497		
	Lower risk	8.30			
Gender	Female	8.22	.3772		
	Male	7.76			
Age (year), categorical	0–17	6.80	.0639		
	18–64	7.61			
	≥65	9.17			
Race/ethnicity	White	7.72	.0742		
	Hispanic	9.45			
	Other	20.27			
Education or school attendance	Child (still in school)	6.68	.0676		
	High school education or less	8.67			
	Some college or college graduate	8.06			
Annual household income	<\$35,000	7.12	.0248	7.88	.0473
	\$35,000–\$74,999	7.09		7.50	
	≥\$75,000 or more	9.65		9.56	
BMI category	Underweight	13.73	.2840		
	Normal weight	8.21			
	Overweight/obese	7.66			
Own or rent home	Other	21.76	.0002	12.03	<.0001
	Rent	5.70		5.95	
	Own	7.88		7.90	
Insecticide or herbicide use	No	8.23	.3238		
	Yes	7.35			
Homeopathic treatments or vitamins	No	7.19	.0489		
	Yes	8.61			
Any tobacco use or exposure	No	8.03	.8433		
	Yes	7.87			
Main water sources					
Drinking water	Bottled water	8.07	.5034		
	Filtered well water	8.70			
	Unfiltered well water	7.41			
Cooking water	Bottled water	6.71	.0161		
	Filtered well water	9.18			
	Unfiltered well water	8.32			
Bathing	Filtered well water	5.49	.1940		
	Unfiltered well water	8.04			

continued ►

TABLE 4 *continued***Predictors of Creatinine-Adjusted Urinary Arsenic Levels ( $\mu\text{g/g}$ ), Hernando County Arsenic Biomonitoring Project, Florida, 2012–2013**

Categorical Variables	Level	Unadjusted Models		Adjusted Model	
		Least Square	F-Test	Least Square	F-Test
		Geometric Means*	p-Value	Geometric Means*	p-Value
Brushing teeth	Bottled water	6.77	.7101		
	Filtered well water	7.48			
	Unfiltered well water	8.03			
Wash fruits and vegetables	No	6.79	.3575		
	Yes	8.07			
Own a swimming pool	No	8.09	.7638		
	Yes	7.85			
Continuous Variables	Unit of Measurement	Geometric Mean	F-Test	Geometric Mean	F-Test
		Ratios*	p-Value	Ratios*	p-Value
Years in current home	Years	0.99	.0113	0.99	.0316
Main water sources (3 days prior to survey)					
8 oz glasses of filtered tap water	Servings	1.01	.2996		
8 oz glasses of unfiltered tap water	Servings	1.00	.6645		
8 oz glasses of tap water outside of home	Servings	0.98	.0187	0.98	.00087
8 oz glasses of bottled or vended water	Servings	1.00	.6041		
Used swimming pool	Times/3 days	1.03	.5547		
Main dietary sources (3 days prior to survey)					
Chicken	Ounces	0.97	.0858		
Brown rice or other cooked whole grains	Servings	1.12	.0686		
White rice	Servings	1.15	.0101	1.10	.0073
Fruit: fresh, frozen, canned	Servings	1.01	.3348		
Fruits or vegetables grown at home	Servings	1.10	.2677		
Glasses of 100% pure fruit juice	Servings	0.98	.0414		
Wine	Servings	1.05	.0096	1.06	.0012
Beer	Servings	1.01	.1504		
Seafood dietary sources** (3 days prior to survey)					
Fish, including tuna	Ounces	1.24	<.0001	1.21	<.0001
Seafood	Ounces	1.28	<.0001	1.21	<.0001

BMI = body mass index.

\*Weighted exponentiated least square means and exponentiated parameter estimates reported.

\*\*Participants were asked to abstain from consuming fish and seafood in the 3-day period prior to study visit because of the large impact of these items on total urinary arsenic levels. Not all participants abstained, according to self-reported dietary history.

(adults) or BMI percentiles (<20 years). We also calculated geometric means for urinary arsenic and creatinine-adjusted urinary arsenic to minimize the effects of outliers on average values.

We weighted responses to account for different probabilities of household inclusion between high-risk and low-risk households and within-household participation rates. Descriptive statistics were calculated, includ-

ing weighted mean and standard error (*SE*) or frequency and weighted percentage. Statistics accounted for the sampling design and clustering of responses within households, and included a finite population correction

TABLE 5

**Predictors of Creatinine-Adjusted Urinary Arsenic Levels (µg/g) Among Those Who Abstained From Fish and Seafood Consumption in the 3-Day Period Prior to Survey, Hernando County Arsenic Biomonitoring Project, Florida, 2012–2013**

Categorical Variables	Level	Unadjusted Models		Adjusted Model	
		Least Square	F-Test	Least Square	F-Test
		Geometric Means*	p-Value	Geometric Means*	p-Value
Risk status	Higher risk	7.01	.7858		
	Lower risk	6.84			
Gender	Female	6.69	.2642		
	Male	7.16			
Age (year), categorical	0–17	6.09	.1115		
	18–64	6.58			
	≥65	7.82			
Race/ethnicity	White	6.77	.1629		
	Hispanic	8.21			
	Other	11.70			
Education or school attendance	Child (still in school)	5.98	.0234		
	High school education or less	7.71			
	Some college or college graduate	6.86			
Annual household income	<\$35,000	6.77	.0346	7.82	.0341
	\$35,000–\$74,999	6.16		7.16	
	≥\$75,000	8.14		9.32	
BMI category	Underweight	8.34	.5312		
	Normal weight	7.18			
	Overweight/obese	6.71			
Own or rent home	Other	13.14	.0080	11.50	.0027
	Rent	6.13		6.57	
	Own	6.86		6.91	
Insecticide or herbicide use	No	7.10	.3558		
	Yes	6.47			
Homeopathic treatments or vitamins	No	6.29	.0472		
	Yes	7.42			
Any tobacco use or exposure	No	6.95	.8928		
	Yes	6.85			
Main water sources (3 days prior to survey)					
Drinking water	Bottled water	6.95	.8621		
	Filtered well water	7.15			
	Unfiltered well water	6.72			
Cooking water	Bottled water	6.16	.1208		
	Filtered well water	7.41			
	Unfiltered well water	7.21			

continued ►

TABLE 5 *continued*

**Predictors of Creatinine-Adjusted Urinary Arsenic Levels ( $\mu\text{g/g}$ ) Among Those Who Abstained From Fish and Seafood Consumption in the 3-Day Period Prior to Survey, Hernando County Arsenic Biomonitoring Project, Florida, 2012–2013**

Categorical Variables	Level	Unadjusted Models		Adjusted Model	
		Least Square	F-Test	Least Square	F-Test
		Geometric Means*	p-Value	Geometric Means*	p-Value
Bathing	Filtered well water	5.49	.4231		
	Unfiltered well water	6.95			
Brushing teeth	Bottled water	5.89	.6944		
	Filtered well water	7.48			
	Unfiltered well water	6.93			
Wash fruits and vegetables	No	6.54	.7413		
	Yes	6.95			
Own a swimming pool	No	6.90	.9250		
	Yes	6.96			
Continuous Variables	Unit of Measurement	Geometric Mean	F-Test	Geometric Mean	F-Test
		Ratios*	p-Value	Ratios*	p-Value
Years in current home	Years	0.99	.0900		
Main water sources (3 days prior to survey)					
8 oz glasses of filtered tap water	Servings	1.00	.3980		
8 oz glasses of unfiltered tap water	Servings	1.00	.8281		
8 oz glasses of tap water outside of home	Servings	0.99	.4420		
8 oz glasses of bottled or vended water	Servings	1.00	.9723		
Used swimming pool	Times/3 days	0.90	.0836		
Main dietary sources (3 days prior to survey)					
Chicken	Ounces	0.97	.0765		
Brown rice or other cooked whole grains	Servings	1.12	.0355		
White rice	Servings	1.09	.0117	1.11	.0016
Fruit: fresh, frozen, canned	Servings	1.01	.6054		
Fruits or vegetables grown at home	Servings	1.03	.6968		
Glasses of 100% pure fruit juice	Servings	0.99	.4735		
Wine	Servings	1.05	.0021	1.05	.0012
Beer	Servings	1.02	.0161		

BMI = body mass index.

\*Weighted exponentiated least square means and exponentiated parameter estimates reported.

factor. We calculated bivariate associations using Rao–Scott chi-square tests or design-adjusted *t*-tests, with *p*-values reported.

Weighted analysis of covariance models compared the mean creatinine-adjusted arsenic levels by various risk factors. A final regression model was obtained using backwards

elimination of nonsignificant variables. For categorical variables, weighted least square geometric means (LSGM) for creatinine-adjusted urinary arsenic levels were reported with *F*-test *p*-values. For continuous variables, geometric mean ratios (GMR) and *F*-test *p*-values were reported. Finally, we conducted

a sensitivity analysis to determine if significant sources of urinary arsenic differed for those participants who abstained from consuming fish/seafood as requested in the 3 days prior to the study visit. All statistical analyses were performed with SAS version 9.3 software and based on a type I error rate of  $\alpha = .05$ .

## Results

Participants were excluded if they had not resided in the household 3 days prior to the study visit ( $n = 2$ ), had inadequate urine samples ( $n = 2$ ), or had purchased their own POE system ( $n = 6$ ), resulting in a loss of two households. After exclusions, 350 participants were available for analysis from 170 (49%) low-risk and 180 (51%) high-risk households.

Most participants were female (51%), 18–64 years (52%), White, non-Hispanic (90%), and had more than a high school education (61%). Almost 50% had an annual household income of \$35,000–\$74,999. Most were classified as overweight or obese (59%). No significant differences in these characteristics were seen by risk status (Table 1).

Most (99%) participants resided in Brooksville, Florida, in ZIP codes 34601 (28%) and 34602 (51%). Most owned their home (97%), with the average length of residence being 12.66 years ( $SE = 0.65$ ). More high-risk individuals resided in 36401 and 36402, and more low-risk individuals resided in other ZIP codes ( $p < .01$ ). Among high-risk individuals, 42% used a kitchen POU filter and 50% reported bottled water as their DEP-provided solution (Table 2).

### Potential Sources of Arsenic Exposure

Most respondents reported bottled water as their main source for drinking (51%) and unfiltered well water for cooking (51%); bathing or showering (98%); brushing teeth (95%); and gardening, irrigation, and landscaping (99%). Most people washed fruits and vegetables before consumption (95%) and reported not using herbicides or insecticides in the previous 3 days (74%). Many participants used homeopathic treatments/vitamins (58%) and owned a swimming pool (41%). One quarter of participants used or were exposed to tobacco products (25%). High-risk residents were significantly more likely to use bottled or filtered well water for drinking, cooking, and brushing teeth ( $p$ -values  $< .01$ ) (Table 2).

We calculated average servings of water and food items to determine their relative contributions to urinary arsenic (Table 3). Low-risk residents consumed more chicken (3.66 oz versus 2.91 oz;  $p = .05$ ) and unfiltered tap water (12.07 versus 0.95 glasses per 3-day period;  $p < .01$ ), and used their swimming pools more frequently (0.71 versus 0.23

times per 3-day period;  $p = .03$ ). High-risk residents consumed more filtered tap water (7.08 versus 1.66 glasses per 3-day period;  $p < .01$ ) and bottled or vended water (12.87 versus 7.47 glasses per 3-day period;  $p < .01$ ). No other significant differences were noted.

### Well Water and Urinary Arsenic Levels

The average household well water arsenic level, as tested by DEP, for all participants was 15.35  $\mu\text{g/L}$  ( $SE = 1.64$ ). The average for low-risk residents was 1.58  $\mu\text{g/L}$  ( $SE = 0.20$ ), significantly less than that found for high-risk residents, which was 29.65  $\mu\text{g/L}$  ( $SE = 3.17$ ;  $p < .01$ ).

Average urinary arsenic was not significantly different by risk status. The overall geometric mean was 8.27  $\mu\text{g/L}$  (95% confidence interval [CI] [7.54, 9.07]), and the overall creatinine-adjusted geometric mean was 7.99  $\mu\text{g/g}$  (95% CI [7.35, 8.69]). The creatinine-adjusted geometric mean was 7.68  $\mu\text{g/g}$  (95% CI [6.94, 8.51]) for high-risk and 8.30  $\mu\text{g/g}$  (95% CI [7.26, 9.49]) for low-risk individuals.

### Associations With Creatinine-Adjusted Urinary Arsenic Levels

Households with an annual income  $\geq \$75,000$  (LSGM: 9.65  $\mu\text{g/g}$ ;  $p = .02$ ) and those taking homeopathic treatments (LSGM: 8.61  $\mu\text{g/g}$ ;  $p = .05$ ) had higher levels of arsenic in their residents, while individuals who rented homes had lower levels (LSGM: 5.70  $\mu\text{g/g}$ ;  $p < .01$ ) than comparison groups. Individuals using filtered well water (LSGM: 9.18  $\mu\text{g/g}$ ) or unfiltered well water (LSGM: 8.32  $\mu\text{g/g}$ ) for cooking had higher levels than those using bottled water (LSGM: 6.71  $\mu\text{g/g}$ ;  $p = .02$ ) (Table 4).

Average urinary arsenic levels increased significantly as servings of fish, seafood, white rice, and wine increased, but decreased as fruit juice consumption and years in current home increased. As the serving size for fish and seafood increased by one ounce, the average urinary arsenic increased by 24% (both GMRs: 1.24;  $p < .0001$ ). Increases were smaller for white rice (GMR: 1.15;  $p = .01$ ) and wine (GMR: 1.06;  $p < .01$ ). Urinary arsenic decreased as consumption of tap water outside of the home increased (GMR: 0.98;  $p = .02$ ), years in current home increased (GMR: 0.99;  $p = .01$ ), and consumption of fruit juice increased (GMR: 0.98;  $p = .04$ ). In the final multivariable model, household income; own

or rent home; years in current home; consumption of tap water outside the home; and fish, seafood, white rice, and wine consumption remained significant predictors of creatinine-adjusted urinary arsenic levels (Table 4).

Similar relationships were identified in the sensitivity analysis (Table 5). In bivariate models, high school education or higher; household income of  $\geq \$75,000$ ; not owning or renting the residence; use of homeopathic treatments or vitamins; and consuming brown rice or other cooked whole grains, white rice, wine, and beer were significantly associated with increased urinary arsenic. Education, brown rice consumption, and beer consumption were also significantly associated with increased urinary arsenic, but not in the main analysis. Furthermore, cooking water, years in current home, glasses of tap water outside the home, and glasses of 100% pure fruit juice were not significantly associated with arsenic as in previous analyses. In multivariable models, only income, owning or renting the residence, and consumption of white rice and wine remained significant.

## Discussion

Long-term exposure to arsenic is related to an increased risk of many types of cancer, cardiovascular disease, diabetes mellitus, neurodevelopmental disorders, and reproductive effects (Ahsan et al., 2006; Chen et al., 2011; Farzan et al., 2015; Gilbert-Diamond et al., 2011; James et al., 2015; Jiang et al., 2015; Jones, Tellez-Plaza, Sharrett, Guallar, & Navas-Acien, 2011; Quansah et al., 2015). We conducted this analysis to better understand other arsenic sources in a population exposed to higher levels of well water arsenic. There was no difference in total creatinine-adjusted urinary arsenic and few differences in consumption patterns by household risk status. Compared with national estimates from the 2011–2012 U.S. National Health and Nutrition Examination Survey (NHANES), creatinine-adjusted arsenic in our study was in good agreement (study: 7.99  $\mu\text{g/g}$  versus NHANES: 7.77  $\mu\text{g/g}$ ) (CDC, 2015). Nonwater-related risk factors contributed to higher arsenic levels among participants, regardless of household risk status.

Various socioeconomic and household-level factors were associated with urinary arsenic levels, including years living in current home, household income, and home

ownership in this study. For every 1 year in the current home, urinary arsenic decreased by 1%, suggesting that individuals living in the area for longer might be more aware of risk and might be taking measures to reduce their household level exposure.

Individuals reporting higher household income had higher urinary arsenic. Socioeconomic status is widely recognized as being associated with dietary intake and nutrition. While we did control for known arsenic-containing foods and intake of water, other sources might have been overlooked. Other studies have found links between higher socioeconomic status and higher urinary arsenic (Saoudi et al., 2012; Tyrrell, Melzer, Henley, Galloway, & Osborne, 2013). One study found seafood consumption was an important mediator between arsenic and socioeconomic status (Tyrrell et al., 2013). Household income remained significant in our sensitivity analysis.

Consumption of contaminated drinking water is a known contributor to urinary arsenic levels (Roberge et al., 2012). We found high-risk residents were more likely to use bottled or filtered water for drinking, cooking, and brushing teeth than lower-risk individuals. In adjusted analyses, increased consumption of tap water outside of home was associated with decreased urinary arsenic, suggesting that individuals likely are consuming water at work or school from public water systems in which contaminant levels are highly regulated. No other water consumption/use variables were associated with urinary arsenic; furthermore, consumption of tap water outside the home was not a significant predictor in sensitivity analyses.

Several food sources are associated with arsenic exposure. Probabilistic exposure modeling has been used to determine major food contributors to arsenic intake using NHANES data. These results suggest that total and inorganic arsenic exposure from food is 14 and 2 times higher than exposure from drinking water, respectively. Specifically, vegetables (24%); fruit juices and fruits (18%); rice (17%); beer and wine (12%); and flour, corn, and wheat (11%) contribute significant amounts of daily inorganic arsenic (Xue, Zartarian, Wang, Liu, & Georgopoulos, 2010).

Our study also assessed food and beverage consumption. Fruits, vegetables, and

fruit juices were not significant contributors, though several others were identified. Beer was also not significant, but wine was, as in other studies (Lovreglio et al., 2012; Saoudi et al., 2012). Arsenic in wine might be related to contamination from agricultural chemical applications or transfer of arsenic from the soil to the grapes. Arsenic concentrations are higher in red wines than white wines (Bertoldi, Villegas, Larcher, Santato, & Nicolini, 2013), which we did not assess.

White rice consumption is an important source of arsenic exposure (Gilbert-Diamond et al., 2011; Li, Sun, Williams, Nunes, & Zhu, 2011; Xue et al., 2010), accounting for approximately 17% of daily inorganic arsenic intake in the U.S. (Xue et al., 2010) and as much as 60% in certain U.S. subpopulations (Li et al., 2011). Our study showed increased urinary arsenic associated with white rice consumption, which is the highest contributor after fish and seafood consumption.

Fish and seafood consumption are known sources of organic arsenic; however, they might also contribute small amounts of inorganic arsenic (Navas-Acien, Francesconi, Silbergeld, & Guallar, 2011). In our study, we requested that participants abstain from fish and seafood consumption in the 3-day period prior to sampling. Not all participants complied, according to self-reported dietary history. Analysis for the total population showed fish and seafood consumption were the biggest contributors to total urinary arsenic, even with less than 15% of our participants reporting consumption. Several other factors remained significant in the sensitivity analysis, indicating their importance as potential sources of arsenic exposure.

There are a few limitations that should be noted. We used total urinary arsenic as our outcome, though adverse health outcomes are associated with inorganic arsenic. Speciated results were obtained for a few individuals with high (>30 µg/L) total urinary arsenic; the predominant species (86%) was arsenobetaine, an organic species found in shellfish. Approximately 15% of participants did not follow our request to abstain from fish and seafood consumption, which we addressed in sensitivity analyses. Finally, we relied on self-reported data, so some measurement error or recall bias is possible; however, we tried to minimize potential biases by assessing consumption in the 3-day period prior to sampling.

## Conclusion

These results indicate that the provision of POU filters and bottled water to the higher-risk households seems to provide adequate protection from arsenic exposure from well water, as average urinary arsenic levels did not differ by household risk status. Additionally, we could find few studies that linked biomonitoring with environmental data (e.g., private well sampling results) and consumption information (i.e., food, water, and other beverages) that also have a comparison group. We did find dietary and socioeconomic factors were associated with increased urinary arsenic, beyond the potential risk of exposure through drinking water. Further studies are needed to more closely examine important contributors to inorganic arsenic exposure specifically in this population. 🐼

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References *continued from page 31*

- Agency for Toxic Substances and Disease Registry. (2007). *Toxicological profile for arsenic*. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. Retrieved from <https://www.atsdr.cdc.gov/pbs/pbs.asp?id=18&tid=3>
- Ahsan, H., Chen, Y., Parvez, F., Argos, M., Hussain, A.I., Momotaj, H., . . . Graziano, J. (2006). Health Effects of Arsenic Longitudinal Study (HEALS): Description of a multidisciplinary epidemiologic investigation. *Journal of Exposure Science & Environmental Epidemiology*, *16*(2), 191–205.
- Bertoldi, D., Villegas, T.R., Larcher, R., Santato, A., & Nicolini, G. (2013). Arsenic present in the soil-vine-wine chain in vineyards situated in an old mining area in Trentino, Italy. *Environmental Toxicology and Chemistry*, *32*(4), 773–779.
- Centers for Disease Control and Prevention. (2012). *Urine multi-element ICP-DRC-MS, method 3018A.2 (total arsenic)*. Retrieved from [https://www.cdc.gov/nchs/data/nhanes/nhanes\\_11\\_12/uhm\\_g\\_met\\_heavy\\_metals.pdf](https://www.cdc.gov/nchs/data/nhanes/nhanes_11_12/uhm_g_met_heavy_metals.pdf)
- Centers for Disease Control and Prevention. (2015). *Fourth national report on human exposure to environmental chemicals, updated tables, February 2015*. Atlanta, GA: Author.
- Chen, Y., Graziano, J.H., Parvez, F., Liu, M., Slavkovich, V., Kalra, T., . . . Ahsan, H. (2011). Arsenic exposure from drinking water and mortality from cardiovascular disease in Bangladesh: Prospective cohort study. *BMJ*, *342*, d2431.
- Farzan, S.F., Chen, Y., Wu, F., Jiang, J., Liu, M., Baker, E., . . . Karagas, M.R. (2015). Blood pressure changes in relation to arsenic exposure in a U.S. pregnancy cohort. *Environmental Health Perspectives*, *123*(10), 999–1006.
- Gilbert-Diamond, D., Cottingham, K.L., Gruber, J.F., Punshon, T., Sayarath, V., Gandolfi, A.J., . . . Karagas, M.R. (2011). Rice consumption contributes to arsenic exposure in U.S. women. *Proceedings of the National Academy of Sciences*, *108*(51), 20656–20660.
- James, K.A., Byers, T., Hokanson, J.E., Meliker, J.R., Zerbe, G.O., & Marshall, J.A. (2015). Association between lifetime exposure to inorganic arsenic in drinking water and coronary heart disease in Colorado residents. *Environmental Health Perspectives*, *123*(2), 128–134.
- Jiang, J., Liu, M., Parvez, F., Wang, B., Wu, F., Eunus, M., . . . Chen, Y. (2015). Association between arsenic exposure from drinking water and longitudinal change in blood pressure among HEALS cohort participants. *Environmental Health Perspectives*, *123*(8), 806–812.
- Jones, M.R., Tellez-Plaza, M., Sharrett, A.R., Guallar, E., & Navas-Acien, A. (2011). Urine arsenic and hypertension in U.S. adults: The 2003–2008 National Health and Nutrition Examination Survey. *Epidemiology*, *22*(2), 153–161.
- Jordan, M., DuClos, C., Kintziger, K., Gray, A., & Bonometti, M.A. (2015). Using an environmental public health tracking biomonitoring study to validate safe water restoration efforts in Florida. *Journal of Public Health Management and Practice*, *21*(Suppl. 2), S75–79.
- Kuczmarowski, R.J., Ogden, C.L., Guo, S.S., Grummer-Strawn, L.M., Flegal, K.M., Mei, Z., . . . Johnson, C.L. (2002). 2000 CDC growth charts for the United States: Methods and development. *Vital Health Statistics*, *11*(246), 1–190.
- Li, G., Sun, G.X., Williams, P.N., Nunes, L., & Zhu, Y.G. (2011). Inorganic arsenic in Chinese food and its cancer risk. *Environment International*, *37*(7), 1219–1225.
- Lovreglio, P., D'Errico, M.N., De Pasquale, P., Gilberti, M.E., Drago, I., Panuzzo, L., . . . Soleo, L. (2012). Environmental factors affecting the urinary excretion of inorganic arsenic in the general population. *La Medicina del Lavoro*, *103*(5), 372–381.
- Navas-Acien, A., Francesconi, K.A., Silbergeld, E.K., & Guallar, E. (2011). Seafood intake and urine concentrations of total arsenic, dimethylarsinate and arsenobetaine in the U.S. population. *Environmental Research*, *111*(1), 110–118.
- Quansah, R., Armah, F.A., Essumang, D.K., Luginaah, I., Clarke, E., Marfoh, K., . . . Dzodzomenyo, M. (2015). Association of arsenic with adverse pregnancy outcomes/infant mortality: A systematic review and meta-analysis. *Environmental Health Perspectives*, *123*(5), 412–421.
- Roberge, J., O'Rourke, M.K., Meza-Montenegro, M.M., Gutiérrez-Millán, L.E., Burgess, J.L., & Harris, R.B. (2012). Binational arsenic exposure survey: Methodology and estimated arsenic intake from drinking water and urinary arsenic concentrations. *International Journal of Environmental Research and Public Health*, *9*(4), 1051–1067.
- Saoudi, A., Zeghnoun, A., Bidondo, M.L., Garnier, R., Cirimele, V., Persoons, R., & Fréry, N. (2012). Urinary arsenic levels in the French adult population: The French National Nutrition and Health Study, 2006–2007. *The Science of the Total Environment*, *433*, 206–215.
- Tyrrell, J., Melzer, D., Henley, W., Galloway, T.S., & Osborne, N.J. (2013). Associations between socioeconomic status and environmental toxicant concentrations in adults in the USA: NHANES 2001–2010. *Environment International*, *59*, 328–335.
- U.S. Environmental Protection Agency. (1994). *EPA Method 200.8: Determination of trace elements in waters and wastes by inductively coupled plasma-mass spectrometry* (Revision 5.4). Retrieved from <https://www.epa.gov/homeland-security-research/epa-method-2008-determination-trace-elements-waters-and-wastes>
- U.S. Environmental Protection Agency. (2007). *Inorganic arsenic: TEACH chemical summary*. Retrieved from <https://archive.epa.gov/region5/teach/web/html/teachsummaries.html>
- Xue, J., Zartarian, V., Wang, S.-W., Liu, S.V., & Georgopoulos, P. (2010). Probabilistic modeling of dietary arsenic exposure and dose and evaluation with 2003–2004 NHANES data. *Environmental Health Perspectives*, *118*, 345–350.



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# Persistence of Bowl Water Contamination During Sequential Flushes of Contaminated Toilets

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**Abstract** Toilets contaminated with infectious organisms are a recognized contact disease transmission hazard. Previous studies indicate that toilet bowl water can remain contaminated for several flushes after the contamination occurs. This study characterized contamination persistence over an extended series of flushes using both indicator particles and viable bacteria. For this study, toilets were seeded with microbe-size microbial surrogates and with *Pseudomonas fluorescens* or *Clostridium difficile* bacteria and flushed up to 24 times. Bowl water samples collected after seeding and after each flush indicated the clearance per flush and residual bowl water contaminant concentration. Toilets exhibited 3 + log<sub>10</sub> contaminant reductions with the first flush, only 1–2 logs with the second flush, and less than 1 log thereafter. Contamination still was present 24 flushes postcontamination. Clearance was modeled accurately by a two-stage exponential decay process. This study shows that toilet bowl water will remain contaminated many flushes after initial contamination, posing a risk of recurring environmental contamination and associated infection incidence.

## Introduction

Toilets splash and produce droplet aerosols when flushed. Aerosolization of microorganisms from contaminated toilets during toilet flushing has repeatedly been demonstrated for various toilet types and organisms during the past 50 years, as reviewed by Johnson, Mead, and coauthors (2013). Large droplet as well as droplet nuclei bioaerosols are produced and can contaminate nearby surfaces and the room air (Barker & Bloomfield, 2000; Barker & Jones, 2005; Bound & Atkinson, 1966; Darlow & Bale, 1959; Gerba, Wallis, & Melnick, 1975; Jessen, 1955; Johnson, Lynch, Marshall, Mead, & Hirst, 2013; Scott & Bloomfield, 1985; Verani, Bigazzi, & Carducci, 2014; Yahya, Cassells, Straub, & Gerba, 1992). This route is a well-recognized

contact disease transmission hazard (Schulster, Chinn, Centers for Disease Control and Prevention, & Healthcare Infection Control Practices Advisory Committee, 2003).

It has been observed that toilet bowl water will remain contaminated for at least several flushes after the initial contamination, and microbial contamination can persist for days or weeks. Barker and Bloomfield (2000) detected residual microorganisms in bowl water 12 days after seeding the toilet with *Salmonella*, and in biofilm below the bowl waterline for 50 days after the seeding, suggesting a possible role of biofilm as a long-term reservoir and source of pathogenic organisms in the bowl water. Contaminated toilets will produce microbe-carrying aerosols during each flush (Barker & Jones, 2005; Darlow & Bale, 1959;

Gerba et al., 1975; Yahya et al., 1992), with associated environmental re-contamination.

A particularly interesting observation by Gerba and coauthors (1975) was that bowl water clearance was incomplete even after seven flushes following contamination of a toilet with either *E. coli* bacteria or MS2 bacteriophage. They measured approximately 3 logs (1,000-fold) concentration reduction with their first flush after seeding, but only approximately 2 logs with the second flush and less than 1 log with subsequent flushes, consistent with previous and subsequent reports for *E. coli* (Darlow & Bale, 1959; Yahya et al., 1992), for *E. coli* and *Serratia marcescens* (Barker & Jones, 2005), and for *E. coli* and MS2 bacteriophage (Gerba et al., 1975). Indeed, Gerba and coauthors found that after the first three flushes, an apparent “plateau” bowl water concentration was reached that did not visibly decline over the next four flushes. The investigators attributed this effect to microbial adhesion to toilet bowl surfaces with subsequent re-release after the flush. We could find no reports of research to duplicate and further examine this contamination persistence phenomenon.

Clearly, the persistence of pathogenic microorganisms in a public toilet (such as in a hospital emergency department waiting area), with aerosolization of pathogenic organisms during subsequent toilet uses by others, could pose a contact- or airborne-disease transmission risk. Similarly, patho-

TABLE 1

**Experimental Conditions**

Toilet Type	Flush Volume Condition	# of Flushes	Particle	Replicate Trials
PAT	Low	12	0.25 µm FM	1
	High			1
HET	Low	24	0.25 µm FM	3
			0.5 µm FM	3
			1.0 µm FM	3
	High	4	0.25 µm FM	3
HET	Low	24	<i>Pseudomonas fluorescens</i>	3
	High			3
FOM	–	24	0.25 µm FM	1
FOM	–	24	<i>Pseudomonas fluorescens</i>	6
FOM	–	24	<i>Clostridium difficile</i>	3

PAT = pressure-assisted toilet; HET = high efficiency gravity flow toilet; FOM = flushometer toilet; FM = fluorescent polymer microspheres.

gen persistence in a patient room toilet with subsequent aerosolization of microbes could pose an environmental contamination risk to patient care staff and other patients.

The purpose of our study was to characterize bowl clearance over an extended series of flushes following initial contamination for several modern toilets. Series of up to 24 flushes postcontamination were conducted using microbe-size fluorescent polymer microspheres, *Pseudomonas fluorescens* bacteria, and *Clostridium difficile* bacteria. The results were compared with those of previous studies with microbial suspensions and also mathematically modeled as a two-stage exponential decay process.

## Methods

### Toilets Selected

The three toilet types selected for our study were a dual flush volume high efficiency gravity flow toilet (HET) with selectable flush volumes of either ~3.9 or ~5.3 liters per flush (Lpf), a dual flush volume pressure-assisted toilet (PAT) of either ~4.2 or ~5.1 Lpf, and a commercial type flushometer (FOM) toilet of ~5.5 Lpf. The HET operates by gravity flow of water from a tank mounted at the rear of the toilet base, whereas the FOM operates via a direct con-

nection to the main water supply and has no tank. The familiar FOM toilets are commonly found in commercial, educational, healthcare, and other public access facilities. The PAT is a fairly recent innovation that employs a pressure vessel inside the toilet tank to provide a more vigorous flush than can be achieved by gravity flow alone, though the flush is less vigorous than that of the FOM (Johnson, Mead, Lynch, & Hirst, 2013). All three toilets were of the siphonic type, in which flush water enters the bowl bottom as a submerged jet directed toward the S-shaped outlet trapway, inducing a siphon effect that empties the bowl. A secondary flush water flow passes through perforations spaced around the underside of the bowl rim and rinses the bowl walls during the flush. When water flow stops, the siphon breaks and stops the flush, with some water in the trapway flowing back into the bowl. All three toilet models had been evaluated under the U.S.–Canadian Maximum Performance (MaP) program that tests the clearance performance of toilets using a standard protocol, and achieved the highest MaP clearance performance rating (Gauley & Koeller, 2009).

### Fluorescent Microsphere Surrogates

Microbial contamination was simulated using monodisperse suspensions of green fluores-

cent polymer microspheres of microbial size 0.25, 0.5, or 1.0 µm after the method of Johnson and Lynch (2008). The toilet bowl water was seeded with a 1 mL aliquot of 1% by volume source suspension and a water sample was collected after mixing. We collected an additional sample within approximately three minutes after each subsequent flush without reseeded. The toilets were installed in a test apparatus that allowed flushed water to be captured for volume measurement. An aliquot of each water sample, diluted as necessary, was filtered through a 25 mm diameter 0.2 µm pore size mixed cellulose ester (MCE) filter. The filter then was removed and mounted on an oversized 75 x 38 mm microscope slide for top-illumination viewing and particle counting using a Nikon Model Eclipse 80i fluorescence microscope fitted with 10x, 20x, and 40x (Plan-Apochromat) objectives.

Particles were counted manually with magnification (10–40x) and field number (10–75) based on particle size and deposition density. For slides with less than one sphere per field, either half or the entire filter was counted. The particle count divided by the aliquot volume and multiplied by the dilution factor (if any) provided an estimate of the suspension concentration in each water sample. The base-10 logarithm of the ratio of preflush to postflush concentrations was a measure, in logs, of toilet clearance.

In order to avoid potential interferences by naturally occurring fluorescent particles that might be present in the main water supply, flush water was prefiltered. For the HET and PAT toilets, we accomplished this by placing a high efficiency cartridge filter in the water supply line. For the FOM toilet, which requires a 1-inch diameter supply line to the flush valve and has a high flow rate, provision of filtered water at a suitable flow rate required using a pressurized tank storage system. Main water at a pressure of 55–70 psi was passed through a high efficiency cartridge filter to a 20-gallon pressure tank for storage until needed for a flush. A 1-inch supply line connected the tank to the toilet. Samples of the filtered water verified that it was particle free. Clearance was assessed for the conditions shown in Table 1.

### *P. fluorescens* and *C. difficile*

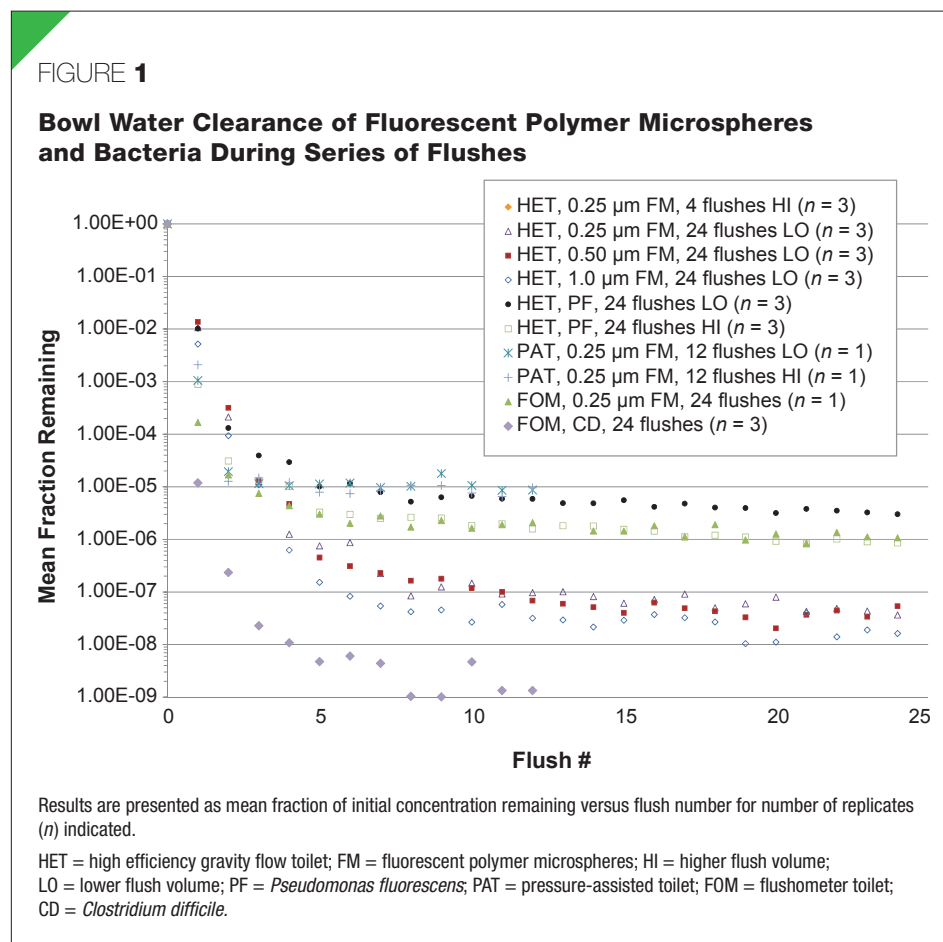
The HET or FOM toilet was seeded with a suspension of either *P. fluorescens* bacteria or a

nontoxic strain of *C. difficile* and flushed 24 times at either the higher or lower flush volume. We obtained University of Oklahoma Biosafety Committee approval prior to commencement of the work. *P. fluorescens* produces greenish-yellow colonies on Kings B agar that fluoresce brightly under 365 (nm) wavelength ultraviolet light. *P. fluorescens* was isolated on tryptic soy agar, inoculated in tryptic soy broth, and incubated at 28 °C for 48 hr. The bacteria/broth suspension was diluted with additional broth until a turbidity of 26 nephelometric turbidity units (NTUs) was reached, as measured using a turbidimeter. This resulted in a source seed suspension concentration of  $\sim 1.5 \times 10^{10}$  bacteria/mL.

*C. difficile* was inoculated into a Cooked Meat Medium and incubated at 37 °C under anaerobic conditions for 48 hr. The bacteria/medium suspension was diluted with additional medium until a turbidity of 100 formazin attenuation units (FAU) was reached, as measured using a Hach DR/890 colorimeter. This resulted in a source seed suspension of 3 to 4 x 10<sup>8</sup> CFUs/mL.

Prior to seeding, we disinfected the toilet bowl by pouring bleach in the bowl and allowing it to sit overnight. The chlorine concentration was approximately 5,000 mg/L (5,000 ppm) in the bowl. We flushed the toilet a minimum of 10 times to clear the chlorine, and then tested the water for total chlorine using a Chlorine Pocket Colorimeter II. We took a 50-mL toilet tank water sample before the initial seeding for microbial plating to verify the absence of the study microbe in the supplied flush water. We then seeded the bowl water with 50 mL of source suspension and stirred, and took the first (preflush) 50-mL water sample. We resampled the bowl water at approximately three minutes after each of the subsequent 24 flushes, and took another tank sample after the 24th flush. A fraction of residual chlorine, typically less than 0.05 ppm, entered the bowl with each flush due to the chlorine content of the main water supply; therefore, samples were dechlorinated with the addition of one drop of sodium thiosulfate solution. We measured the volume of ejected water after each flush. We performed three to six replicate trials at each flush condition.

We filtered each 15-mL water sample utilizing the membrane filtration tech-



nique (Messer & Dufour, 1998). We diluted samples from each flush to avoid cultures that were too numerous to count (TNTC). Diluted samples were filtered through 47 mm diameter 0.45 µm pore size MCE membrane filters utilizing a three-place vacuum filtration manifold and disposable filter cups. For *P. fluorescens*, we placed each filter on Kings B agar and incubated them at 28 °C for 24 hr (Alemu & Alemu, 2013). We observed colonies on slower-growing plates again 48 hr after filtration. We counted colonies under ultraviolet light at 365 nm. For *C. difficile*, each filter was placed on cycloserine-cefoxitin-fructose agar with sodium taurocholate medium and cultured anaerobically at 37 °C for 48 hr, after which colonies were counted. We also observed plates after 72 hr to confirm counts.

We calculated bowl water concentration in CFUs/mL from the plate count, dilution factor, and volume filtered. We performed scoping trials to determine the dilutions needed to ensure a countable filter for each water

sample. Only the preflush and first few post-flush samples required dilution.

**Results**

Approximate mean flush volumes for the lower (LO) and higher (HI) flush volume conditions for the dual-flush toilets were HET LO 3.9 Lpf, HET HI 5.2 Lpf, PAT LO 4.1 Lpf, and PAT HI 4.9 Lpf. The FOM mean flush volume was approximately 5.5 Lpf.

Figure 1 presents bowl water concentration decay results expressed as fraction of initial concentration remaining (mean of all trials). For all toilets, all flush conditions, and all particle suspensions except *C. difficile*, the toilet bowl water remained contaminated throughout the extended series of flushes. Fractional clearance patterns were similar, though not identical, for all conditions, with ~3 logs particle concentration reduction with the first flush, ~1–2 logs reduction with the second flush, and <1 log reductions thereafter. This pattern is consistent with findings reported by others for *S. marcescens* (Barker

TABLE 2

**Cumulative Bowl Water Clearance by Flush Number (Logs\*)**

Toilet Type and Suspension	4 Flushes		12 Flushes		24 Flushes	
	LO	HI	LO	HI	LO	HI
PAT 0.25 µm FM	5.0	5.0	5.1	5.0	–	–
FOM 0.25 µm FM	–	5.4	–	5.7	–	6.0
HET 0.25 µm FM	5.9	5.0	7.0	--	7.4	–
HET 0.5 µm FM	5.3	–	7.2	–	7.3	–
HET 1.0 µm FM	6.2	–	7.5	–	7.8	–
HET PF	4.5	5.4	5.2	5.8	5.5	6.0
FOM PF	5.1		5.6		5.6	
FOM CD	8.0		8.9		ND	

\*Calculated as  $\log_{10}$  (1/fraction remaining after  $n$  flushes).  
 PAT = pressure-assisted toilet; FM = fluorescent polymer microspheres; FOM = flushometer toilet; HET = high efficiency gravity flow toilet; PF = *Pseudomonas fluorescens*; CD = *Clostridium difficile*; LO = lower flush volume; HI = higher flush volume; ND = none detected.

& Jones, 2005; Darlow & Bale, 1959), *E. coli* (Gerba et al., 1975; Yahya et al., 1992), and MS2 bacteriophage (Gerba et al., 1975). Cumulative reductions for the first two flushes were typically 4–5 logs. *C. difficile* appeared to clear faster and more completely than either microspheres or *P. fluorescens* in the FOM toilet, and was not detected after the 12th flush. The pattern of persistence exhibited only gradual concentration decline after the first several flushes, consistent with observations by Gerba and coauthors (1975) for seven-flush experiments with *E. coli* and MS2 bacteriophage. The 3 logs first flush concentration reductions exceeded what would be expected for simple dilution even with perfect mixing, indicating an essentially “plug flow” clearance action as suggested by Darlow and Bale (1959). Cumulative clearances through 4, 12, and 24 flushes varied by toilet type, flush condition, and particle type as shown in Table 2.

## Discussion

These concentration decay patterns observed by Yahya and coauthors (1992) for 3 flushes with *E. coli*, by Barker and Jones (2005) for 4 flushes with *S. marcescens*, and by Gerba and coauthors (1975) for 7 flushes with *E. coli* and MS2 bacteriophage were replicated in several toilet types for 4–24 flushes with

fluorescent microspheres of various sizes and for up to 24 flushes with two types of viable bacteria. For both microspheres and bacteria, there was a rapid initial decline in the first two flushes, totaling generally ~5 logs, but only gradual concentration decline thereafter. The continuing gradual decline, not discernible by Gerba and coauthors (1975) in their 7-flush experiments, was seen to continue throughout the 24-flush series.

The apparent faster attenuation of *C. difficile* counts relative to *P. fluorescens* can be explained by a number of factors: 1) *C. difficile* might have a reduced affinity for attaching to bowl surfaces (less surface charge), 2) *C. difficile* might be more prone to exist as clumps of cells that are easier to flush due to their larger size, or 3) recovery of *C. difficile* might be lower due to culture methods. *P. fluorescens* colonies are easy to detect visually due to their fluorescent nature, while *C. difficile* colonies are more visually obscure. Furthermore, the recovery of *C. difficile* has been shown to vary among different culture media. The taurocholate cycloserine cefoxitin agar medium used in this study has been shown to have lower recoverability for *C. difficile* than some other media (Carson, Boseiwaqa, Thean, Foster, & Riley, 2013; Eckert, Burghoffer, Lalande, & Barbut, 2013). Nevertheless, we observed *C.*

*difficile* to persist in the toilet for at least 12 flushes. This persistent bowl water contamination over an extended number of flushes has clear implications for infectious disease transmission risk should the contaminant be a pathogen that can survive under bowl water conditions, such as *C. difficile*.

The physics of the toilet flush is fairly simple, and it would be expected that fractional clearance would be consistent across flushes. As shown in this and other works, however, it clearly is not consistent. Surface adhesion with subsequent resuspension to the bowl water after the flush seems the most plausible explanation for persistent bowl water contamination, and the similar behavior of inert polymer microspheres and bacteria suggests a physical rather than biological attachment mechanism.

Our water samples were collected within a few minutes of the flush, so resuspension would have to be occurring rapidly. It was unclear, however, whether such resuspension might be limited to a sudden event corresponding to the time period of fluid shear (i.e., the flush duration) or perhaps might continue for some longer time. To explore this question, we conducted a simple follow-up experiment in which we seeded a toilet, flushed four times, and collected bowl water samples from the center of the bowl approximately 2 in. below the water surface at intervals for 30 min following the fourth flush. The results indicated an ongoing resuspension of particles for at least 30 min after the flush, with a doubling of bowl water concentration in that time, from ~300–600 particles/mL, in a linear manner (data not shown). The resuspension might therefore be occurring in a two-phase manner—a rapid release during and/or immediately after the flush, plus a more gradual but still substantial release in the undisturbed bowl water for some period thereafter, likely from submerged bowl surfaces.

The clearance data were modeled from first principles as a two-stage exponential decay due to flush clearance and erosion of an adhered surface layer. Solution of the resulting differential equation yielded:

$$C(x) = \left( C_0 - \frac{R_0}{a-b} \right) e^{-ax} + \frac{R_0}{a-b} e^{-bx}$$

where  $x$  is the flush number,  $C_0$  is the initial bowl water concentration (particles or

CFUs/mL measured),  $R_0$  is an estimated initial reseeded potential (particles or CFUs/mL), and  $a$  and  $b$  are empirical constants that would be a function of the experimental conditions (particle type, toilet type, and flush condition). Least squares fit on the logarithms of the concentrations using Excel Solver for each data set resulted in fits similar to those shown in Figure 2 ( $R^2 > .97$ ) for all but one trial). The model does not contain a third term to account for the continued release after the flush, which should improve the fit.

### Implications for Infectious Disease Transmission in Healthcare Settings

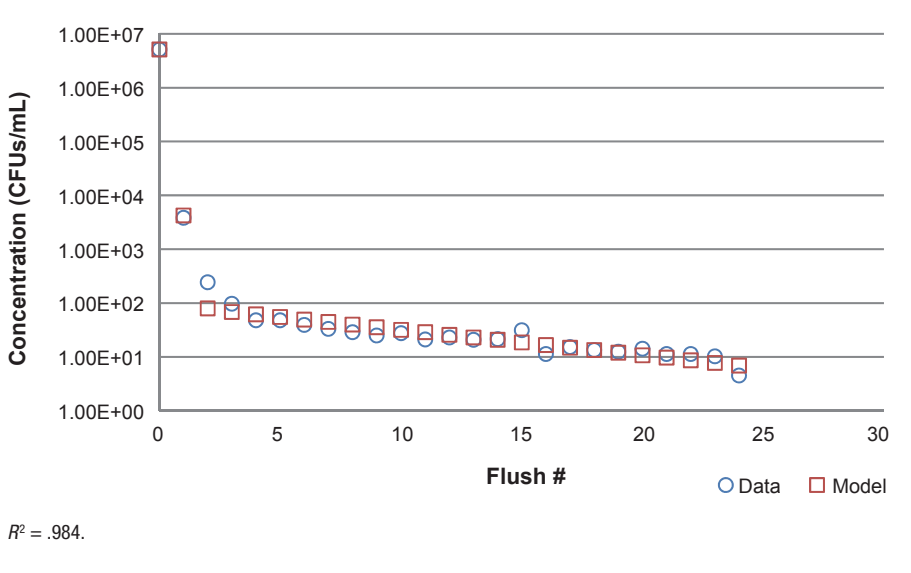
The persistence of bowl water contamination over many flushes after an initial toilet contamination has important implications for infectious disease transmission in healthcare and other facilities. As reviewed by Johnson, Mead, and coauthors (2013), numerous studies have shown that flushing a contaminated toilet will produce droplet and droplet nuclei bioaerosols that can contaminate surfaces and expose persons by contact or air currents. Multiple flushes of a given toilet will occur between cleaning and sanitation even in a healthcare setting, and once contaminated, the toilet will produce bioaerosols with each flush. This information could be particularly important in a healthcare environment if the toilet is used by a patient with, for example, *C. difficile* or norovirus infection. Sethi and coauthors (2010) reported pretreatment fecal loadings of  $10^5$ – $10^6$  *C. difficile* per g of stool in symptomatic patients, while Atmar and coauthors (2008) reported  $10^8$ – $10^9$  norovirus per g of stool, and Caul (1994) reported  $10^6$  norovirus per mL of vomit. The potential for droplet and droplet nuclei aerosolization of these and other gastrointestinal pathogens during sequential flushes of a contaminated toilet, with the associated surface contamination and airborne transport, has not yet been characterized and would be a worthwhile avenue of future research.

### Conclusion

The sequential flush data developed in this work for three different toilet types using viable bacteria and nonviable surrogate particles showed a consistent bowl water clearance pattern that was quite similar to

FIGURE 2

**Modeled and Observed Bowl Water Clearance for *Pseudomonas fluorescens* in Flushometer Toilet Obtained via a Least Squares Fitting Procedure on the Logarithms of the Concentrations**



that reported by other investigators using bacteria and bacteriophages. The clearance pattern in this and other studies suggests a robust and persistent auto-reseeding mechanism that likely involves surface adhesion of particles with subsequent resuspension to the bowl water during and after the flush. The exact auto-reseeding mechanism could not be determined from these data, but it seems likely that a two-phase physical process of surface adhesion and subsequent detachment by hydrodynamic fluid shear during the flush, followed by a slower particle release over many minutes, might be at play. The similarity in clearance patterns for inert polymer microspheres and viable bacteria suggests a physical rather than biological attachment mechanism.

The implication of these results is clear: contaminated toilets are a potential source of recurring surface contamination and droplet nuclei bioaerosol production that could be contributing to healthcare-associated infections. A single toilet flush produces thousands of aerosol droplets, hundreds to thousands of which entrain microbes as large as bacteria and subsequently evaporate to droplet nuclei size and remain airborne for extended periods. It seems highly improb-

able that such droplet and droplet nuclei bioaerosols produced by toilets contaminated with gastrointestinal pathogens would not be contributors to healthcare-associated infection incidence, especially for persistent spore-formers such as *C. difficile*. Additional research is needed to characterize the mechanism of persistent bowl water contamination and identify means to control it, thereby minimizing toilet flush bioaerosol generation and the risk of toilet-related infectious disease transmission by contact or airborne routes. 🦠

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## References

- Alemu, E., & Alemu, T. (2013). Antifungal activity of secondary metabolites of *Pseudomonas fluorescens* isolates as a biocontrol agent of chocolate spot disease (*Botrytis fabae*) of faba bean in Ethiopia. *African Journal of Microbiology Research*, 7(47), 5364–5373.
- Atmar, R.L., Opekun, A.R., Gilger, M.A., Estes, M.K., Crawford, S.E., Neill, F.H., & Graham, D.Y. (2008). Norwalk virus shedding after experimental human infection. *Emerging Infectious Diseases*, 14(10), 1553–1557.
- Barker, J., & Bloomfield, S.F. (2000). Survival of *Salmonella* in bathrooms and toilets in domestic homes following salmonellosis. *Journal of Applied Microbiology*, 89(1), 137–144.
- Barker, J., & Jones, M.V. (2005). The potential spread of infection caused by aerosol contamination of surfaces after flushing a domestic toilet. *Journal of Applied Microbiology*, 99(2), 339–347.
- Bound, W.H., & Atkinson, R.I. (1966). Bacterial aerosol from water closets. A comparison of two types of pan and two types of cover. *Lancet*, 287(7451), 1369–1370.
- Carson, K.C., Boseiwaqa, L.V., Thean, S.K., Foster, N.F., & Riley, T.V. (2013). Isolation of *Clostridium difficile* from faecal specimens—A comparison of chromID *C. difficile* agar and cycloserine-cefoxitin-fructose agar. *Journal of Medical Microbiology*, 62(Pt. 9), 1423–1427.
- Caul, E.O. (1994). Small round structured viruses: Airborne transmission and hospital control. *Lancet*, 343(8908), 1240–1242.
- Darlow, H.M., & Bale, W.R. (1959). Infective hazards of water-closets. *Lancet*, 1(7084), 1196–1200.
- Eckert, C., Burghoffer, B., Lalande, V., & Barbut, F. (2013). Evaluation of the chromogenic agar chromID *C. difficile*. *Journal of Clinical Microbiology*, 51(3), 1002–1004.
- Gauley, W., & Koeller, J. (2009). *Maximum performance (MaP) testing of popular toilet models* (15th ed.). Retrieved from [http://www.allianceforwaterefficiency.org/uploadedFiles/Resource\\_Center/Library/products/MaP/MaP\\_15/Map-15th-edition-Full-Rpt-2009-10-20.pdf](http://www.allianceforwaterefficiency.org/uploadedFiles/Resource_Center/Library/products/MaP/MaP_15/Map-15th-edition-Full-Rpt-2009-10-20.pdf)
- Gerba, C.P., Wallis, C., & Melnick, J.L. (1975). Microbiological hazards of household toilets: Droplet production and the fate of residual organisms. *Applied Microbiology*, 30(2), 229–237.
- Jessen, C.U. (1955). *Luftbårne mikroorganismer. Forekomst og bekæmpelse (Airborne Microorganisms: Occurrence and Control)*. Copenhagen: G.E.C. Gad Forlag.
- Johnson, D.L., & Lynch, R.A. (2008). An efficient analytical method for particle counting in evaluating airborne infectious isolation containment using fluorescent microspheres. *Journal of Occupational and Environmental Hygiene*, 5(4), 271–277.
- Johnson, D.L., Lynch, R.A., Marshall, C., Mead, K., & Hirst, D. (2013). Aerosol generation by modern flush toilets. *Aerosol Science and Technology*, 47(9), 1047–1057.
- Johnson, D.L., Mead, K.R., Lynch, R.A., & Hirst, D.V. (2013). Lifting the lid on toilet plume aerosol: A literature review with suggestions for future research. *American Journal of Infection Control*, 41(3), 254–258.
- Messer, J.W., & Dufour, A.P. (1998). A rapid, specific membrane filtration procedure for enumeration of enterococci in recreational water. *Applied and Environmental Microbiology*, 64(2), 678–680.
- Scott, E., & Bloomfield, S.F. (1985). A bacteriological investigation of the effectiveness of cleaning and disinfection procedures for toilet hygiene. *Journal of Applied Bacteriology*, 59(3), 291–297.
- Schulster, L., Chinn, R.Y.W., Centers for Disease Control and Prevention, & Healthcare Infection Control Practices Advisory Committee. (2003). Guidelines for environmental infection control in health-care facilities: Recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). *Morbidity and Mortality Weekly Report, Recommendations and Reports*, 52(RR10), 1–42.
- Sethi, A.K., Al-Nassir, W.N., Nerandzic, M.M., Bobulsky, G.S., & Donskey, C.J. (2010). Persistence of skin contamination and environmental shedding of *Clostridium difficile* during and after treatment of *C. difficile* infection. *Infection Control and Hospital Epidemiology*, 31(1), 21–27.
- Verani, M., Bigazzi, R., & Carducci, A. (2014). Viral contamination of aerosol and surfaces through toilet use in health care and other settings. *American Journal of Infection Control*, 42(7), 758–762.
- Yahya, M.T., Cassells, J.M., Straub, T.M., & Gerba, C.P. (1992). Reduction of microbial aerosols by automatic toilet bowl cleaners. *Journal of Environmental Health*, 55(3), 32–34.

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► DIRECT FROM CDC ENVIRONMENTAL HEALTH SERVICES BRANCH



Brian Hubbard, MPH

## Success Stories From CDC's Safe Water for Community Health Grantees

**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 column are those of the author(s) and do not necessarily represent the official position of CDC.

Brian Hubbard is the team lead for Safe Water for Community Health within the National Center for Environmental Health.

In 2015, the Centers for Disease Control and Prevention (CDC) Safe Water for Community Health (Safe WATCH) Program awarded cooperative agreements to 14 state and five county health agencies to improve the efficiency and effectiveness of their safe drinking water programs. The main goal of the program is to prevent exposure to waterborne contaminants and protect health. Safe WATCH grantees are using the 10 Essential Environmental Public Health Services (Figure 1) to strengthen programs that address drinking water systems and sources not covered by the U.S. Environmental Protection Agency's Safe Drinking Water Act (e.g., household wells, springs, cisterns).

Health departments have made considerable progress during the first 1.5 years of the Safe WATCH program. Although health departments have worked on activities related to all the essential services, particular emphasis has been placed on

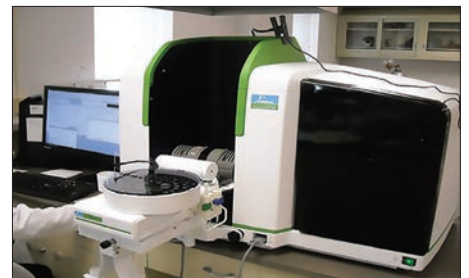
- collecting and organizing household well and water quality data,

- building partnerships with public and private agencies that work on safe drinking water, and
- tailoring outreach and educational materials for well owners.

Here are some of the specific success stories.

Gaston County Health Department (North Carolina) worked in partnership with the University of North Carolina at Charlotte to hire undergraduate students to digitize 7,940 well permits into a database to improve health department efficiency. Using application programming interfaces (APIs) with web-based mapping, they also geocoded 7,763 addresses of the 7,940. These activities have strengthened the county's capacity to monitor, diagnose, and investigate environmental public health problems associated with household wells.

La Crosse County Health Department (Wisconsin) increased well education and testing support to address newly discovered concentrations of metals in the county's well water. In the first year, the program educated



Atomic absorption spectrometer in La Crosse County, Wisconsin.



Broken well cap with mouse nesting material in Madison County, New York.

402 household well owners, which led to 989 water quality tests. The program also purchased an atomic absorption spectrometer (see photo above, top) to measure arsenic in drinking water. The program became the



FIGURE 1

**The 10 Essential Environmental Public Health Services Wheel**



**Additional Resources**

- 10 Essential Environmental Public Health Services: Identify the actions necessary to protect and improve environmental public health ([www.cdc.gov/nceh/ehs/10-essential-services/index.html](http://www.cdc.gov/nceh/ehs/10-essential-services/index.html))
- Environmental Public Health Performance Standards: Assess and improve how programs and systems provide communities with the 10 Essential Environmental Public Health Services ([www.cdc.gov/nceh/ehs/envphps/default.htm](http://www.cdc.gov/nceh/ehs/envphps/default.htm))
- Resources Organized by Essential Services: Find tools to help programs fill performance gaps and contribute to larger performance improvement efforts such as voluntary public health accreditation ([www.cdc.gov/nceh/ehs/10-essential-services/resources.html](http://www.cdc.gov/nceh/ehs/10-essential-services/resources.html))

third public lab in Wisconsin to receive an arsenic certificate and it is currently seeking certification for analysis of lead in drinking water. The spectrometer and additional trained staff have increased the competency of Wisconsin’s environmental public health and laboratory workforce.

**Madison County Health Department (New York)** conducted over 200 well assessments and collected 219 water samples for analysis in 2016. They found that nearly 40% of the household wells tested positive for bacteriological contamination (see photo page 40, bottom). The program educated owners about their test results and taught them how to properly disinfect and protect their water sources. The program used its strong partnerships with public health stakeholders in the local community to create a diverse advisory work group of soil and water specialists, service providers, codes officials, water system operators, and representatives from

other state and local agencies. The health department created a web page with access to maps of contamination sources and water quality data. They have developed and disseminated outreach and educational materials, conducted promotional events, engaged the local media, and consulted with well owners on water testing results and follow up. The activities have broken down barriers between the health department and well owners, and have led to increased testing of household wells.

**Tacoma-Pierce County Health Department (Washington)** worked on outreach to educate users and water system managers on the health implications of contaminated water and the importance of routine testing. The program sent notification letters to the owners, managers, and users of 108 out-of-compliance water systems and provided an opportunity to update water system records with current contact information.

It is notable that the state of Washington defines public water systems as “any water system that serves more than one household, or serves a commercial establishment.” Specifically, Washington defines Group B water systems as those with 2–14 service connections. These systems must meet state and local requirements for water quality and operations. After the department’s first year of outreach activities, they achieved close to 70% system compliance and the county has an updated database with water quality data and information on system management. These activities helped to assure compliance with laws and regulations in the county.

CDC’s Environmental Health Services Branch (EHSB) manages the Safe WATCH program. EHSB has also been working with national partner organizations—ChangeLab Solutions (CLS) and the Public Health Foundation (PHF)—to provide guidance to environmental health practitioners based on interactions with Safe WATCH partners. PHF summarized quality improvement technical assistance activities with Safe WATCH partners in the March 2017 *Journal of Environmental Health* (Lamers & Hubbard, 2017). In July 2017, CLS released the guidance document,

Closing the Gap: Using Policy to Improve Drinking Water Quality in Federally-Unregulated Drinking Water Systems (ChangeLab Solutions, 2017). This guidance highlights how policy can be used at local and state levels to ensure access to safe drinking water for people who use private wells.

In the future, EHSB will continue to disseminate new guidance documents as they are developed. The National Center for Environmental Health and National Environmental Health Association plan on developing

a national practice network that addresses federally-unregulated drinking water issues. To learn more about CDC's Safe WATCH program, visit [www.cdc.gov/nceh/ehs/safe-watch/index.html](http://www.cdc.gov/nceh/ehs/safe-watch/index.html).

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**References**

ChangeLab Solutions. (2017). *Closing the water quality gap: Using policy to improve drinking water in federally-unregulated drinking water systems*. Retrieved from <http://changelabsolutions.org/publications/water-quality>

Lamers, V., & Hubbard, B.C. (2017). What actions are health departments taking to improve safe drinking water programs? *Journal of Environmental Health*, 79(7), 38–40. Retrieved from <https://www.cdc.gov/nceh/ehs/docs/jeh/2017/mar-safe-water.pdf>

**ACCREDITED ENVIRONMENTAL HEALTH SCIENCE AND PROTECTION PROGRAMS**

The following colleges and universities offer accredited environmental health programs for undergraduate and graduate degrees (where indicated). For more information, please contact the schools directly, visit the National Environmental Health Science and Protection Accreditation Council (EHAC) website at [www.ehacoffice.org](http://www.ehacoffice.org), or contact EHAC at [ehacinfo@eahap.org](mailto:ehacinfo@eahap.org).

**Baylor University**  
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**Benedict College**  
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**Wright State University**  
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\*Typical reading time at 1.0 mg/cm<sup>2</sup> with 2-sigma confidence on most samples



## EH CALENDAR

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**UPCOMING NEHA CONFERENCES**

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June 25–28, 2018: NEHA 2018 Annual Educational Conference & Exhibition, Anaheim, CA. For more information, visit [www.neha.org/aec](http://www.neha.org/aec).

July 8–11, 2019: NEHA 2019 Annual Educational Conference & Exhibition, Nashville, TN.

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

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**NEHA AFFILIATE AND REGIONAL LISTINGS**

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**Alabama**

October 17–19, 2017: Annual Education Conference, hosted by the Alabama Environmental Health Association, Mobile, AL. For more information, visit [www.aeha-online.com](http://www.aeha-online.com).

**California**

October 13, 2017: CEHA Update 2017, hosted by the Central Chapter of the California Environmental Health Association, Fresno, CA. For more information, visit [www.ceha.org](http://www.ceha.org).

**Illinois**

October 19–20, 2017: Annual Educational Conference, hosted by the Illinois Environmental Health Association, East Peoria, IL. For more information, visit <http://iehaonline.org>.

**Jamaica**

October 22–26, 2017: International Environmental Conference and IFEH Council Meeting, hosted by the Jamaica Association of Public Health Inspectors in association with the IFEH Americas Region Group member countries, Montego Bay, Jamaica. For more information, contact [japhi.ifeh.conference@gmail.com](mailto:japhi.ifeh.conference@gmail.com).

**Kansas**

October 11–13, 2017: Joint Annual Conference and Trade Show, hosted by the Kansas Environmental Health and Kansas Small Flows Associations, Wichita, KS. For more information, visit [www.keha.us](http://www.keha.us).

**Missouri**

October 4–6, 2017: Annual Education Conference, hosted by the Missouri Environmental Health Association, Osage Beach, MO. For more information, visit [www.mmfeha.org/meha](http://www.mmfeha.org/meha).

**Nebraska**

October 26, 2017: Annual Conference, hosted by the Nebraska Environmental Health Association, Ashland, NE. For more information, visit [www.nebraskaneha.com](http://www.nebraskaneha.com).

**North Dakota**

October 17–19, 2017: Fall Education Conference, hosted by the North Dakota Environmental Health Association, Medora, ND. For more information, visit <http://ndeha.org/wp/conferences>.

**Rhode Island**

October 4–5, 2017: 55th Annual Yankee Conference on Environmental Health, hosted by the Rhode Island Environmental Health Association, Newport, RI. For more information, <https://rieha.wildapricot.org>.

**Tennessee**

October 4–6, 2017: 71st Annual Interstate Environmental Health Seminar, hosted by the Tennessee Environmental Health Association, Gatlinburg, TN. For more information, visit [www.wvdhhr.org/wvas/IEHS/index.asp](http://www.wvdhhr.org/wvas/IEHS/index.asp).

**Texas**

October 9–13, 2017: Annual Educational Conference, hosted by the Texas Environmental Health Association, Austin, TX. For more information, visit [www.myteha.org](http://www.myteha.org).

**Virginia**

October 23, 2017: Fall Educational Conference, hosted by the Virginia Environmental Health Association, Richmond, VA. For more information, visit <http://virginiaeha.org/educational-sessions>.

**Wisconsin**

October 18–20, 2017: Educational Conference, hosted by the Wisconsin Environmental Health Association, Sheboygan, WI. For more information, visit [www.weha.net](http://www.weha.net).

**Wyoming**

October 10–12, 2017: Annual Education Conference, hosted by the Wyoming Environmental Health Association and Wyoming Food Safety Coalition, Cody, WY. For more information, visit [www.wehaonline.net](http://www.wehaonline.net).

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**TOPICAL LISTING**

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**Food Safety and Protection**

November 6–9, 2017: Integrated Foodborne Outbreak Response and Management (InFORM) 2017 Conference, Garden Grove, CA. For more information, visit [www.apfl.org/conferences/InformConf/Pages/default.aspx](http://www.apfl.org/conferences/InformConf/Pages/default.aspx).  

# CAREER OPPORTUNITIES

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Columbus, OH  
Eureka, CA  
Grand Junction, CO  
Grand Rapids, MI  
Honolulu, HI  
Idaho Falls, ID  
Kansas City, MO/KS  
Lexington, KY  
Little Rock, AR  
Louisville, KY

Lubbock, TX  
Midland, TX  
Oakland, CA  
Odessa, TX  
Owatonna, MN  
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Portland, OR  
Rapid City, SD  
Richmond, VA  
Rochester, NY

San Diego, CA  
Shreveport, LA  
Sioux Falls, SD  
St. Louis, MO  
Syracuse, NY  
Tulsa, OK  
Washington, DC  
Wichita, KS  
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### Canada

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Calgary  
Montreal  
Toronto  
Vancouver  
Winnipeg

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

## Did You Know?

You can share your event with the environmental health community by posting it directly on our community calendar at [www.neha.org/news-events/community-calendar](http://www.neha.org/news-events/community-calendar). Posting is easy and it's a great way to bring attention to your event.

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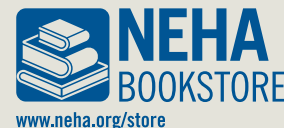


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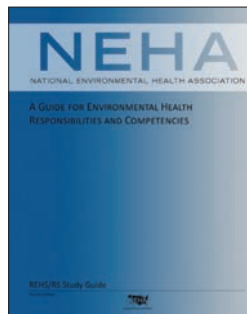
# RESOURCE CORNER

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!



## REHS/RS Study Guide (4th Edition)

National Environmental Health Association (2014)

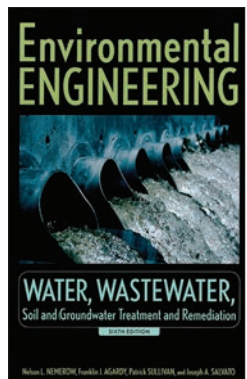


The Registered Environmental Health Specialist/Registered Sanitarian (REHS/RS) credential is NEHA's premier credential. This study guide provides a tool for individuals to prepare for the REHS/RS exam and has been revised and updated to reflect changes and advancements in technologies and theories in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

308 pages / Paperback  
Member: \$149 / Nonmember: \$179

## Environmental Engineering: Water, Wastewater, Soil and Groundwater Treatment and Remediation (6th Edition)

Edited by Nelson L. Nemerow, PhD; Franklin J. Agardy, PhD; Patrick Sullivan, PhD; and Joseph A. Salvato (2009)



First published in 1958, Salvato's *Environmental Engineering* has long been the definitive reference for generations of sanitation and environmental engineers. The most recent edition was completely rewritten by leading experts in the field and offers succinct new case studies, new process and plant design examples, and added coverage of such subjects as urban and rural systems. This volume covers water and wastewater treatment, water supply, soil and groundwater remediation and protection, and industrial waste management. Study reference for NEHA's Registered Environmental Health Specialist/Registered Sanitarian credential exam.

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## Certified Professional-Food Safety Manual (3rd Edition)

National Environmental Health Association (2014)

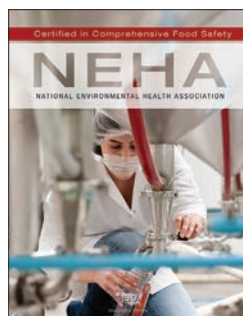


The Certified Professional-Food Safety (CP-FS) credential is well respected throughout the environmental health and food safety field. This manual has been developed by experts from across the various food safety disciplines to help candidates prepare for NEHA's CP-FS exam. This book contains science-based,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

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

## Certified in Comprehensive Food Safety Manual

National Environmental Health Association (2014)



The Food Safety Modernization Act has recast the food safety landscape, including the role of the food safety professional. To position this field for the future, NEHA is proud to offer the Certified in Comprehensive Food Safety (CCFS) credential. The CCFS is a midlevel credential for food safety professionals that demonstrates expertise in how to ensure food is safe for consumers throughout the manufacturing and processing environment. It can be utilized by anyone wanting to continue a growth path in the food safety sector, whether in a regulatory/oversight role or in a food safety management or compliance position within the private sector. The *CCFS Manual* has been carefully developed to help prepare candidates for the CCFS exam and deals with the information required to perform effectively as a CCFS.

356 pages / Spiral-bound paperback  
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# UPCOMING CLASSES

NOVEMBER 28–29, 2017

- Certified in Comprehensive Food Safety (CCFS) Credential Review Course
- Certified Professional – Food Safety (CP-FS) Credential Review Course
- Food Safety Auditor Certificate Training Course

Courses will take place during the Food Safety Consortium. To register, visit <http://foodsafetyconsortium.net/>

EARLY JANUARY 2018

- NEHA's Registered Environmental Health Specialist/Registered Sanitarian (REHS/RS) Online Review Course begins early 2018

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# JEH QUIZ

## FEATURED ARTICLE QUIZ #2

### Effectiveness of a Multifaceted Occupational Noise and Hearing Loss Intervention Among Landscaping and Groundskeeping Workers

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

1. Read the featured article carefully.
2. Select the correct answer to each *JEH* Quiz question.
3. a) Complete the online quiz found at [www.neha.org/publications/journal-environmental-health](http://www.neha.org/publications/journal-environmental-health),  
b) Fax the quiz to (303) 691-9490, or  
c) Mail the completed quiz to  
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Be sure to include your name and membership number!
4. One CE credit will be applied to your account with an effective date of October 1, 2017 (first day of issue).
5. Check your continuing education account online at [www.neha.org](http://www.neha.org).
6. You're on your way to earning CE hours!

#### Quiz Registration

Name \_\_\_\_\_

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#### JEH Quiz #6 Answers May 2017

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

→ Quiz deadline: January 1, 2018

1. According to 2014 U.S. Department of Labor data, there are approximately \_\_\_ full-time groundskeeping workers in the U.S.
  - a. half a million
  - b. one million
  - c. two million
  - d. three million
2. Federal law requires employers to protect worker hearing whenever noise exposures are at or above an 8-hour time-weighted average of
  - a. 75 A-weighted decibels (dBA).
  - b. 80 dBA.
  - c. 85 dBA.
  - d. 90 dBA.
3. Sound levels above \_\_\_ can be harmful enough to cause hearing loss.
  - a. 90 dB
  - b. 100 dB
  - c. 110 dB
  - d. 120 dB
4. The following are minimum requirements for hearing conservation programs when the action threshold level is exceeded:
  - a. a monitoring program.
  - b. employee training.
  - c. recordkeeping.
  - d. employee audiometric testing program.
  - e. all the above.
5. One of the primary objectives of this study was to evaluate perceptions and personal behavior of wearing hearing protection devices.
  - a. True.
  - b. False.
6. The study participants were \_\_\_ male and \_\_\_ female.
  - a. 55%; 45%
  - b. 85%; 15%
  - c. 97%; 3%
  - d. 99%; 1%
7. The most commonly used landscaping power tool reported by workers was a
  - a. weed trimmer.
  - b. chain saw.
  - c. leaf blower.
  - d. push mower.
8. Of the study participants that ever had a hearing test, \_\_\_ reported that the results of the tests were normal.
  - a. 66%
  - b. 68%
  - c. 70%
  - d. 72%
9. When asked about the importance of wearing hearing protection devices, \_\_\_ of study participants rated wearing earplugs as important or extremely important.
  - a. 82%
  - b. 85%
  - c. 92%
  - d. 96%
10. When asked about the frequency of wearing hearing protection devices, \_\_\_ of study participants indicated that they wear earplugs always or most of the time.
  - a. 42%
  - b. 46%
  - c. 58%
  - d. 69%
11. \_\_\_ of study participants felt that hearing loss was normal and part of growing old.
  - a. Eighteen percent
  - b. Thirty-two percent
  - c. Fifty-eight percent
  - d. Seventy percent
12. Protection from excessive noise in the occupational setting requires efforts by the employee alone.
  - a. True.
  - b. False.



## Thank you for Supporting the NEHA/AAS Scholarship Fund

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## Did You Know?

NEHA offers several online courses. The Professional Food Handler Online Certificate Course is now open for registration. Participants will receive an ANSI-certified printable certificate upon course completion. To learn more, visit [www.neha.org/professional-development/education-and-training/professional-food-handler](http://www.neha.org/professional-development/education-and-training/professional-food-handler).

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# NEHA 2017 AEC WRAP-UP



## Local Solutions. National Influence.

Jonna Ashley  
Kristie Denbrock  
Soni Fink  
Faye Koeltzow  
National Environmental  
Health Association

### GRAND RAPIDS, MICHIGAN

Over 800 environmental health professionals convened at NEHA's 81st Annual Educational Conference (AEC) & Exhibition to deliberate, learn, and exchange ideas and experiences regarding the urgent issues facing environmental health both locally and nationally. The picturesque Grand River served as the backdrop to five days of workshops, networking, and over 200 educational sessions covering noteworthy, and sometimes controversial, topics such as marijuana edibles, restaurant grading, body art, and environmental justice.

During the Opening Session, Representative Brenda Lawrence (D-Michigan) commenced the AEC by urging everyone to "stay woke" on environmental health legislative issues and delivered an inspiring keynote address that had attendees talking throughout the conference. Representative Lawrence's address was a rare opportunity to hear a government official speak boldly and knowledgeably on the topics that matter most to environmental health professionals, which demonstrates NEHA's ongoing commitment to being the national voice for environmental health advocacy.

National and local issues were not the only topics covered during the 2017 AEC. NEHA pushed the boundaries of this year's theme by welcoming attendees and presenters from across the globe. A global leadership panel discussion was held among environmental health association directors from Australia, Canada, Jamaica, the United Kingdom, and the U.S. to further international connections and facilitate discussions on challenges and insights from around the world.



NEHA 2017 AEC photos courtesy of Casey Stormes, Fresh Look Video, www.freshlookvideo.com.

As always, some of the most important connections at the AEC were made over food and drinks with old friends and new colleagues. There was no shortage of socializing and community in Grand Rapids! Almost 600 environmental health professionals showed up at the Brews, Blues, & BBQ event to share stories

and laughs, and sample a bit of the local flavor in "Beer City."

We look forward to another year of connecting, learning, and having fun at the 2018 AEC being held June 25-28 in Anaheim, California. Check out the 2018 AEC promo on page 51. We hope to see you there!

## KEYNOTE ADDRESS & OPENING SESSION

### Representative Brenda Lawrence Claims Environmental Health Workforce Critical to Environmental Justice in 2017 AEC Keynote Address



Representative Brenda Lawrence (D-Michigan) opened the 2017 AEC with a powerful and passionate keynote address on the role of the environmental health workforce in environmental justice. She began by praising the work of environmental health professionals, stating that the “environmental health workforce is critical and is what oils the wheels of this great country...the impact is honorable and based on helping a human being.”

Representative Lawrence is also supporting the environmental health workforce by sponsoring H.R. 1909—the Environmental Health Workforce Act of 2017—that addresses the need for education and training for environmental health professionals. “Every American deserves the right to safe drinking water, clean air to breathe, and a healthy community to raise their children,” Lawrence said. She encouraged 2017 AEC attendees to “continue to do what you are doing” and to use the AEC as a time for learning.

### Opening Session: Environmental Justice Panel Discussion

Continuing with the topic of environmental justice, Dr. Renée Branch Canady, chief executive officer of the Michigan Public Health Institute, led a panel discussion, “Aiming for Equity.”

Joining Dr. Canady was Dr. Pamela Pugh, public health advisor for the City of Flint; Dr. Marcus Cheatham, health officer for the Mid-Michigan District Health Department; and Ponsella Hardaway, executive director of Detroit’s Metropolitan Organizing Strategy Enabling Strength (MOSES) nonprofit organization.

The thought-provoking discussion centered on issues such as water and lead contamination in Flint, water shut offs in Detroit, and the polybrominated biphenyls event in mid-Michigan. The panel spoke of the need to nationally raise key issues in critical health threats.



*Dr. Renée Branch Canady (left) and Representative Brenda Lawrence (right) share notes and a laugh before the Keynote Address & Opening Session.*



*Grand Rapids Mayor Rosalynn Bliss, the first female mayor of the city, welcomes NEHA and the 2017 AEC attendees to her fair city.*



*The “Aiming for Equity” panelists from left to right: Dr. Renée Branch Canady, Dr. Marcus Cheatham, Ponsella Hardaway, and Dr. Pamela Pugh.*



*Dr. David Dyjack relays audience questions to the “Aiming for Equity” panelists.*

## EDUCATION & TRAINING

Over 800 AEC attendees participated in approximately 200 educational sessions, learning labs, workshops, and networking events. Topics ranged from marijuana edibles and the restaurant grading debate to a live tattoo demonstration and body art trends for the 21st century.

It was standing room only with more than 130 attendees engaged in the “Marijuana Edibles: Are They Safe? Challenges and Successes of Our States” panel discussion. Attendees heard from state and local regulatory agencies, legal and laboratory testing experts, and edible industry partners who discussed issues crucial to the safety of the growing process, product development for recreational and medical distribution facilities, legal challenges, and enforcement. The discussion also included how food safety is ensured and the challenges and successes related to dosage monitoring, pathogen testing, labeling and packaging controls, hazard analysis and critical control point (HACCP) plans, and training.

To gain a global environmental health perspective, a panel of environmental health presidents and directors from Australia, Canada, Jamaica, the United Kingdom, and the U.S. assembled to discuss emerging issues and topics facing their countries during “Global Leadership: Executive Directors Weigh-In.”

In keeping with emerging issues, a late breaking session to address the opioid addiction crisis was added to the agenda with a packed room of interested attendees.

With so many topics covered in areas such as informatics, water, food safety, preparedness, climate and health, and more, the most difficult decision to make for attendees was which tracks and sessions to attend. NEHA thanks all the presenters, moderators, and attendees who made these 200 sessions possible and successful.



### Closing Session

Bringing the conference to a close was an incredible panel discussion on sustainability. “Sustainability: What Does Green Mean for Health Officials” was moderated by Josh Jacobs, technical information and public affairs manager for UL. Joining the panel was Walker Smith, director of global affairs and policy at the U.S. Environmental Protection Agency; Gabe Wing, director of safety and sustainability for Herman Miller; and Eric DeLong, deputy city manager for Grand Rapids.

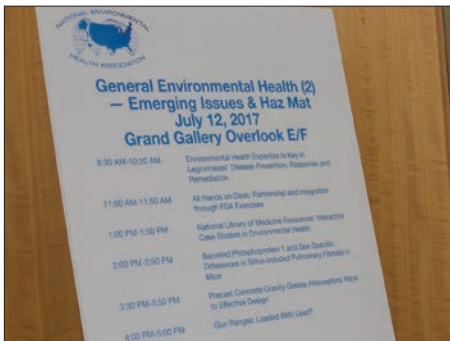
Each panelist gave a presentation on what sustainability means to their specific area and provided examples of projects in which they are involved. They closed the session with a discussion on how sustainability is an integral part of building, procurement, governance, and business, and the need for all to work together.



UL's Josh Jacobs moderates the closing session panel, which was sponsored by NEHA's Business and Industry Affiliate.



Closing session panelists from left to right: Walker Smith, Eric DeLong, and Gabe Wing.





## 2017 AEC Session Tracks

This year's educational program featured over 200 sessions within 11 tracks and 25 disciplines, as well as over 40 research posters.

- 1. Water**
  - Onsite Wastewater
  - Recreational Water
  - Water Quality
- 2. Air**
  - Air Quality
- 3. Food**
  - Food Safety & Defense
- 4. Informatics**
  - Environmental Health Tracking & Informatics
  - Technology & Environmental Health
- 5. Built Environments**
  - EH Health Impact Assessment
  - Healthy Homes & Communities
  - Land Use Planning & Design
  - School & Institutions
- 6. Emergency Preparedness**
  - Emergency Preparedness & Response
- 7. General Environmental Health**
  - Emerging Environmental Health Issues
  - Hazardous & Toxic Materials
  - General Environmental Health
  - Solid Waste
  - Sustainability
  - International Environmental Health
- 8. Special Populations**
  - Children's Environmental Health
  - Environmental Justice
  - Uniformed Services
- 9. Workforce & Leadership**
  - Leadership & Management
- 10. Climate & Health**
  - Climate Change
- 11. Infectious & Vectorborne Diseases**
  - Pathogens & Outbreaks
  - Vector Control & Zoonotic Diseases

“I learned various ways to better educate myself and my department. Great information (and support) from peers!”

– AEC attendee

### Preconference Courses and Workshops

The 2017 AEC also included a variety of pre-conference offerings that were held from July 8–10.

As in the past, credential review courses and exams were offered for those interested in earning a NEHA credential. A two-day review course for NEHA's Certified Professional–Food Safety credential was offered and attendees had the opportunity to take the credential exam after the course. New this year, NEHA offered an online review course for the Registered Environmental Health Specialist/Registered Sanitarian (REHS/RS) credential prior to the AEC. As part of the online course, a four-hour review course was held at the AEC for those that participated in the online portion of the course. The REHS/RS credential exam was then held afterwards.

Several new preconference workshops were offered this year. Survival Skills for Environmental Health Leaders was developed to meet the multiple training needs of newly appointed and seasoned environmental health officials. The interactive workshop focused on management versus leadership and successful strategies and best practices for leaders. Another new offering was the Affiliate Leadership Workshop. This workshop was specifically designed to share information and tools to assist environmental health association leaders in the management of their organizations. The workshop covered topics



on conference planning, board responsibilities, financial management and budgeting, strategic planning, successful fundraising, and membership engagement.

Finally, NEHA offered a workshop on private well water—Private Well Outreach and Assessment of Environmental Health Professionals. This workshop covered best practices for well owner outreach, online resources, and the use of a new assessment tool for the evaluation of private well vulnerability to contamination.

### Poster Sessions



## AEC IS THE TALK OF THE TOWN

The 2017 AEC filled the news wires while in Grand Rapids. AEC attendees and members made appearances on several news outlets.

- NEHA members were featured on Fox News 17 discussing the purpose of the conference, topics covered, and what happens behind the scenes.  
[www.fox17online.com/2017/07/10/national-environmental-health-association](http://www.fox17online.com/2017/07/10/national-environmental-health-association)
- Michigan Representative Brenda Lawrence spoke to local NPR News and addressed how the profession is working to prevent another Flint water crisis.  
[www.wgvtvnews.org/post/michigan-rep-brenda-lawrence-how-prevent-next-flint-water-crisis](http://www.wgvtvnews.org/post/michigan-rep-brenda-lawrence-how-prevent-next-flint-water-crisis)
- NEHA President-Elect Adam London and NEHA Director of Government Affairs Joanne Zurcher were interviewed on the WGTV Morning Show where they discussed the importance of the environmental health profession.  
[www.wgvtvnews.org/post/environmental-health](http://www.wgvtvnews.org/post/environmental-health)
- NEHA Executive Director Dr. David Dyjack was on ABC WZZM 13 and highlighted the 2017 AEC and its educational sessions.  
[www.wzzm13.com/news/national-environmental-health-association-conference-in-grand-rapids/456480774](http://www.wzzm13.com/news/national-environmental-health-association-conference-in-grand-rapids/456480774)

## #NEHAaec2017 and #EHmatters Twitter Posts

### **CDC EPHTracking @CDC\_EPHTracking**

Attending conferences are a great way to share & learn about best practices. Our grantees presented at #NEHAaec2017 this year! #TrackingChat

### **Pam Protzel Berman @Bermans3Pam**

Interesting session on using innovation to improve environmental health #NEHAaec2017

### **Vanessa Lamers @vlamers**

EPA is tackling marine litter, which bioaccumulates up food chain (you don't want to eat plastic, do u?) #NEHAaec2017

### **Enviro-Decon @EnviroDecon**

We're excited to be attending the #NEHAaec2017 this week. Thanks for having us @nehaorg! Come chat with us at our booth! #AirQuality

### **Charles @charlcb1**

@RepLawrence What a speech! #NEHAaec2017 #StayWoke

### **Joanne Zurcher @JoanneZurcher1**

Environmental Health is Public Health. No.1 Health Crisis Opioid Addiction being discussed #NEHAaec2017 #EHmatters

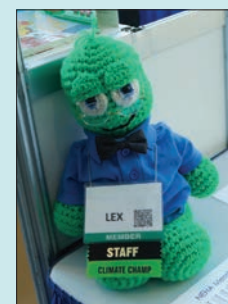
## AEC Social Media and Conference App Winners

New this year, we encouraged attendees to share their conference photos and experiences via social media using #NEHAaec2017 and #EHmatters. Social media winners were awarded a \$25 Amazon gift card. Below is a list of this year's winners.

- Janie Cambron (@Jne310): Received 25+ favorite tweets for “#EHmatters in #grandrapids with 35% tree canopy & awesome local partnerships! Great opening remarks by the @mayorbliss #NEHAaec2017”
- Patricia Facquet (@PatriciaFacquet): Received 20+ favorite tweets for “#StayWoke get informed, Environmental Justice, Social Justice. Stand up say NO. U.S. Great Democracy @AdelphiUtweets #NEHAaec2017 #EHMatters”
- Bryan Brooks (@BryanWBrooks): Received 10+ favorite tweets for “Each year 1 in 6 Americans get foodborne illness; 50% associated with restaurants. @nehaorg #FoodSafetyMatters @CDCEnvironment #NEHAaec2017”

Our ever-popular Connect4 App Gaming Challenge was offered again at the 2017 AEC. Attendees competed for prizes and bragging rights by attending and scanning QR codes for events and sessions, as well as scanning QR codes for exhibitors and attendees. Connect4 App Gaming Challenge winners were placed in a drawing (if scoring 150+ points) and were awarded a \$50 Amazon gift card. Below is a list of this year's winners.

- Erica Craddock, Food Safety Auditor, Advanced Fresh Concepts Franchise Corp.
- Clint Pinion, Assistant Professor, Eastern Kentucky University
- Ericka Sanders, Sanitarian II, Nebraska Department of Agriculture



NEHA's Lex was ready for the Connect4 App action with his name badge and QR code!

# FUN WAS HAD BY ALL AT THE SPECIAL EVENTS HELD AT THE 2017 AEC!

## UL Event

This special event held at the Grand Rapids Public Museum had something for everyone! Attendees were able to munch on appetizers and enjoy a cold drink while enjoying all the site had to offer—an elegant galleria with dance floor, the “Streets of Old Grand Rapids,” a carousel, free planetarium shows, and various exhibits.



## Brews, Blues, & BBQ

While Mother Nature didn't cooperate and the event was moved indoors, people still “caught” the excitement and enjoyed some good food and music with friends!



## Sponsors, Partners, and Contributors

We appreciate the following sponsors and organizations that helped make this conference possible!

### Diamond Sponsor

UL

### Platinum Sponsors

Accela  
Hedgerow Software Ltd.  
National Restaurant Association  
NSF International

### Gold Sponsors

Tyler Technologies (FKA Digital Health Department, Inc.)  
Prometric

### Silver Sponsors

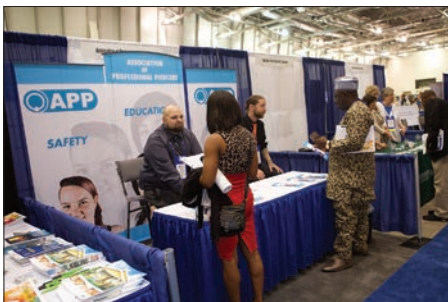
NEHA's Business and Industry Affiliate  
Orkin  
Ozark River Portable Sinks  
Sweeps Software, Inc.

### Special Thanks

Association of Environmental Health Academic Programs  
NEHA Endowment Fund Donators (see page 7)  
NEHA's Technical Advisors  
Uniformed Services Environmental Health Association

## EXHIBITION

The 2017 AEC Exhibition was packed with information, new products, and invaluable services to help attendees and their organizations improve their environmental health programs and operations. The Exhibition kicked off Monday night with nearly 700 people at the Exhibition Grand Opening & Party. The new Student Career Center located in the Exhibition provided students the opportunity to obtain new skills, speak with employers, and receive feedback on their résumés. Everyone that attended the evening's event enjoyed food and fun, in addition to meeting new friends, catching up with old friends, and taking advantage of the opportunity to do business. The Exhibition also gave attendees the chance to view over 40 posters that represented a broad spectrum of environmental health issues and engage with presenters in a lively interactive format.



### 2017 AEC Exhibitors

- |   |  |
|---|--|
| Accela  | Michigan State University Online MS in Food Safety         |
| Advanced Business Software, LLC                       | Mycometer  |
| Air Chek, Inc.  | National Environmental Health Association                  |
| Amalgam   | National Library of Medicine                               |
| American Academy of Sanitarians                       | National Precast Concrete Association                      |
| American Chemistry Council                            | National Restaurant Association                            |
| American Public Health Association                    | National Swimming Pool Foundation                          |
| Association of Environmental Health Academic Programs | NEHA Business and Industry Affiliate                       |
| Association of Food and Drug Officials                | NSF International  |
| Association of Professional Piercers                  | Office of Lead Hazard Control/HUD                          |
| CDC NCEH/ATSDR  | Ozark River Portable Sinks                                 |
| Citizens for Radioactive Radon Reduction              | Paster Training, Inc.                                      |
| Custom Data Processing, Inc.                          | Prometric  |
| Ecolab–EcoSure  | QuanTEM Food Safety Laboratories                           |
| Eljen Corporation                                     | Serim Research   |
| Enviro-Decon Services                                 | StateFoodSafety.com  |
| FDA/CFSAN   | Sweeps Software, Inc.                                      |
| Glo Germ Company                                      | Taylor Technologies, Inc.                                  |
| GOJO Industries                                       | ThermoWorks  |
| Hach Company  | Tyler Technologies (FKA Digital Health Department, Inc.)   |
| HealthSpace USA Inc                                   | Underwriters Laboratories                                  |
| Hedgerow Software Ltd.                                | The University of Findlay                                  |
| Hoot Systems, LLC                                     | USDA Food and Nutrition Service, Office of Food Safety     |
| Industrial Test Systems, Inc.                         | USDA Food Safety and Inspection Service                    |
| Inspect2GO Health Inspection Software                 | U.S. EPA Indoor Environments Division                      |
| International Food Protection Training Institute      | U.S. EPA Office of Research and Development Communications |
| Jamaica Association of Public Health Inspectors       | U.S. EPA Water Security Division                           |
| Keys to a Healthy Home                                |  |
| Lion Technology                                       |  |
| Michigan State University Extension                   |  |



## AWARDS & HONORS

Numerous notable individuals and organizations were recognized at the AEC. For more information about NEHA's awards, please visit [www.neha.org/about-neha/awards](http://www.neha.org/about-neha/awards).

### Accela/NEHA 2017 AEC Scholarships

This year, Accela Environmental Health and NEHA partnered to award nine scholarships to professionals to attend the 2017 AEC.

Debra Abramson  
LaToya Backus  
Ryan Bailey  
Karen Brown  
Wade Dishaw  
Jeremy Maxson  
Jason Ravenscroft  
Shannyn Sanger  
Chris Westover

### AEHAP Student Research Competition

The Association of Environmental Health Academic Programs (AEHAP) and the Environmental Health Services Branch of the Centers for Disease Control and Prevention's National Center for Environmental Health present this award to students who have conducted outstanding research benefitting the field of environmental health.

Justin Bunn, East Carolina University  
Amos Kosgey, Eastern Kentucky University  
Ambrose K. Maritim, Eastern Kentucky University  
Blake Rushing, East Carolina University

### Davis Calvin Wagner Sanitarian Award

This award represents the highest honor the American Academy of Sanitarians bestows upon its diplomates.

CAPT John Sarisky

### Dr. R. Neil Lowry Grant

This award, given by the Association of Pool & Spa Professionals, honors and recognizes public health officials who have made outstanding contributions to advance the public's healthy and safe use of recreational water.  
Quechan Parks & Recreation

### HUD Secretary's Award for Healthy Homes

The U.S. Department of Housing and Urban Development (HUD), in partnership with NEHA, give this award to recognize excellence in making indoor environments healthier through healthy homes research, education,

and program delivery, especially in diverse, low-to-moderate income communities.

*Public Housing:* Denver Housing Authority (Denver, CO)

*Cross Program Coordination:* Vermont Weatherization One Touch Program (VT)

*Policy Innovation:* Tribal Healthy Homes Network (WA)

*Research Innovation:* Rutgers University, Urban Entomology Lab (New Brunswick, NJ)

### Innovating for Environmental Health App Challenge Award

By way of an app challenge, teams of developers and creatives competed to build apps that solve environmental health issues. Below are the winning teams from the hackathons in Los Angeles and Detroit.

*AquaData Team:* Herminio Garcia and Sarah Han

*TapCheck Team:* Zachary Collins, Martese Goosby, and Khalob Kognata

### Jack B. Hatlen Distinguished Service Award

Presented by AEHAP, this award is given to an individual who has demonstrated dedication to the profession through mentorship, education, and promotion.

Carolyn Hester Harvey

### NEHA Affiliate Certificates of Merit

Awarded to affiliate members and teams who made exemplary contributions to the profession. Each affiliate selects winners based upon its own criteria for recognition.

#### Individuals

Paul Bilowus (Nat'l Capital Area)  
Steven Diaz (MN)  
Heather Gallant (MA)  
James Hodina (IA)  
Jennifer Kosak (MI)  
Jerry McNamar (KS)  
Welford Roberts (Uniformed Services)  
Lucas Tafoya (NM)  
Cody Talbott (WY)  
Rep. Mike Tyron (IL)  
Margaret Voyles (IN)

#### Team

FL—2016 FEHA Annual Education Meeting Planning Committee  
IA—Iowa Environmental Health Association Legislative Committee  
IN—IEHA 2016 Annual Fall Educational Conference Volunteers  
ND—Onsite Sewage Treatment System Technical Review and Education Board  
NM—2016 Southwest Regional FDA Conference and NMEHA Meeting Host

### NEHA Past Presidents Award

Each year, NEHA's Past Presidents Affiliate identifies a hero from the profession who not only accomplishes much on behalf of environmental health but also does a lot of work behind the scenes.

Scott Holmes

### NEHA Presidential Citations

This special award is given to individuals who have made exemplary contributions to NEHA during the president's term of office. President David Riggs presented three citations.

Henroy P. Scarlett  
Stan Hazan  
David Theno (posthumous award)

### NSF International Scholarship

AEHAP, in partnership with NSF International, offers a paid internship project to students from National Environmental Health Science and Protection Accreditation Council-accredited programs.

Jacob McGee, Eastern Kentucky University

### Samuel J. Crumbine Consumer Protection Award

This award is given annually to local environmental health jurisdictions that demonstrate unsurpassed achievement in providing outstanding food protection services to their communities. The purpose of the award is to encourage innovative programs and methods that reduce or eliminate the occurrence of foodborne illnesses, recognize the importance of food protection at the local level, and stimulate public interest in foodservice sanitation.

Boulder County Public Health (CO)  
Kansas City Health Department (MO)

## Walter S. Mangold Award

### Robert W. Powitz, MPH, PhD, RS, DLAAS

NEHA presented the 2017 Walter S. Mangold Award, its premier honor, to Robert “Bob” W. Powitz. The Walter S. Mangold Award recognizes and honors individuals for outstanding contributions to the advancement of the environmental health professional. It is the highest honor that NEHA can bestow upon one of its members.

Dr. Powitz was selected for the Mangold Award because of his illustrious career and the respect he has earned among his peers and colleagues in the environmental health profession.

Michèle Samarya-Timm of the American Academy of Sanitarians, who nominated Dr. Powitz along with the New Jersey Environmental Health Association, praised him for the impact he has had on the evolution of environmental health. In her nomination letter she stated, “Dr. Robert W. Powitz has spent his career championing evidence-based practice in environmental health; all of his work is framed by a commitment to the sanitarian profession and illustrates the opportunities for the professional outside of the traditional health department role. As his long and storied career illustrates, Dr. Powitz’s work has changed the classic meme of



*Michèle Samarya-Timm and Dr. Robert Powitz celebrate after Dr. Powitz was honored with the Mangold Award.*

the environmental health profession through his commitment to continuing education, stimulating others to be knowledgeable and proficient in the sanitarian craft, and assuring and creating innovations in environmental health practice. He is the personification of a model sanitarian.”

The Mangold Award is a highlight achievement for Dr. Powitz, who has already received several professional awards. Dr. Powitz received his first license as a sanitarian 50

years ago and throughout his career, he has demonstrated initiative, leadership, and dedication in the environmental health field. In 1984, he established R.W. Powitz & Associates, PC, a professional corporation specializing in environmental public health and contamination control advisory services to industry, law firms, insurance companies, and government agencies. He is currently principal and forensic sanitarian for this corporation. He also serves as health director for the Town of Franklin, Connecticut.

Dr. Powitz is active in several environmental health organizations, an author of numerous articles and books, and a member of several boards and committees. He has spent his career working to elevate the practice of environmental health, and his involvement and achievements are impressive and extensive. Dr. Powitz’s peers continually highlight his passion for elevating the environmental health profession and innovation. He has immersed himself in the field and has risen to the top of his field.

To read more about Dr. Powitz’s career, please visit [www.neha.org/about-neha/awards/walter-s-mangold-award](http://www.neha.org/about-neha/awards/walter-s-mangold-award).

## Walter F. Snyder Environmental Health Award

### CAPT Wendy Fanaselle, MS, RS, DAAS

NSF International and NEHA presented this prestigious award to CAPT Wendy Fanaselle in recognition of more than 30 years of significant and lasting impact to environmental health and public service. The Snyder Award honors NSF International’s cofounder and first executive director, Walter F. Snyder, who provided outstanding contributions to the advancement of environmental and public health.

“Wendy Fanaselle’s accomplishments reflect the principles expressed by Walter F. Snyder and the public health mission of NSF International,” says Kevan P. Lawlor, NSF International president and CEO. “A hallmark of CAPT Fanaselle’s career has been bringing people together to craft and implement practical and effective solutions to environmental health problems and creating new systems to ensure the sustainability of these solutions. These accomplishments make her a worthy recipient of the Walter F. Snyder Award.”



*CAPT Wendy Fanaselle proudly receives the Snyder Award from Kevan Lawlor (left), NSF International president and CEO, and Dr. David Dyjack (right), NEHA executive director and CEO.*

CAPT Fanaselle is a risk assessment project manager for the Food and Drug Administration’s Center for Food Safety and Applied Nutrition, where she is responsible for over-

seeing and developing major food safety risk assessments. In this role, she has led the development of a risk assessment on foodborne norovirus acquired from ill employees in retail food facilities. The assessment quantitatively evaluates the impact of different interventions in food establishments on reducing the risk of norovirus foodborne illness, provides a better understanding of the norovirus transmission pathway, and identifies compliance with removing symptomatic food employees as a priority in preventing norovirus foodborne illness.

To read more about CAPT Fanaselle’s career, please visit [www.nsf.org/newsroom/wendy-fanaselle-earns-walter-f-snyder-environmental-health-award-from-nsf](http://www.nsf.org/newsroom/wendy-fanaselle-earns-walter-f-snyder-environmental-health-award-from-nsf).

## NEHA NEWS

**NEHA Membership Vote**

By Jonna Ashley ([jashley@neha.org](mailto:jashley@neha.org))

NEHA will be holding a special election this fall asking all eligible voting members to approve amendments to the membership sections of NEHA's Articles of Incorporation and Bylaws. Specifically, we are asking to reduce the number of membership categories from nine (active/individual, sustaining, institutional, life, student, emeritus, international, and subscribing) to five (professional, emerging professional, retired professional, international, and life), and to remove barriers in the membership criteria.

As a current member, you will find that the new membership categories are comprehensive and allow you to be flexible in choosing the category that best fits your career from year to year. Students and new professionals would be incentivized by a membership category designed to meet their needs. We propose to sunset the Sustaining and Educational membership categories. At the same time, we are committed to aligning our membership program with our original mission to advance the environmental health professional. NEHA will continue to partner with colleges and universities to advance our shared goal of educating and engaging the next generation of environmental health professionals. NEHA will work with our sponsors and exhibitors to ensure that we are offering high quality options for advertising and exhibiting with us.

Our long-term aim is for NEHA to be the most essential and influential environmental health professional association in the world. To achieve that, our membership categories should reflect the needs of our constituents and provide membership categories that reflect today's career paths. In the process, we hope to attract new members and retain current members so that we can speak with a louder and more effective voice on behalf of environmental health professionals.

**Increasing Innovation in Environmental Health**

By Solly Poprish ([spoprish@neha.org](mailto:spoprish@neha.org))



Phone, desktop, and website applications (apps) have the power to inform, prevent harm, and educate. By integrating technology and environmental health, we can create a culture of health that uses public data to create innovative tools and resources for communities.

By way of an app challenge, teams of developers and creatives competed to build apps on various environmental health topics. For example, apps might function to share symptom data, create community-around alternative transportation, educate users on health risks—the opportunities are endless.

The 2017 Innovating for Environmental Health App Challenge, sponsored by Hedgerow Software, was launched in May 2017. NEHA participated in three weekend-long, in-person events as a part of AngelHack's Global Hackathon Series where teams competed to build community-focused apps.

The first event was held in Los Angeles, California, on May 13–14. The second event was held in Detroit, Michigan, on May 19–21. And the final event was held in Silicon Valley, California, on July 29–30. NEHA attended these events to advocate for environmental health and to inspire and guide teams to create apps to help solve water quality issues and better utilize environmental health data. At the end of each event, NEHA selected a winning team and awarded each team a monetary prize and a stipend to attend NEHA's Annual Educational Conference (AEC) & Exhibition.

At the Los Angeles event, there were over 100 participants and five teams that pitched unique apps to NEHA that were aimed at solving water quality issues. Los Angeles County Department of Environmental Health staff also attended to provide support and a local environmental health perspective. The weekend's winner was the AquaData team, which created a reporting app that enables users to report location-based data such as water leakage from pipes and spills. The data are then translated into a reporting format and sent directly to relevant agencies to address the issues faster.

The Detroit event was larger in size, with over 200 participants, and was led by Wayne State University. The winning team that weekend was TapCheck. They utilized publicly available U.S. Environmental Protection Agency water system data to create an app that instantly provides drinking water quality information based on geographic location and the corresponding municipal water system.



NEHA's Solly Poprish (third from left) poses with the Los Angeles and Detroit 2017 Innovating for Environmental Health App Challenge winners at the 2017 AEC. Photo courtesy of Casey Stormes, Fresh Look Video.

The Los Angeles and Detroit winners attended the 2017 AEC in Grand Rapids, Michigan, this July and presented their apps during an education session to an audience of over 50 attendees. When audience members were asked to raise their hands if they could imagine implementing these apps in their own communities, almost every hand went up. In addition to presenting, the teams received the Innovative App Award at the AEC Awards Ceremony [see photo above]. AquaData team member Herminio Garcia expressed that he "had a great experience learning about



## NEHA NEWS

all the ins and outs of environmental health, as well as interacting with all of the attendees at the conference.”

NEHA participated in the final event of the summer in Silicon Valley, California, in July. The weekend was the largest event of the series with over 300 attendees. Over 10 apps were pitched to NEHA, each with the mission of better utilizing environmental health data. The winning team created Safe California, a platform and model for easily sharing environmental health data to educate and empower residents. The weekend's winners will attend the NEHA 2018 AEC in Anaheim, California.

The 2017 Innovating for Environmental Health App Challenge series was an exciting and collaborative opportunity. It introduced developers to the environmental health community and showed the tangible potential of bringing these two areas together. If you have ideas in regard to this initiative or would like to learn more, please contact Christl Tate ([ctate@neha.org](mailto:ctate@neha.org)) or visit [www.neha.org/eh-topics/health-tracking-0/innovating-eh](http://www.neha.org/eh-topics/health-tracking-0/innovating-eh). 🐼



Employers increasingly require a professional credential to verify that you are qualified and trained to perform your job duties. Credentials improve the visibility and credibility of our profession, and they can result in raises or promotions for the holder. For 80 years, NEHA has fostered dedication, competency, and capability through professional credentialing. We provide a path to those who want to challenge themselves, and keep learning every day. Earning a credential is a personal commitment to excellence and achievement.

Learn more at [neha.org/professional-development/credentials](http://neha.org/professional-development/credentials).



### A credential today can improve all your tomorrows.



#### DirectTalk

*continued from page 66*

role for our industry. Who can we cooperate with to learn more about the needs of women in the workplace? What implications are there for the ways and means of executing our field work? What workplace policies should NEHA employ to accommodate our association workforce, which is, by the way, almost 70% female?

Our AEC is a great place to explore how to engage in cooperation and improvisation. This commitment will be on full display at the 2018 AEC in Anaheim, California. The opening panel session will highlight our state environmental health colleagues represented by the Association of State and Territorial Health Officials (ASTHO). The

panel will characterize the interdependence of local practitioners with state agencies and describe how we can more effectively work with our state counterparts. We have also offered ASTHO meeting space to encourage them to convene their annual environmental health meeting at our AEC host hotel. We can accomplish a lot together with ASTHO, which will require a healthy dose of improvisation and cooperation.

We have also invited the Council of State and Territorial Epidemiologists and the Association of Public Health Laboratories to hold sessions at the 2018 AEC that will examine cross-disciplinary issues such as data, surveillance, and emerging diagnostic technologies. The private sector will also be well represented as a globally-recognized leader in food safety has already agreed to provide the

opening keynote address. Bridging and bonding. Cooperating and improvising.

I close by observing that the speaker who defaulted on his commitment to speak at the 2017 AEC inadvertently did us a favor. His decision led to us embarking on a discovery that changed our perception of our professional role in opioid addiction. We collaborated with new talent. We improvised. We took risks. We emerged better off than when we started. While there are limits to this approach, I now have a refreshed perspective for the road ahead. 🐼

*Dave*

[ddjjack@neha.org](mailto:djjack@neha.org)  
Twitter: @DTDjjack

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

David Dyjack, DrPH, CIH

## Cooperate and Improvise

Panic ensued as I learned that the primary speaker for a major session at our 2017 Annual Educational Conference (AEC) & Exhibition was pulling out just days before he was supposed to speak. How could he do that? What was I going to do with the time slot, which was strategically embedded before our closing session? I perused my mental rolodex for environmental health experts who might step in as suitable replacements. Ideally these people would “owe me one,” so I could arm twist them into attending or doing double duty. I also had a nagging feeling that I was not being creative with the opportunity presented by this crisis.

So, on July 3, a week before the AEC began, I reached out to Debra Houry, MPH, MD. Dr. Houry is the director of the Centers for Disease Control and Prevention’s National Center for Injury Prevention and Control. I am an acquaintance of Dr. Houry and she is a professional I admire. I politely begged her to speak at our meeting on the issue of opioid addiction for reasons you probably know. Opioid addiction is a major scourge on our nation and public health professionals are wrestling with this issue from coast to coast. My rationale was that our profession should become part of the conversation. Where better to shine a light on this issue than at our AEC?

Dr. Houry’s response was nimble, polite, and direct: I had not provided her sufficient time to plan for such a presentation. Nonetheless, my gut told me the opioid issue was important. I recruited the assistance of then incoming NEHA President Adam London, who successfully recruited local talent from Grand Rapids

*Our profession  
can cooperate and  
improvise for the  
greater good of the  
nation’s health.*

to speak to our members. On the opening day of the AEC, we inserted the opioid session into our conference app and I mentally prepared for low or no attendance. What I wasn’t ready for was what happened next.

First, I received criticism from many individual members. “What does opioid addiction have to do with us?” I was also accused of “mission creep.” As my heart sunk, I was approached by NEHA member Alan Dellapenna, who first chewed me out because as NEHA’s technical advisor for injury prevention, he was heretofore not aware of the session. He then promptly inquired if he could moderate the presentation as this issue is an area in which he is professionally active. I readily agreed to let him moderate.

At the appointed time, I entered the room assigned to the session and was overwhelmed by what I observed. I counted at least 75 people in attendance. Recall, this session was on the very last day of the conference. I madly took notes as attendees regaled each other with how the epidemic had impacted them

professionally—needle exchange programs, drug take back initiatives. Environmental health professionals reported being re-assigned to opioid work in lieu of their routine assignments. As it turns out, opioid addiction is an environmental health issue and we need to cooperate with addiction and mental health experts.

As I scan the landscape, I see many other areas where our profession can cooperate and improvise for the greater good of the nation’s health. We already are in some cases, but we haven’t taken the last step and claimed credit for our good work. A prime illustration is our contribution to operational functioning of the public health system writ large. I increasingly observe nonclinical public health leaders that have their roots in the environmental health profession. While larger jurisdictions require a doctor of medicine degree or a registered nurse credential for their health officials, many others do not. And most, if not all, have associate director positions staffed by people from our profession. I intend to learn more about our invisible leadership through focus groups conducted in fiscal year 2018.

Our profession is increasingly dominated by women. I have some preliminary data to support this notion, such as the gender composition of accredited schools and programs. I also see it firsthand when I speak at affiliate meetings. A couple of years ago, Michèle Samarya-Timm and her colleagues hosted an AEC session called “The Women of NEHA.” I believe they were ahead of their time. Our association should take on the leadership

*continued on page 65*

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## Environmental Health Software

The image displays two views of the Inspect2GO software. On the left is a desktop web dashboard. On the right is a mobile app interface shown on a tablet.

**Web Dashboard:**

- Header: Inspect2GO logo, user profile (Inspect2go Admin).
- Left sidebar menu: Dashboard, Scheduler, Forms, Inspections, Food, Sewage, Well, Pool, Child Care, Complaints, Permitting, Accounting, Reports.
- Main content area: "Dashboard Control panel" with breadcrumb "Home > Dashboard".
- Key metrics: "22 Users" (blue box), "823 Food Inspections (past 30 days)" (orange box), and a pie chart.

**Mobile App Interface:**

- Header: Inspect2GO logo, location: "533 Maple Ave., Irvine, CA 92673".
- Checklist items with status buttons (IN, OUT, N/A, R, N/O, COS):
  - 20. Proper cooling time and tempera....
  - 21. Proper hot holding temperatures
  - 22. Proper cold holding temperatures (Example: "Cut tomatoes stored at 68.6 deg")
  - 23. Proper date marking a
  - 24. Time as a Public Health
- Bottom section: "CONSUMER ADVISORY" and "HIGHLY SUSCEPTIBLE F".

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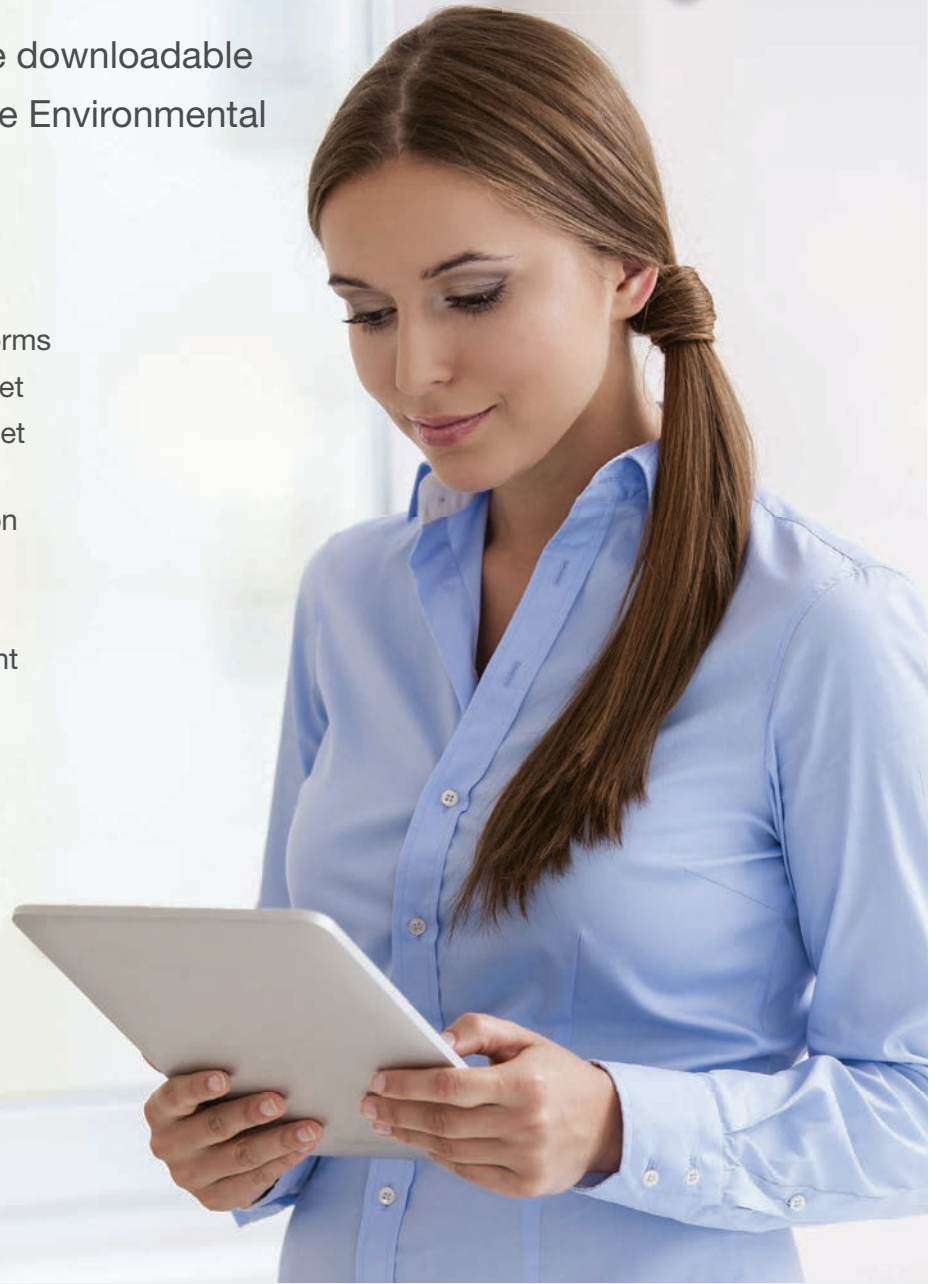
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## ▶ INTERNATIONAL PERSPECTIVES

# Reducing Risk of Respiratory Illness Associated With Traditional Cookstoves in a Rural Community in India: An Initial Assessment

Samuel A.K. Patha, MPH, GPH,  
CHES, LEHS  
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**Abstract** Unvented biomass cookstoves present a recognized respiratory health risk in developing countries. The purpose of this study was to characterize fine particle indoor air pollution (IAP) concentrations in dwellings using traditional cookstoves in a rural community in India. It also aimed to understand if a culturally acceptable clean cookstove intervention was needed to reduce the risk of respiratory illnesses from exposure to combustion products from traditional cookstoves. We took  $PM_{2.5}$  concentrations and  $\leq 0.5 \mu m$  particle counts inside a sample of dwellings during the use of traditional cookstoves. The data were analyzed to indicate the magnitude of IAP. In households with traditional cookstoves, average  $PM_{2.5}$  concentrations were  $172.8 \mu g/m^3$ , and the particle counts  $\leq 0.5 \mu m$  averaged 346,150. The  $PM_{2.5}$  concentrations from the traditional cookstoves were shown as unhealthy per the  $PM_{2.5}$  air quality index (AQI) of the U.S. Environmental Protection Agency. Partnering with local community members, an improved prototype metal cookstove was designed to be fuel-efficient and vent the smoke out of the dwellings. We found  $PM_{2.5}$  concentrations and  $\leq 0.5 \mu m$  particle counts for the new stove averaged  $21.5 \mu g/m^3$  and 60,812, respectively. The  $PM_{2.5}$  concentrations from the new stove are at an acceptable level per the AQI.

## Introduction

Around the world there are different types of fuels that are used for cooking and heating. While people in the developed world are accustomed to electricity or gas for cooking and heating purposes, most of those in the developing world rely upon biomass fuels, such as wood, cow dung, and crop waste. On the basis of cleanliness, efficiency, cost, convenience, and decreasing health impacts, biomass fuels are at the bottom of the energy ladder (World Health Organization [WHO],

2016a). Globally, it is estimated that some three billion people depend on biomass fuels to meet everyday needs such as cooking and heating (Bensch & Peters, 2015; Desai, Mehta, & Smith, 2004; Dherani et al., 2008; Smith, 1987; Smith, Mehta, & Maeusezahl-Feuz, 2004). That number represents 41% of the world's current population. Combustion of biomass is the dominant source of indoor air pollution (IAP) (Torres-Duque, Maldonado, Pérez-Padilla, Ezzati, & Viegi, 2008; Zhang & Smith, 2007). In high-mortality developing

countries, IAP ranks fourth among preventable risk factors contributing to the global burden of disease (Smith, 1993; WHO, 2002).

Those people in households using traditional open-fire cookstoves are rarely aware of the health risk such stoves can bring into their lives. There are many respiratory and other related health issues linked to the exposure of combustion products on a daily basis. Women exposed to IAP from poorly functioning and unvented cookstoves have a significantly higher risk of asthmatic attacks, with an odds ratio of 1.26 (Agrawal, 2012), which increases if people in the household also smoke tobacco. Furthermore, exposure to this type of IAP is associated with "both chronic bronchitis and emphysema phenotypes of chronic obstructive pulmonary disease (COPD) as well as a distinct form of obstructive airway disease called bronchial 'anthracofibrosis'" (Assad, Balmes, Mehta, Cheema, & Sood, 2015).

There is a great need for interventions that would reduce the exposure to IAP, reduce the risk for incident COPD, and "attenuate the longitudinal decline in lung function" (Assad et al., 2015). Biomass cookstoves produce significant black carbon emissions, which have a strong association with systolic blood pressure (SBP) (Baumgartner et al., 2014). Studies have also shown that clean cookstove interventions have effectively decreased SBP levels. In one study in Nicaragua, a clean cookstove intervention showed that a 5.9 mmHg reduction in SBP level was observed among women  $\geq 40$  years and a 4.6 mmHg reduction was observed among obese women, with a confidence interval of 95% (Clark et al., 2013).

The World Health Organization (WHO) has indicated that IAP can also be associated

TABLE 1

## Survey 1: Community Characterization Instrument

Question #	Question
1	Village name
2	Population as of December 2015
3	Number of houses as of December 2015
4	Nearest major city
5	Distance from nearest major city
6	Predominant religion: 1) Hinduism, 2) Christianity, 3) Muslim, or 4) other
7	Major language used: 1) Hindi, 2) Telugu, 3) English, or 4) other
8	Roadway system: 1) good, 2) fair, 3) poor, or 4) nil
9	Postal mail: 1) good, 2) fair, 3) poor, or 4) nil
10	Railway system: 1) good, 2) fair, 3) poor, or 4) nil
11	Cell phone service: 1) good, 2) fair, 3) poor, or 4) nil
12	Internet service: 1) good, 2) fair, 3) poor, or 4) nil
13	Health center: 1) yes or 2) no
14	Distance to nearest health center
15	Hospital: 1) yes or 2) no
16	Distance to nearest hospital
17	Police station: 1) yes or 2) no
18	Distance to nearest police station
19	Primary or middle school: 1) yes or 2) no
20	Distance to nearest primary/middle school
21	High school: 1) yes or 2) no
22	Distance to nearest high school
23	College: 1) yes or 2) no
24	Distance to nearest college
25	Houses with cookstoves: 1) traditional, 2) liquid petroleum gas (LPG), 3) electric, and 4) other
26	Number of houses that could benefit from using a cookstove
27	Most popular cookstove used: 1) traditional, 2) LPG, 3) electric, or 4) other
28	Most widely used fuel for cooking: 1) crop residues, 2) coal, 3) cow dung, 4) wood, 5) LPG, 6) electricity, 7) others, or 8) mostly biomass

TABLE 2

## Survey 2: Household Cookstove Information

Question #	Question
1	Head of the household name
2	Your name
3	Age
4	House number
5	Phone number
6	Who cooks food at home: 1) wife, 2) husband, 3) daughter, 4) son, or 5) other
7	How many hours per day do you spend cooking
8	What kind of stove do you use: 1) traditional, 2) liquid petroleum gas (LPG), 3) electric, or 4) other <i>Questions 11, 12, 13, 14, 16, 17, 18, 20, and 21 were asked if "traditional" was selected</i>
9	Are you happy with your current stove: 1) yes or 2) no
10	What fuel do you use for cooking: 1) crop residues, 2) coal, 3) cow dung cakes, 4) trash, 5) paper, 6) wood, 7) LPG, 8) electricity, or 9) mostly biomass
11	Does your stove release a lot of smoke: 1) yes, 2) no, 3) maybe, or 4) unsure
12	Do you believe that breathing in smoke is harmful to your health: 1) yes, 2) no, or 3) unsure
13	Do you usually have small children around while you cook: 1) yes, 2) no, or 3) sometimes
14 and 15	Is there any one in your house that smokes tobacco: 1) yes or 2) no <i>If yes, do they usually smoke inside or outside of the house: 1) inside, 2) outside, or 3) both</i>
16	Have you heard of improved cookstove before: 1) yes or 2) no
17	Would you be interested in getting an improved cookstove for your kitchen that releases no smoke: 1) yes or 2) no
18 and 19	How much money would you be willing to spend on an improved cookstove <i>If yes, would you be willing to buy it on a loaning system: 1) yes or 2) no</i>
20	Who collects the biomass fuel for cooking: 1) father, 2) mother, 3) son, 4) daughter, or 5) other
21	How many hours per week do you spend in scavenging biomass fuel

with other chronic illnesses such as tuberculosis, cataracts, and asthma (WHO, 2002). A causal pathway diagram by Haas explains the reasons for low birth weights and also reports how IAP can lead to several other diseases in a chain reaction (Fullerton, Bruce, & Gordon, 2008). Additionally, IAP contains particulate matter and carbon monoxide; increased exposure to particulate matter leads to increased maternal lung diseases, which in turn leads to reduced nutrient intake and reduced oxygen delivery to the placenta. Reduced nutrient intake by the mother and reduced oxygen

supply to the placenta results in impaired fetal growth, which could cause preterm delivery or low birth weight. Increased exposure to carbon monoxide also results in reduced oxygen content in maternal and child blood, and results in preterm delivery or low birth weight (Fullerton et al., 2008).

Thus, through various diseases as a result of exposure to IAP, many lives are affected—not just through earlier mortality but also by many years of lost disability adjusted life years (DALYs) and sick days. A study done in 2010 showed that approximately 9.9 million

DALYs were attributable globally to ambient PM<sub>2.5</sub> from household cooking with solid fuels (Chafe, 2014). A more recent study showed that 16.9 million DALYs are due to IAP from poor cooking methods in India alone (Rohra & Taneja, 2016). According to a 2014 report from WHO, globally 4.3 million deaths—equivalent to the entire population of Kentucky—were attributable to IAP in 2012, almost all of them in developing countries. Additionally, WHO reported that there were one million deaths in India in 2010 because of IAP (WHO, 2016b). Thus,



Woman cooking on an open cook fire with a monitor being used to measure pollution levels.



New improved metal cookstove prototype with smoke chamber and chimney to vent smoke out of the house.

WHO lists IAP as the “leading environmental cause of death in the world” and responsible for more deaths than malaria (Martin, Glass, Balbus, & Collins, 2011).

From the above listed data, it is clear that IAP is a serious health concern on a global scale, and especially in India. The purpose of this environmental assessment pilot study was to 1) understand the magnitude of IAP levels in dwellings in a community in India called Solaipalem and 2) demonstrate a basis for an intervention to help community members reduce the risk of respiratory illnesses associated with indoor cooking. We also wanted to design, manufacture, and complete preliminary tests on a new improved metal cookstove (NIMC) prototype that would be affordable and culturally acceptable in a real house setting.

A continuing goal of this project is to work towards eliminating cultural barriers to an improved cookstove by employing community members of Solaipalem to finalize and mass produce an effective and affordable clean cookstove aligned with their cultural needs. This approach not only has the potential to promote health but also to foster economic development by keeping the cookstove production jobs within the community. Ultimately, the overall purpose of this effort is to assist community members in reduc-

ing respiratory health risk through adoption of clean cookstoves. The study presented in this article only addresses the initial environmental assessment and pilot study of NIMC within this community in rural India.

## Materials and Methods

### Samples and Participants

We visited Solaipalem, a rural village in the southeastern state of India called Andhra Pradesh, in December 2015 for the initial environmental assessment and to determine if a more comprehensive project was feasible. This community was chosen because it had never been accessed for studies related to IAP. Solaipalem has some 175 dwellings with a population of about 900, the predominant religion is Hinduism, and most of the community speaks Telugu. A partnering agency, Free Me Foundation, had an established presence in the community, helped facilitate participating households, and will be part of organizing community health workers in the future.

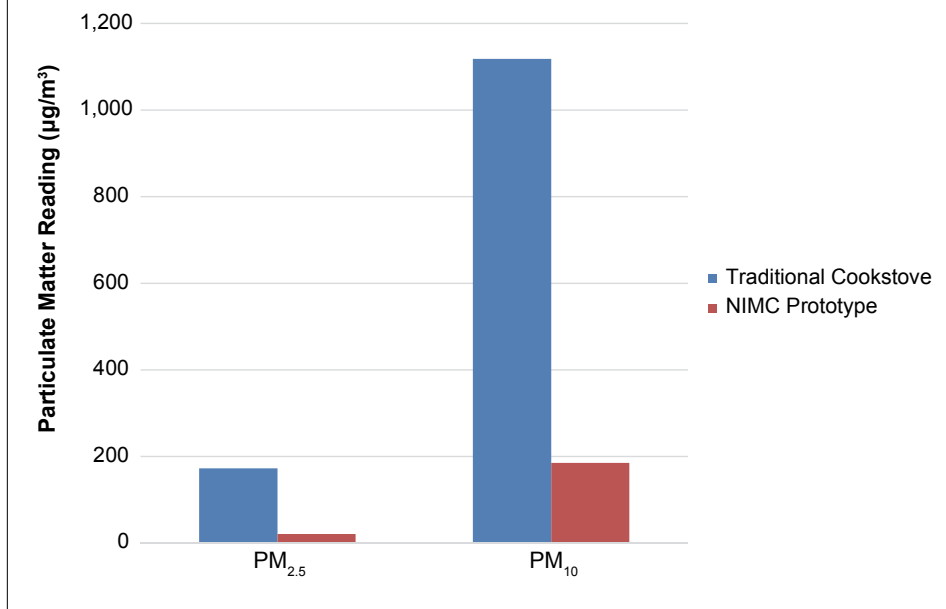
The community lacks proper roads, a railway system, postal services, a police station, Internet services, a hospital, and a high school. The lack of services requires most of the community to travel 15–30 miles to

access services. Solaipalem has a mixture of traditional mud houses with palm leaf roofs, as well as concrete houses. Almost all of the dwellings rely on biomass fuels and use traditional cookstoves on a daily basis. This community is a farming-based community where most of the adult males, and some females as well, work daily on their farms—or as contracted laborers—to earn income to cover their living costs. Their daily wages range between \$1–\$3, expressed in U.S. dollars.

Within this community, we monitored and recorded IAP levels in the dwellings of eight different families over a period of 3 weeks. This number was chosen based on a previous pilot study in India using an average of nine houses per village among four villages (Smith, Aggarwal, & Dave, 1983). The eight families in this study were not selected randomly, but were chosen upon the suggestion of community leaders because they had traditional mud stoves in their homes. Each of the dwellings was considered to be typical for the community in terms of construction and the use of traditional biomass-fueled cookstoves that were nonvented. Each family was also informally interviewed throughout the study about their present cooking practices and views on alternative types of cookstoves.

FIGURE 1

### Particulate Matter Reading Comparison Between Traditional Cookstoves and New Improved Metal Cookstove (NIMC) Prototypes



#### Survey Instrument Development and Data Collection

We developed two information-gathering instruments prior to initiation of the study. One survey (Table 1) aimed to characterize the community and understand the logistical aspects of the village to help determine the feasibility of an intervention. The other survey (Table 2) aimed to understand the cooking culture and attitudes of the community members through informal interviews. The logistical aspects of the community were obtained from village leaders, while the cooking culture and attitudes were obtained through several informal interviews with each participant family.

#### Particle Measurement and Data Collection

We took particulate matter mass concentrations and particle count readings using a Met One Aerocet 531 monitor at an operational flow rate of 2.83 L/min. The measurements were taken at various times of the day depending on the availability of the households and on their traditional times when they cooked their meals. Multiple readings in each dwelling were taken at different times to obtain average daily particle pollution levels.

We placed the particle monitor above the stove in most dwellings to record pollution levels as the smoke was emitted from each stove (see photo on page E3, left). The monitor was field-calibrated each day using a zeroing procedure before taking each of the measurements. After excluding the calibration readings and occasional error readings, 81 measurements of PM<sub>2.5</sub> and PM<sub>10</sub> concentrations, along with the ≤0.5 µm and ≥5.0 µm particle counts were taken in eight different dwellings harboring various stove types. Readings often varied because of the airflow inside the dwellings. As some mud stoves were just outside the dwellings, many readings had to be excluded because the wind gave errors in readings. In dwellings where the walls were made of crop residues, air easily flowed inside the house and also gave errors in readings. Of the 81 total readings, 33 were readings of the traditional indoor/outdoor mud stoves and 8 were readings of the NIMC prototype.

#### New Improved Stove Design

Researchers were able to team up with local community members to design and fabricate a NIMC prototype (see photo on page

E3, right) made from locally available materials. The NIMC prototype was made from cast iron and enclosed within a smoke chamber. It also had a metal exhaust pipe to vent the smoke. Various other biomass-improved stoves available in the current Indian market cost around \$30–\$40 (Vikram Stoves & Fabricators, 2016); our NIMC prototype cost ≤\$25 each.

#### Data Analysis

Mean values of the particle measurements for all of the cookstove readings were calculated and PM concentrations and ≤0.5 µm particle counts were compared between the traditional cookstoves that were monitored and the NIMC prototype using column charts. The informal interviews were evaluated for trends and the main themes were recorded.

#### Results

In households with open-fire traditional cookstoves, the particulate matter levels and particle counts were significantly higher compared with the NIMC prototype cookstove. The PM<sub>2.5</sub> and PM<sub>10</sub> concentrations with the traditional stoves averaged 172.8 µg/m³ and 1,118.1 µg/m³, respectively (Figure 1). In our tests with the NIMC prototype, the PM<sub>2.5</sub> and PM<sub>10</sub> concentrations averaged 21.5 µg/m³ and 185.5 µg/m³, respectively (Figure 1).

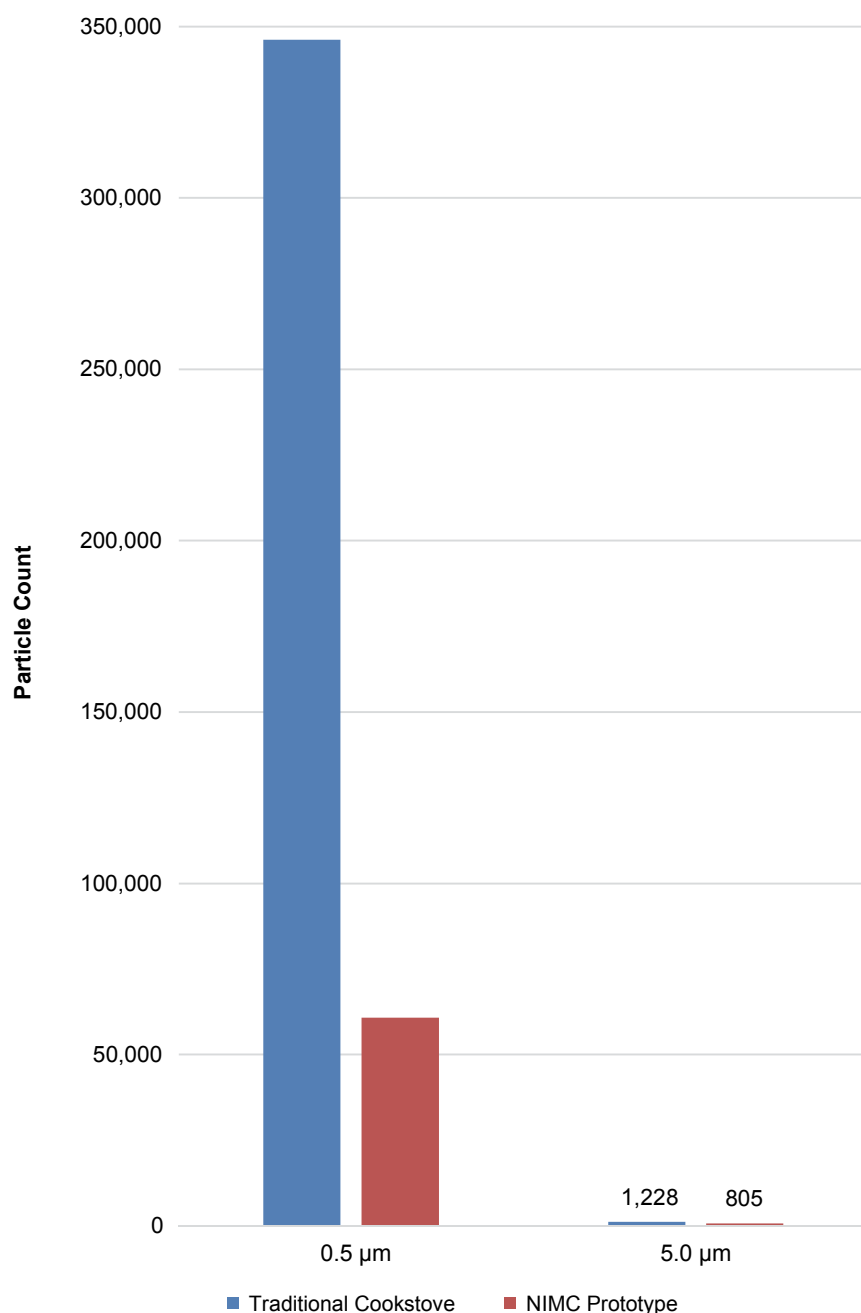
Traditional cookstove particle counts ≤0.5 µm averaged 346,150 and the particle counts of ≥5.0 µm averaged 1,227.8, while the ≤0.5 µm and ≥5.0 µm counts with the NIMC prototype averaged 6,0812.3 and 804.5, respectively (Figure 2).

Through the informal interviews, it was learned that almost 100% of the time mothers cook the food at home and that they also gather the biomass needed for cooking. Most of them use a traditional cookstove. Mothers usually spend 4–7 hr/day cooking food for the family and 6–7 hr/week scavenging for the biomass to use as fuel. When asked if they were happy with their current stove, all of them mentioned that they were satisfied even though they were aware of more modern and cleaner fuel stoves. They indicated that they were happy with their current stoves because they did not have to spend a lot of money for fuel, and they were accustomed to it. When asked if their current stove produces a lot of smoke and if they believed it to be harmful to them,



FIGURE 2

### Particle Count Comparison Between Traditional Cookstoves and New Improved Metal Cookstove (NIMC) Prototypes



100% said it produced a lot of smoke and that it was harmful to them. The smoke did not produce any immediate effects, though, so therefore they were less concerned about it. Almost all of them expressed interest

in obtaining an improved cookstove that released no smoke indoors, either through an affordable loan or subsidy of some type.

## Discussion

The fine particulate matter concentrations from traditional stoves and the NIMC prototype were compared with the air quality index (AQI) (Airnow, 2016a) from the U.S. Environmental Protection Agency (U.S. EPA) to understand the potential health effects of fine particulates. Even though AQI takes the aggregate effect of pollutants such as particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide, the AQI calculator (AirNow, 2016b) was used to calculate the AQI score solely based on  $PM_{2.5}$  and  $PM_{10}$  concentrations.

The  $PM_{2.5}$  average of  $172.8 \mu\text{g}/\text{m}^3$  from the traditional stove constitutes a respiratory health risk and the health effects statement from the U.S. EPA says that at this level of  $PM_{2.5}$  there will be “increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; increased respiratory effects in general population” (AirNow, 2016b). The  $PM_{2.5}$  average of  $21.5 \mu\text{g}/\text{m}^3$  from the NIMC prototype, however, is at a good level on the AQI and no health effect statement is realized. The  $PM_{10}$  average of  $1,118.1 \mu\text{g}/\text{m}^3$  with a traditional stove is at a hazardous level with a corresponding health effect statement from the U.S. EPA: “Serious risk of respiratory symptoms and aggravation of lung disease, such as asthma; respiratory effects likely in general population” (AirNow, 2016b). The  $PM_{10}$  average of  $185.5 \mu\text{g}/\text{m}^3$  from the NIMC prototype is at unhealthy levels as well and needs further study.

The average ambient  $PM_{2.5}$  concentrations range between  $13.8$ – $18.2 \mu\text{g}/\text{m}^3$  in cities such as Cincinnati, El Centro, Bakersfield, Los Angeles, and Fresno in the U.S. (McCarthy, 2015). The  $PM_{2.5}$  levels within the houses of the Solaipalem community are  $\geq 10$  times the concentrations of some of the large cities in the U.S.

In addressing a major cultural aspect of cookstoves, qualitative results identified that when using the NIMC prototype, there was no difference in the taste of food; the only difference was that the improved cookstove vented the smoke out. The vacuum generated by the airflow outside the house helped to pull the smoke out of the smoke chamber.

## Conclusion

Particulate matter measured in dwellings of Solaipalem, India, indicated extensive exposure to combustion products such as  $PM_{2.5}$

and PM<sub>10</sub> from ineffective and poorly ventilated stoves. This initial assessment confirmed the need for a clean cookstove intervention, and elements should include a stove that has acceptable fuel efficiency, vents emissions, produces sufficient heat for cooking, and does not alter the taste of the food.

The tested NIMC prototype functioned efficiently and vented the smoke out of the house. It was tested several times and has the following benefits: 1) safer due to reduced smoke exposure because of venting to the outside, 2) durable and long lasting because of the heavy duty cast iron, 3) more mobile compared with traditional mud stoves, 4) heat efficient because it reduces the products of combustion due to improved fuel efficiency, 5) time efficient because heat is directed to the pot and less time is spent in scavenging for wood, and 6) fuel efficient because of improved heat transfer and airflow control. This initial study has shown that an improved cookstove can be produced within the community with materials that are locally available and acceptable by local community members.

Particulate matter with a diameter between 2.5–10 µm can pass the defense system in the nasal passages and penetrate the upper airways, while particulate matter with diameter ≤2.5 µm can pass beyond the lungs into the bloodstream, and be an invisible killer. The particulate matter concentrations and particle count data generated in this study indicate that the problem of IAP is a serious one in this community. The community's willingness to participate and help throughout the project provides hope that there will be major participation when the actual intervention takes place.

Additional research is necessary to produce even less PM<sub>10</sub> and ≥5.0 µm and larger emissions, and to determine whether PM<sub>10</sub> concentrations and ≥5.0 µm counts result mainly because of inefficiency or if it's the quality of air in the community, or both. Further, the stove design needs to be made available throughout the community to determine if a majority would culturally adopt it and could financially afford it.

Readings often varied because of the airflow inside the dwellings. As some mud stoves were just outside the dwellings, many readings had to be excluded because the wind gave errors in readings. In dwellings where the walls were made out of crop residues, air easily flowed inside the house and also gave errors in readings.

Based on this initial assessment, the feasibility of moving forward and initiating local production of an improved cookstove to reduce the risk of chronic respiratory illness is promising. Finally, researchers studying clean cookstoves should perform needs assessments before they get started. The focus should be on user priorities and acculturating the stove to the place where the intervention will be performed.

It is clear that the Solaipalem community and many other rural communities like it in India have high rates of IAP. The government of India, however, has not addressed many of these communities' needs in relation to the IAP problem. We call upon the government of India to work towards eliminating this global health problem by advocating clean fuels to all rural communities, and partnering collaboratively with nongovernmental

organizations that are working to eradicate this problem.

The proposed full project is currently at the intervention planning stage and will be going into full operation in the beginning of 2018. From the results of this pilot study, the NIMC needs to be aesthetically and culturally devised, as well as locally produced to promote economic development within the community. In addition to production considerations, we aimed to increase community mobilization by involving local women as advocates for clean cookstove adoption. Such women may be seen as early adopters of the clean cookstoves and be helpful to further tailor the intervention process as community health advocates. 🌱

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## References

- Agrawal, S. (2012). Effect of indoor air pollution from biomass and solid fuel combustion on prevalence of self-reported asthma among adult men and women in India: Findings from a nationwide large-scale cross-sectional survey. *Journal of Asthma*, 49(4), 355–365.
- AirNow. (2016a). *Air quality index (AQI) basics*. Retrieved from <https://airnow.gov/index.cfm?action=aqibasics.aqi>
- AirNow (2016b). *AQI calculator: AQI to concentration*. Retrieved from [https://airnow.gov/index.cfm?action=resources.aqi\\_conc\\_calc](https://airnow.gov/index.cfm?action=resources.aqi_conc_calc)
- Assad, N.A., Balmes, J., Mehta, S., Cheema, U., & Sood, A. (2015). Chronic obstructive pulmonary disease secondary to household air pollution. *Seminars in Respiratory and Critical Care Medicine*, 36(3), 408–421.
- Baumgartner, J., Zhang, Y., Schauer, J.J., Huang, W., Wang, Y., & Ezzati, M. (2014). Highway proximity and black carbon from cookstoves as a risk factor for higher blood pressure in rural China. *Proceedings of the National Academy of Sciences*, 111(36), 13229–13234.
- Bensch, G., & Peters, J. (2015). The intensive margin of technology adoption—Experimental evidence on improved cooking stoves in rural Senegal. *Journal of Health Economics*, 42, 44–63.

## References

- Chafe, Z.A., Brauer, M., Klimont, Z., Dingenen, R.V., Mehta, S., Rao, S., . . . Smith, K.R. (2014). Household cooking with solid fuels contributes to ambient PM<sub>2.5</sub> air pollution and the burden of disease. *Environmental Health Perspectives*, 122(12), 1314–1320.
- Clark, M.L., Bachand, A.M., Heiderscheidt, J.M., Yoder, S.A., Luna, B., Volckens, J., . . . Peel, J.L. (2013). Impact of a cleaner-burning cookstove intervention on blood pressure in Nicaraguan women. *Indoor Air*, 23(2), 105–114.
- Desai M.A., Mehta S., & Smith, K.R. (2004). *Indoor smoke from solid fuels: Assessing the environmental burden of disease*. Geneva, Switzerland: World Health Organization. Retrieved from [http://www.who.int/quantifying\\_ehimpacts/publications/9241591358/en](http://www.who.int/quantifying_ehimpacts/publications/9241591358/en)
- Dherani, M., Pope, D., Mascarenhas, M., Smith, K.R., Weber, M., & Bruce, N. (2008). Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: A systematic review and meta-analysis. *Bulletin of the World Health Organization*, 86(5), 390–398C.
- Fullerton, D.G., Bruce, N., & Gordon, S.B. (2008). Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 102(9), 843–851.
- Martin, W.J., II, Glass, R.I., Balbus, J.M., & Collins, E.S. (2011). A major environmental cause of death. *Science*, 334(6053), 180–181.
- McCarthy, N. (2015, January 23). Air pollution: Chinese and American cities in comparison. *Forbes*. Retrieved from <http://www.forbes.com/sites/niallmccarthy/2015/01/23/air-pollution-chinese-and-american-cities-in-comparison-infographic/#468b680f7d01>
- Rohra, H., & Taneja, A. (2016). Indoor air quality scenario in India—An outline of household fuel combustion. *Atmospheric Environment*, 129, 243–255.
- Smith, K.R. (1987). *Biofuels, air pollution, and health: A global review*. New York, NY: Plenum Press.
- Smith, K.R. (1993). Fuel combustion, air pollution exposure, and health: The situation in developing countries. *Annual Review of Energy and the Environment*, 18, 529–566.
- Smith, K.R., Aggarwal, A.L., & Dave, R.M. (1983). Air pollution and rural biomass fuels in developing countries: A pilot village study in India and implications for research and policy. *Atmospheric Environment* (1967), 17(11), 2343–2362.
- Smith, K.R., Mehta, S., & Maeusezahl-Feuz, M. (2004). Indoor air pollution from household use of solid fuels. In M. Ezzati, A.D. Lopez, A. Rodgers, & C.J.L. Murray (Eds.), *Comparative quantification of health risks. Global and regional burden of disease attributable to selected major risk factors* (Vol. 1, pp. 1435–1493). Geneva, Switzerland: World Health Organization.
- Torres-Duque, C., Maldonado, D., Pérez-Padilla, R., Ezzati, M., & Viegli, G. (2008). Biomass fuels and respiratory diseases: A review of the evidence. *Proceedings of the American Thoracic Society*, 5(5), 577–590.
- Vikram Stoves & Fabricators. (2016). *Bio Classic*. Retrieved from <http://www.vikramstoves.com>
- World Health Organization. (2002). *The world health report 2002—Reducing risks, promoting healthy life*. Retrieved from <http://www.who.int/whr/2002/en>
- World Health Organization. (2014). *Burden of disease from household air pollution for 2012: Summary of results*. Retrieved from [http://www.who.int/phe/health\\_topics/outdoorair/databases/HAP\\_BoD\\_results\\_March2014.pdf?ua=1](http://www.who.int/phe/health_topics/outdoorair/databases/HAP_BoD_results_March2014.pdf?ua=1)
- World Health Organization. (2016a). *Indoor air thematic briefing 2*. Retrieved from <http://www.who.int/indoorair/info/briefing2.pdf>
- World Health Organization. (2016b). *Addressing the challenge of air pollution in India*. Retrieved from [http://www.searo.who.int/india/topics/air\\_pollution/air\\_pollution\\_media\\_note.pdf?ua=1](http://www.searo.who.int/india/topics/air_pollution/air_pollution_media_note.pdf?ua=1)
- Zhang, J., & Smith, K.R. (2007). Household air pollution from coal and biomass fuels in China: Measurements, health impacts, and interventions. *Environmental Health Perspectives*, 115(6), 848–855.