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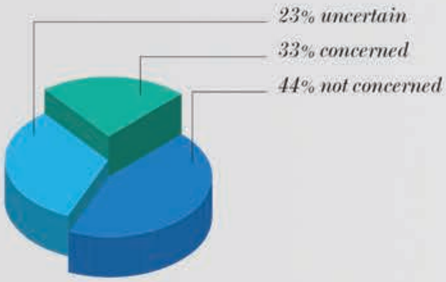

TYPES OF TRAINING RECEIVED

OCCUPATIONAL HEALTH AND SAFETY

Challenges for Cosmetologists

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ABOUT THE COVER

This month's cover article, "Occupational Health Survey of Cosmetologists in Minnesota," explores the occupational health and safety challenges faced by cosmetologists. A survey was sent to licensed cosmetologists to collect demographic data, work history, respiratory symptoms, product usage, and health and safety training. While training related to customer safety and sanitizing processes were completed by a majority of cosmetologists, training regarding worker safety and personal health are lacking. Almost 50% of surveyed cosmetologist reported respiratory symptoms related to their work, which indicates a pressing need for education, prevention, and intervention methods.

See page 8.

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PRESIDENT'S MESSAGE

David E. Riggs,
MS, REHS/RS

With a Little Help From My Friends

Recently it was my privilege to talk about the National Environmental Health Association (NEHA) and what it means for our association to be the premier organization for environmental health. As I presented the many ways that NEHA serves the professional practitioner, I also considered who it takes to make NEHA the go-to environmental health organization.

The first group of people that comes to mind is the NEHA staff and management. This small but talented, dedicated, and intelligent group of professionals is responsible for the ongoing operation of our association. The many changes in NEHA over the last two years have been carried on their shoulders. It has been their responsibility to implement new software systems for all phases of headquarter function including membership and learning management systems and a new and expanded Web site. Also of importance is that NEHA is in the midst of implementing a new accounting system under the direction of a new financial director.

Another great accomplishment will be the roll out of the NEHA 2017 Annual Educational Conference (AEC) & Exhibition in Grand Rapids, Michigan. The 2017 AEC will be a new version of our AEC with more streamlined and interactive presentations on the most current national and local concerns and issues. Keynote and session presentations will feature national leaders and practitioners. Check out the 2017 AEC promo on page 49 for more information and to register.

In addition to our NEHA staff, this association could not exist or function without our volunteers. NEHA is first and foremost a volunteer professional organization. Volunteers range from the board of directors, which consists of five national officers and nine regional vice-presidents, to technical advisors, subject matter experts, and peer reviewers, as well as state affiliate presidents. These are but a few of the volunteer professionals that our association depends upon to function and accomplish the work of representing, educating, and communicating with all members.

> *NEHA is an organization that depends upon all of us volunteering our time, knowledge, and expertise.*

Our state affiliate presidents and officers are leaders on the state and local levels. It is through the state affiliates that NEHA maintains its connections to the membership and on-the-ground environmental health professionals. It is through this relationship that practitioners can keep NEHA aware of environmental health laws, regulations, and trends. It is also through this relationship that NEHA can address concerns and develop position papers, as well as provide education aimed toward local and state needs. Most, if not all, of our national volunteers began by being active members and officers in their state affiliates. State affiliates are the foundation of NEHA and give strength, expertise, and diversity to our national organization.

Another group of volunteers that plays a major role in the success of NEHA is the technical advisors. These volunteers are experts in their chosen fields. They work with NEHA staff during the AEC to put together the educational program, as well as provide their expertise to the board of directors and staff on questions and concerns that arise throughout the year. Recruiting speakers, reviewing abstracts, and moderating AEC sessions make up just a short list of what our technical advisors do.

Our *Journal of Environmental Health* is an outstanding example of a professional journal that presents noteworthy articles and columns on current issues, concerns, and environmental health practices, as well as scientifically sound research and application. It would be impossible to publish such a fine periodical without the *Journal's* managing editor, staff, technical editors, peer reviewers, columnists, and submitting authors. The combination of our staff and volunteers makes our *Journal* valid, original, logical, and scientifically sound.

Our volunteers also play a vital role in the success of NEHA and the environmental health profession; they are the people who donate time to various committees, projects, and professional activities. This group operates and volunteers on local, state, and national levels. Whether you volunteer to serve a city or county commission or board, or a civic or charitable organization, you expand the visibility of our profession. It is also important to volunteer to serve on your state affiliates committees to build an active organization that promotes environmental health.

It is impossible to recognize or thank all the volunteers that NEHA, state affiliates, and our profession depend upon for their success. NEHA is an organization that depends upon all of us volunteering our time, knowledge, and expertise to support our profession and our association.

Over the years, I have posed the question, "How did you get into the environmental health profession?" The answers have ranged from "It was an open job where I could use my degree," to "I started out studying pharmacy and didn't like it so I transferred my science credits into environmental health." Many of us found our way into the environmental health profession via different paths and many of us have made a conscious decision to join NEHA. We have found that our association is the premier environmental health organization and the recognized voice of environmental health practitioners. As members, we should feel the obligation and privileged to volunteer at all levels to ensure we remain a viable and top notch organization.

It is with pride in my profession that I say thank you to our volunteers that contribute to NEHA. If you want to get involved with either NEHA or your state affiliate, let us know. You can also go to www.neha.org/membership-communities/get-involved to learn more about all the volunteer opportunities NEHA offers. I believe volunteering will be rewarding and may change your career and life, like it did for mine.

David E. Riggs
davideriggs@comcast.com

Did You Know?

NEHA has created blogs for the columns written by our president and executive director. You can read the columns online, leave your comments, and start a conversation. Check out these blogs at www.neha.org/membership-communities/get-involved/blog.

SUPPORT THE NEHA ENDOWMENT FOUNDATION

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

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

Thank you.

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Special invitation to the AEC President's Reception, name in the Journal *for one year, and endowment pin.*

Occupational Health Survey of Cosmetologists in Minnesota

Kathleen G. Norlien, MS, CPH
Asthma Program
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Abstract **Cosmetologists face a variety of occupational health and safety challenges. To gather information on respiratory issues related to work as a cosmetologist, licensed cosmetologists were invited by e-mail to participate in a short online survey. The survey collected demographic data, work history, respiratory symptoms, product usage, and health and safety training. Results revealed that while 57% of cosmetologists reported having received training on customer or consumer safety, only 10.5% had received training on worker health such as work-related asthma and/or breathing issues. Respiratory symptoms were reported by 46% of respondents. Length of employment and the use of glues or adhesives were associated with a diagnosis of asthma.**

Background

Employment as a cosmetologist, nail technician, or esthetician can be a hazardous occupation and nearly half a million workers in the U.S. alone are employed in these professions. This number includes an estimated 460,520 persons employed as cosmetologists (343,140), skincare specialists (38,290), and pedicurists or manicurists (79,090) (Bureau of Labor Statistics, 2014). In Minnesota in 2014, the Minnesota's Board of Cosmetologist Examiners (BCE) had 17,403 licensed operators for cosmetology (12,747), esthetician (1,610), and manicurist (3,046) practice. A total of 16,204 persons were licensed as managers of these three areas of practice (R. Gaspard, Minnesota Board of Cosmetologist Examiners, personal communication, August 6, 2015). Hairdressers, hairstylists, and cosmetologists are trained to provide beauty services such as shampooing, cutting, coloring, and styling hair. They may also apply makeup, dress wigs, perform hair removal, and provide nail and skin care services.

A number of chemicals such as alcohols, aldehydes, and dyes are used in cosmetology (Espuga et al., 2011; Kreiss et al., 2006; Mendes et al., 2011; Nemer, Kristensen, Nijem, Bjertness, & Skogstad, 2013; Slater et al., 2000; Tsigonia et al., 2010). Glues and adhesives are widely used for hair and nail extensions (Lindström, Suojalehto, Henriks-Eckerman, & Suuronen, 2013). Additional chemicals are used to clean and sanitize equipment used on hair, nails, and skin. Many of these chemicals are both lung and skin irritants. In addition to the irritation produced, previous studies have reported an increased risk of cosmetologists and apprentices in the field of cosmetology developing asthma from working with these chemicals (Kreiss et al., 2006; Leino, Tammilehto, Luukkonen, & Nordman, 1997; Mounier-Geyssant, Oury, Mouchot, Paris, & Zmirou-Navier, 2006).

In the late 1990s, Leino and coauthors studied the working conditions and health of workers in hairdressing salons in Finland. While physical and chemical working conditions in the salons were found to be satisfactory, exposures to many chemicals were still considered to be a significant health problem (Leino, Kähkönen, Saarinen, Henriks-Eckerman, & Paakkulainen, 1999; Leino et al., 1998). In addition, the observed prevalence of respiratory diseases among hairdressers has been estimated to be 5%–25% (Blainey, Ollier, Cundell, Smith, & Davies, 1986; Iwatsubo et al., 2003; Leino, Tammilehto, Paakkulainen, Orjala, & Nordman, 1997).

Unlike the U.S., some countries such as Finland and France have extensive reporting systems that can be used to track occupational illness. Studies done in France have looked at early markers of airway inflammation and occupational asthma in hairdressing apprentices (Acouetey et al., 2013; Tossa et al., 2009). In France, hairdressing ranks third among those occupations with the highest risk of occupational asthma (OA); however, it is the leading cause of OA among females. For both men and women, the risk of OA in hairdressers was determined to be 308 cases per million workers, with a higher risk of OA found only in baker/pastry workers and car painters (Tossa et al., 2009).

In the U.S., the licensure of cosmetologists, estheticians, and manicurists is left largely up to each state. The Minnesota Department of Health (MDH) conducted an investigation after receiving a complaint in late 2010 from a woman who developed severe asthma-like symptoms after she received a professionally applied hair straightening treatment called a Brazilian Blowout. The woman's respiratory symptoms included eye and nose irritation, and she was eventually diagnosed with reactive airways dysfunction syndrome (RADS). Her RADS symptoms began during the hair treatment and persisted for one year after that treatment. It was suspected that these hair straightening products containing formaldehyde were now being used elsewhere in Minnesota, just as they had been used in Oregon and Canada (Health Canada, 2013; Oregon Occupational Safety and Health Administration, 2010). While these hair products posed a potential health risk to consumers who might be sensitive to them, health risks would be even greater for more heavily exposed workers or cosmetologists who routinely and repeatedly work with these hair treatment products.

A health alert was issued by MDH in April 2011 to inform cosmetologists about the potential hazards to using hair products that contain formaldehyde (MDH, 2011). Subsequent discussions with and cooperation from Minnesota's BCE led MDH to electronically survey licensed cosmetologists, manicurists, and estheticians to explore the issues of health and safety training in this group of licensed workers.

Methods

The survey, developed by MDH and BCE, consisted of 30 questions pertaining to potential workplace exposures, the types of products used, perceptions of risk associated with use of these products, health and safety training received, and self-reports of asthma.

Specifically, information from survey participants was collected on the participant's area of licensure (cosmetologist, manicurist, esthetician), age, sex, years in profession, current employment status, smoking status, safety-related topics such as safety training received, training on respiratory hazards, types of products she/he works with, whether or not she/he reads product labels, protective actions or equipment used, how she/he feels about her/his knowledge of health and safety, and perception of risk associated with workplace. In addition, information regarding asthma was collected. This information included self-report of physician or health-care provider-diagnosed asthma, asthma symptoms, and the relationship of asthma to her/his work both in current and past jobs. Due to limited resources, this survey was offered only in English.

BCE maintains a list of e-mails for many of its licensees and provided MDH with 19,853 e-mail addresses in late November 2011. Once duplicate and unusable addresses were removed, 18,692 e-mail addresses remained and were used to e-mail a link to the survey to all listed licensees. These licensees included cosmetologists who work with hair, manicurists who work with nails, and estheticians who work with skin.

The initial survey link informed the recipients that MDH and BCE were sponsoring the survey. The directions requested that the recipient complete a brief survey on workplace safety for cosmetologists, estheticians, and manicurists. A second notice regarding the survey was sent again to provide the survey link and to urge people to take the survey if they had not yet done so. Another reminder was sent stating that over 1,000 people had taken the survey. The number of participants rose to 1,750 by the time the final message, "only 24 hours left to complete the survey," was sent.

Data was collected using Vovici software and SAS version 9.3 was used to complete all statistical analyses. Frequencies were created to provide descriptive demographic characteristics for the population. Chi-square estimates were calculated for comparisons between subgroups of the study population. The Cochran–Armitage test was used to test for trends between exposure variables and the probability of an asthma diagnosis. Logistic stepwise regression models were also used to determine variables that increased the probability of an asthma diagnosis (i.e., age, length of employment, smoking status, glue or adhesives exposures, the number of exposures, and employment status).

Results

Of the 2,058 people who started this survey, 1,774 were licensed as a cosmetologist, 247 held esthetician licenses, and 198 were licensed as manicurists. Some of the 2,058 licensees held licenses in more than one area. Furthermore, 96.5% of the respondents were women (n = 1,826). Cosmetologists had the greatest representation among all survey participants, with a total of 1,684 identifying themselves as only a cosmetologist. Those identifying themselves as only an esthetician or nail technician were excluded from the analysis due to the small numbers.

Participants were asked to identify which age bracket, in 10-year increments, they belonged to. The youngest participants reported that they were between 15–24 years, while the oldest group consisted of respondents older than 64 years. The majority of respondents (32.2%) were between 25–34 years of age and 93% identified themselves as White (Table 1).

This survey also asked participants about their perception of risk regarding their occupation. When asked whether or not they believed that products used in the workplace posed a risk to their health, 44% did not believe they were at risk, 33% had concerns, and 23% answered that they didn't know. Of the 634 workers who felt that their health was at risk, less than 10% believed that risk to be high. Some 51% believed their risk to be of medium concern.

When participants were asked about workplace safety training, the majority of respondents (77.9%) replied that they had been trained on disinfection or sanitizing processes. Training on breathing problems, skin problems, and chemical hazards were reported only by 10.5%, 27.9%, and 44.8% of respondents, respectively (Figure 1). Nearly 18% of the survey group reported having had no training on health and safety issues, although there were fewer younger cosmetologists who reported no training (23% and 31% of the 15–24 and 25–34 year groups, respectively) as compared with the older cosmetologists (54% and 56% of the 55–64 and older than 64 year groups, respectively).

When asked whether or not they had ever had health and safety training, 61.6% of the cosmetologists reported having received some form of health and safety training; however, only 20.4% reported having received training specific to respiratory protection.

Study participants were asked to identify any and all work exposures they faced from a list of seven categories provided: adhesives or glues, hair curling/wave products (permanents), hair straighteners (like Brazilian Blowout), hair coloring, hair bleaches, cleaning/sanitizing/disinfecting products,

TABLE **1**

Selected Characteristics of Participants in Cosmetology Survey

Category	# (%)
Gender	
Male	67 (3.5)
Female	1,826 (96.5)
Age category (years)	
15–24	166 (8.8)
25–34	609 (32.2)
35–44	417 (22.0)
45–54	385 (20.3)
55–64	241 (12.7)
65+	75 (4.0)
Smoking status	
Current	284 (15.0)
Former	431 (22.8)
Never	1,178 (62.2)
Years employed in industry	
0–5	417 (22.0)
6–10	440 (23.2)
11–15	253 (13.4)
16–20	148 (7.8)
20+	635 (33.5)
Race	
White	1,751 (92.5)
Asian	60 (3.2)
Southeast Asian	34 (56.7)
U.S.-born	14 (23.3)
Other	12 (20.0)
Black	35 (1.8)
African-born	2 (5.7)
U.S.-born	33 (94.3)
Hispanic	14 (0.7)
Central American-born	3 (23.1)
U.S.-born	10 (76.9)
American Indian	11 (0.6)
Other or unknown	22 (1.2)

FIGURE **1**

Health and Safety Training Topics Surveyed Cosmetologists Received Training On

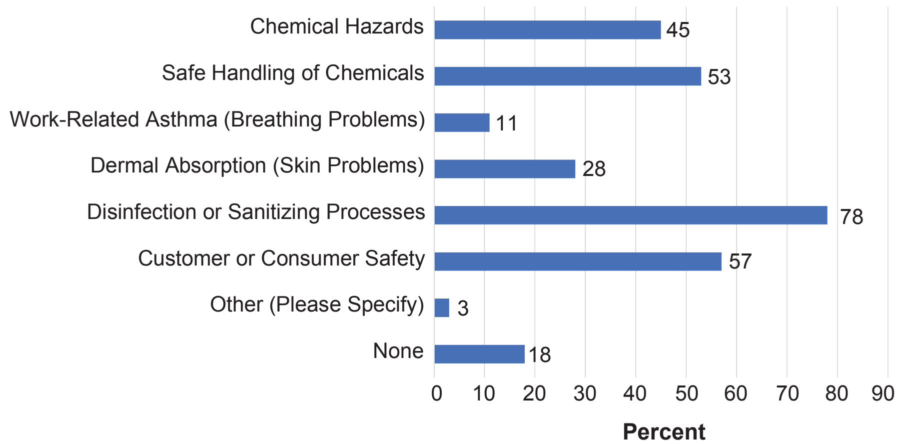

TABLE **2**

Frequency of the Number of Exposures Identified by Respondents

# of Exposures	Frequency	%	Cumulative Frequency	Cumulative %
1	71	4.2	71	4.2
2	86	5.1	157	9.3
3	175	10.4	332	19.7
4	689	40.9	1,021	60.6
5	457	27.1	178	87.8
6	206	12.2	1,684	100

and "other" chemicals (please explain). The majority of cosmetologists identified multiple exposures, with 80.3% reporting four or more exposures at work (Table 2). Of the exposure groups listed, cleaning/sanitizing/disinfecting products were the most frequently identified as an exposure, followed by hair coloring products. Adhesives or glues had the fewest individuals identify these agents as a common exposure (Table 3). Participants were also asked to identify with what frequency they had breathing problems in the workplace. The majority, 53.4%, stated they had never had an issue with breathing problems in the workplace. A total of 3.9% stated they had an almost daily occurrence of breathing problems in the workplace (Table 4).

Of the cosmetologists surveyed, 16.1% of the respondents indicated that a healthcare provider had told them they have asthma. When comparing the diagnosis of asthma by a healthcare provider by the type of exposure (curling product usage, straightener usage, coloring product usage, etc.), no significant relationships were found at the $\alpha = .05$ level. Only the use of adhesives or glues was marginally close to a significant relationship with a *p*-value of .07 (Table 5). Using the Cochran–Armitage test for trend, an increasing number of exposures was not found to increase the probability of diagnosis of asthma by a healthcare provider ($p = .12$). Age and length of employment were found to be significant predictors of an increased probability of asthma diagnosis, $p = .01$ and $p = .001$, respectively. Smoking status (never, former, and current) were found to be nonsignificant ($p = .69$). Both vari-

TABLE 3

Frequency of Respondents to Exposure Type

Exposure Type	Frequency	%
Adhesives or glues	303	18
Hair curling/wave products (permanents)	1,436	58.3
Hair straighteners (like Brazilian Blowout)	611	36.3
Hair coloring	1,532	91
Hair bleaches	1,470	87.3
Cleaning, sanitizing, or disinfecting products	1,614	95.8
Other chemicals (please explain)	90	5.3

TABLE 4

Frequency of Breathing Problems in the Workplace

Breathing Problems	Frequency	%	Cumulative Frequency	Cumulative %
1–2 times a month	115	7.3	115	7.3
Every day or almost every day	63	4.0	178	11.3
Every week, but not every day	91	5.8	269	17.0
Less than once a month	381	24.1	650	41.1
More than 2 times a month, but not every week	87	6.0	737	46.6
Never	845	53.4	1,582	100

TABLE 5

Relationship Between Asthma Diagnosis and Exposure Results

Exposure	Chi-Square Value	*p*-Value
Adhesive or glue usage	3.22	.07
Curling/wave product usage	1.41	.24
Straightener usage	2.46	.12
Coloring product usage	0.03	.87
Bleaching usage	0.75	.39
Cleaning/sanitizing/disinfecting product usage	0.41	.52
Other chemical usage	2.23	.14

ables (how frequently do you have breathing problems at work and do these breathing problems subside away from the workplace) were significant ($p < .0001$).

Stepwise logistic regression was used to understand which factors have the greatest contribution to the likelihood of an asthma diagnosis. The following variables were entered into the model to predict the likelihood of an asthma diagnosis: age, length of employment, smoking status, adhesive/glue exposure, number of exposures, and employment status. Employment status was characterized in two different forms. The first employment status variable was dichotomized between employed and not employed; the second had several levels of employment including unemployment, retirement, change in employment, and disability. Depending on the employment status variable selected, different variables remained in the model using stepwise logistic regression. With a dichotomized employment variable, only length of employment remained in the model (p = .0006), whereas, with a multiple level variable for employment, several variables (length of employment, current employment, and the use of adhesives and glues) remained within the model (p = .0002, .1140, and .0150, respectively).

Discussion

Results of our survey, along with previous publications, indicate that this group of licensed workers is at increased risk for development of respiratory disease due to workplace exposures. Of the variables that remained significant predictors in the model, exposure to adhesives and glues has been identified as a potential asthmagen in previous literature (Kreiss et al., 2006; Lindstrom et al., 2013; Reutman et al., 2009). Length of employment could describe the need for repeated and prolonged exposures to induce asthma-like symptoms, or possibly the recognition of these symptoms. Those who have retired from the cosmetology industry and have sought employment elsewhere might have identified salon workplace exposures as triggers for their asthma symptoms and therefore left the cosmetology workforce to preserve their health.

In addition to the types of products used, this survey also gathered information on the perceptions of risk associated with use of these products, and health and safety training received by Minnesota's licensed cosmetologists, manicurists, and estheticians. Although most study participants reported that they had received health and safety training, our survey indicated that this training is focused on safety for the customer or consumer rather than personal safety of the worker to the potential occupational exposures. Very few of these workers received training on respiratory issues related to their occupation.

Worker education can improve work-related knowledge, behavior, and health symptoms, and reduce exposures for select air contaminants, even in nail salons where there may be language barriers (Quach et al., 2013). Providing health and safety training to cosmetologists, manicurists, and estheticians should be a priority for schools of cosmetology and continuing education for workers to be licensed in these occupations. This training should provide information on routes of exposure including respiratory and dermal exposures, diseases that may result from working with chemicals, and methods that can be used to minimize or eliminate potentially harmful exposures.

While it would be good to have medical surveillance of these workers, systematic medical surveillance rarely occurs in the absence of regulation by the Occupational Safety and Health Administration (OSHA) in the U.S. (Kreiss, 2013). Regulation of hazards is a slow and often contested process, even for substances affecting many workers. Cosmetologists, manicurists, and estheticians historically have not been covered by OSHA because many of the operations have few employees and often stylists rent their chair. In addition, these places of employment generally do not have the services of an industrial hygienist or safety manager to respond to health complaints and other issues that might arise.

The lack of regulation in this workforce in Minnesota means that efforts must be made to better educate workers on safety practices necessary for worker protection. A recent study evaluated the level of understanding and compliance with health and safety legislation among hairdressers and manicurists in the UK. While the authors did not look specifically at respiratory hazard training and focused mostly on the use of gloves through their "Bad Hand Day?" campaign, it was found that when most employees had been trained and made aware of the health hazards, they took suitable and sufficient precautions to protect themselves and their clients (Harris-Roberts, Bowen, Sumner, & Fishwick, 2013).

There may also be issues related to language, especially for manicurists, as 78% are of Asian/Pacific Islander descent in Minnesota. Of this group, only 62.1% report speaking English at least "well" and 72.1% report most often speaking Thai or Vietnamese at home (Ruggles Genadek, Goeken, Grover, & Sobek, 2015). We found that the cosmetologists surveyed in Minnesota were far more aware of the hazards to the client than aware of hazards that they may encounter on the job, particularly respiratory or breathing hazards.

While there is much to be done, progress is being made. Since this survey was completed, a new law was passed in Minnesota to require 3 hours of continuing education "pertaining to health, safety, and sanitation matters consistent with the U.S. Department of Labor's Occupational Safety and Health Standards" (Cosmetologist Continuing Education Requirements, 2016). Considering that 46% of respondents reported that they had experienced breathing problems such as coughing, wheezing, shortness of breath, or chest tightness during the past year, and that 14.5% reported that these symptoms got better on days when they were not at work, it is critical that these workers be educated about potentially harmful exposures in their field of work. Further efforts should be made to increase health and safety training for these licensed workers.

Limitations

While the study sample is a small portion of the total Minnesota cosmetologist population, comparisons of potential exposures and the increased probability of asthma diagnosis were possible.

As a survey, our work did not include any measurement of workplace chemicals or exposures and relied solely on self-report from participants. Participants were not provided individual or unique links, thus allowing for multiple responses from a single participant. This survey did not investigate other atopic work-related diseases of cosmetologists, manicurists, and estheticians such as cases of hand dermatoses or allergic rhinitis, nor did it investigate physical or musculoskeletal issues resulting from work in these fields. Leino and coauthors (1999) found that Finnish hairdressers left their profession because of asthma or eczema, which was found to be 3.5 times greater in hairdressers as compared with the control group. Asthma was the only disease included in this survey, along with whether or not the person's asthma and/or breathing problems were related to work.

Over 96% of our respondents were women (n = 1,826). This finding is consistent with gender ratios in previous studies and the proportion of female cosmetologists (94.6%) reported by American Community Survey data for Minnesota (Ruggles et al., 2015). Our sample was weighted heavily on White respondents who speak English. Future surveys should also be offered in a variety of Asian languages to better represent other demographic groups.

Conclusions

Results of this survey indicate that the length of employment and the use of adhesives or glues were significant predictors of an increased probability of reporting that a cosmetologist had ever been told by a healthcare professional that they had asthma.

Further study of this group is warranted. Future studies should separate the three areas of licensure and study materials should be provided in a variety of languages to increase and ensure participation. The inclusion of skin disease and more specific information regarding products and exposures in any follow-up survey should be considered. Working as a cosmetologist, manicurist, or esthetician can put one at risk for developing a number of conditions; follow up of this population to identify potential exposures, as well as methods for education, prevention, and intervention, are needed.

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JEH Quiz #4 Answers

January/February 2017

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

➔ Quiz deadline: August 1, 2017

1. Nearly __ workers in the U.S. are employed as cosmetologists, manicurists, or estheticians.
   a. a quarter million
   b. half a million
   c. one million
   d. two million

2. The survey link was e-mailed to __ licensed cosmetologists, manicurists, and estheticians in Minnesota.
   a. 14,335
   b. 16,791
   c. 18,692
   d. 19,853

3. The survey was offered in different languages.
   a. True.
   b. False.

4. Of the 2,058 people who started the survey, __ were women.
   a. 89%
   b. 92%
   c. 97%
   d. 99%

5. Of the survey participants, __ believe that products used in the workplace do not pose a risk to their health.
   a. 11%
   b. 23%
   c. 33%
   d. 44%

6. Of the survey participants who felt their health was at risk, less than __ categorized that risk as high.
   a. 5%
   b. 10%
   c. 15%
   d. 20%

7. When asked about workplace safety training, __ of survey participants indicated that they have been trained on disinfection or sanitizing processes.
   a. 45%
   b. 53%
   c. 57%
   d. 78%

8. Nearly __ of survey participants indicated having had no training on health and safety issues.
   a. 18%
   b. 22%
   c. 24%
   d. 28%

9. __ of survey participants reported four or more chemical exposures at work.
   a. Sixty percent
   b. Seventy percent
   c. Eighty percent
   d. Ninety percent

10. Of the chemical categories provided, __ were the most frequently identified as an exposure.
    a. cleaning and sanitizing products
    b. adhesives and glues
    c. hair straighteners
    d. hair coloring products

11. Of the survey participants, __ indicated that a healthcare provider had told them they have asthma.
    a. 6%
    b. 10%
    c. 16%
    d. 20%

12. Age and length of employment were found to be significant predictors of an increased probability of asthma diagnosis.
    a. True.
    b. False.

Cryptosporidiosis Outbreak Associated With a Single Hotel

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Abstract **We investigated a gastrointestinal illness cluster among persons who attended a baseball tournament (>200 teams) during July 2015. We interviewed representatives of 19 teams; illness was reported among only the 9 (47%) teams that stayed at Hotel A ($p < .01$). We identified 55 primary cases. A case-control study demonstrated that pool exposure at Hotel A was significantly associated with illness (odds ratio: 7.3; 95% confidence interval: 3.6, 15.2). Eight out of nine (89%) stool specimens tested were positive for *Cryptosporidium*, with *C. hominis* IfA12G1 subtype identified in two specimens. The environmental health assessment detected a low free available chlorine level, and pool water tested positive for *E. coli* and total coliforms. A possible diarrheal contamination event, substantial hotel pool use, and use of cyanuric acid might have contributed to this outbreak and magnitude. Aquatic facilities practicing proper operation and maintenance (e.g., following the Centers for Disease Control and Prevention's Model Aquatic Health Code) can protect the public's health.**

Introduction

Cryptosporidium is a protozoan parasite that can cause gastrointestinal illness in humans and animals (Heymann, 2008). This parasite is transmitted by the fecal–oral route, with infection occurring after the ingestion of highly infective, immediately infectious oocysts through contact with an infected person or animal and through contaminated water or food (Chappell et al., 2006). The average incubation period is 7 days (range: 4–28 days); symptoms of acute, watery diarrhea can last up to 4 weeks. Among immunocompetent persons, cryptosporidiosis typically causes a self-limited diarrheal disease; however, it can cause chronic disease and even life-threatening malabsorption in the immunocompromised (Davies & Chalmers, 2009; Heymann, 2008; Hunter et al., 2004).

Cryptosporidiosis is a nationally notifiable disease, with approximately 8,000–9,000 cases reported in the U.S. annually (Painter, Hlavsa, Collier, Xiao, & Yoder, 2015). Nearly 30 species of *Cryptosporidium* are known; however, *C. parvum* and *C. hominis* account for more than 90% of human cases. *C. parvum* is predominantly found in the mammalian intestinal tract and is transmitted zoonotically, whereas *C. hominis* primarily infects the human intestinal tract (Bouzid, Hunter, Chalmers, & Tyler, 2013; Xiao, Fayer, Ryan, & Upton, 2004). *Cryptosporidium* has emerged as the predominant cause of recreational water-associated outbreaks in the U.S. and worldwide (Baldursson & Karanis, 2011; Hlavsa et al., 2015; Hopkins, Hague, Hudgin, Ross, & Moore, 2013; Mayne et al., 2011; Widerström et al., 2014).

On July 30, 2015, the Shelby County Health Department (Memphis, Tennessee) received reports of gastrointestinal illness among persons who had traveled to Tennessee to participate in a multistate baseball tournament (>200 teams) held in Southaven, Mississippi (<15 miles from Memphis, Tennessee). The Tennessee Department of Health and Shelby County Health Department, in cooperation with local and state health departments in Alabama, Florida, and Georgia, performed a joint investigation.

Methods

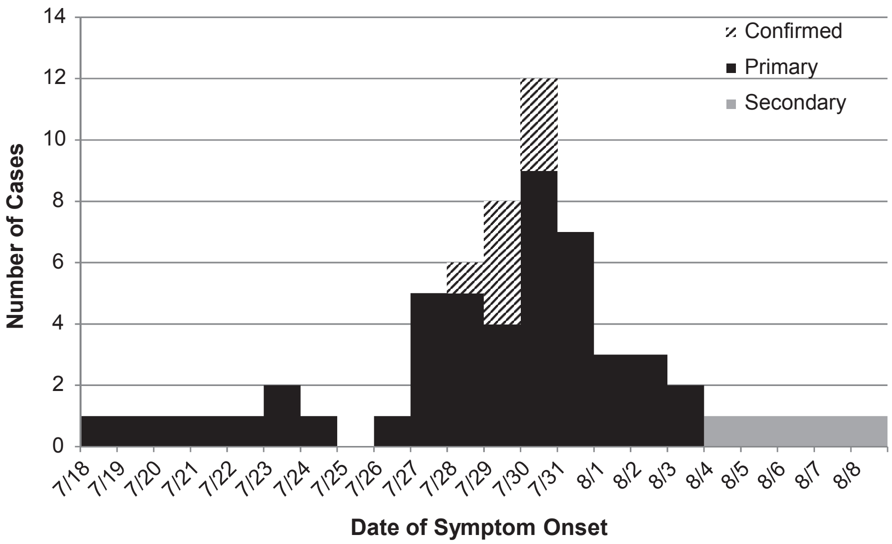
Epidemiologic and Laboratory Investigation

Initial reports of illness were only from persons affiliated with the baseball tournament, so standardized telephone interviews were conducted with a convenience sample of 19 participating teams to determine illness scope.

Through speaking with the baseball teams, it became evident that illness was reported only among the teams whose players and family members stayed at a single hotel (Hotel A); therefore, we decided to focus our investigation on Hotel A. A questionnaire was developed in order to identify additional cases at the hotel and to serve as the primary data collection tool for the case

FIGURE 1

Epidemic Curve of Cryptosporidiosis Associated With Hotel A, July 18–August 8, 2015 (*n* = 60)



control study. We identified potential cases by using player and family rosters obtained from team coaches or managers. Hotel A provided guest registration data to identify additional persons who were ill and potential control subjects.

We defined a primary case as vomiting or diarrhea (≥3 stools in 24 hours) among guests who stayed at Hotel A with symptom onset dates July 15–August 3, 2015. These dates represent approximately one incubation period before and two incubation periods after the exposure period of interest. A secondary case was a person with vomiting or diarrhea, with symptom onset on or after August 4, 2015, and a household contact of a primary case. Control subjects had stayed at Hotel A during the same time frame and had no gastrointestinal illness.

Guests at the hotel during July 2015 were invited to complete a standardized questionnaire, which was available online during August 7–17, 2015. Invitations to the online questionnaire were sent to 326 households, and 156 (48%) households responded. Information including demographics, illness, and sick contacts, as well as food, water, and other potential exposures was requested for each member of the household. Heads of household could complete surveys concerning multiple household members. A convenience subset of households received a follow-up open-ended, semistructured telephone interview to ascertain additional details about their experience, including pool conditions, communication with hotel management, and observed pool maintenance.

Data were analyzed by using Epi Info 7.1.5.2, and odds ratios (*OR*) with corresponding 95% confidence intervals (*CI*s) were calculated for selected exposures. Pearson's chi-squared test was used to measure associations between categorical case status and individual exposure variables. Nonresponses were excluded from analysis; percentages, *OR*, and *CI* calculations were based on respondents who answered each question. All *p*-values were two-sided and considered statistically significant if < .05.

Stool specimens were requested from persons who were ill, and tested for *Cryptosporidium* and bacterial and viral pathogens by standard methods. Stool specimens positive for *Cryptosporidium* were sent to the Centers for Disease Control and Prevention (CDC) for species identification and molecular subtyping by polymerase chain reaction amplification and subsequent bidirectional sequencing of the 18S rRNA gene and 90 kDa glycoprotein gene (gp60) (Alves et al., 2003; Xiao, 2010).

Environmental Health Investigation

An environmental health assessment of the pool at Hotel A was performed on August 5, 2015. We collected a small volume, "grab" water sample of approximately 10 L of water from the pool's sand filter and tested for *Cryptosporidium* and *Giardia* (U.S. Environmental Protection Agency, 2005). We analyzed one 100 mL water sample directly from the pool for *E. coli* and total coliforms (Eaton, 2005).

Results

Epidemiologic and Laboratory Investigation

Illness was reported only among all nine teams that stayed at Hotel A ($p < .01$). There were 55 primary cases (including 8 with laboratory confirmation), and 5 secondary cases of cryptosporidiosis identified (Figure 1). Illness onset dates of 55 primary case-patients ranged from July 17 to August 3, 2015. Median age was 11 years (range: 3–65 years); 42 (76%) were male. Illness onset dates of 5 secondary case-patients ranged from August 4 to August 8, 2015. Median age was 30 years (range: 12–41 years) and 4 (80%) were female.

Among all 60 patients, 59 (98%) reported diarrhea, 44 (73%) abdominal cramps, 43 (72%) nausea, 41 (68%) fatigue, and 26 (43%) vomiting. Less than one third of patients (19 out of 60) reported having fever (32%). More than one third of patients (21 out of 60) sought medical care (35%), and one required hospitalization (3%). The median illness duration was 5 days (range: 2–21 days).

Data were collected on 250 persons (55 primary cases, 5 secondary cases, and 190 control subjects). In bivariate analysis, which excluded secondary cases, the only risk factor significantly associated with illness was swimming in the pool at Hotel A ($n = 44/55$; *OR*: 7.3; 95% *CI*: 3.5, 15.2) (Table 1).

Analysis of swimming exposure by date revealed the most significant risk associated with illness to be on July 23 ($n = 25/55$; *OR*: 11.3; 95% *CI*: 5.2, 24.6). Additional survey questions were asked about specific pool activities (swallowing water, diving, swimming with head underwater, and playing pool games) and observations (diapered infants or animals observed in the pool) among swimmers at the pool; however, none was significantly associated with illness. Eating breakfast or dinner at Hotel A, using the hotel refrigerator or ice machine, eating at nearby restaurants, eating a group meal prepared with outside food, and eating at the concession stand at the tournament were not significantly associated with illness.

Of nine stool specimens tested, eight (89%) were positive for *Cryptosporidium* and negative for bacterial and viral pathogens. Of six *Cryptosporidium* specimens sent to the CDC CryptoNet laboratory, two (33%) were typeable and identified as *C. hominis* IfA12G1 subtype.

Among those who responded, 34 out of 48 (71%) of case-patients and 26 out of 67 (39%) of control subjects felt that the pool water appeared dirty or unclean at any time ($p < .01$). Furthermore, 5 of 48 (10%) persons who were ill reported swimming for multiple days while ill with diarrhea (i.e., could have potentially contaminated the pool). One of the persons who was ill reported swimming with diarrhea daily at the hotel pool from July 17 to July 22; two of the persons who were ill reported swimming with diarrhea between July 23 and July 25.

Moreover, 15 of 57 (26%) of case-patients and 62 of 180 (34%) of control subjects reported knowledge that recreational water could be contaminated and make people sick. And 28 of 44 (64%) of case-patients and 36 of 66 (55%) of control subjects who responded reported swallowing pool water either accidentally or intentionally while swimming, though the difference between groups was not significant.

The follow-up interviews with case-patients and their families revealed numerous anecdotes about Hotel A's pool during the outbreak period. Multiple families reported cloudy pool water. Some guests not associated with the baseball tournament noted that the hotel seemed crowded and the pool area was often congested. Multiple persons noted that a supply of clean towels was unavailable, and piles of dirty towels were observed near the pool.

TABLE **1**

Bivariate Analysis of Select Exposures Associated With Cryptosporidiosis Outbreak, July 18–August 10, 2015

Exposure	Case-Patients (*n* = 55)		Control Subjects (*n* = 190)		*OR*	95% *CI*
	#	%	#	%		
Swimming (all dates)	44	80	67	36	7.3	3.5, 15.2
Swimming July 18	4	7	11	6	1.3	0.4, 4.2
Swimming July 19	2	4	12	6	0.6	0.1, 2.6
Swimming July 20	2	4	10	5	0.7	0.1, 3.2
Swimming July 21	2	4	9	5	0.8	0.2, 3.6
Swimming July 22	8	15	8	4	3.9	1.4, 10.9
Swimming July 23	25	45	13	7	11.3	5.2, 24.6
Swimming July 24	27	49	20	11	8.2	4.1, 16.6
Swimming July 25	33	60	39	21	5.8	3.0, 11.1
Swimming July 26	24	44	39	21	3.0	1.6, 5.7
Swimming July 27	21	38	25	13	4.1	2.0, 8.1
Swimming July 28	15	27	9	5	7.5	3.1, 18.4
Swimming July 29	2	4	3	2	2.4	0.4, 14.4
Hotel breakfast (all days)	45	85	138	73	2.0	0.9, 4.6
Hotel dinner (all days)	17	32	45	24	1.5	0.8, 2.9
Hotel refrigerator	48	89	161	86	1.3	0.5, 3.4
Hotel ice machine	36	65	97	52	1.8	0.9, 3.3
Any restaurant	50	94	165	89	2.0	0.6, 7.1
Outside food	23	45	59	33	1.7	0.9, 3.2
Tournament concessions	11	22	37	20	1.1	0.5, 2.3

OR = odds ratio; *CI* = confidence interval.
Note. The nonresponse rate per question range was 0%–5.24%; average nonresponse rate was 0.9%.

Environmental Health Investigation

Hotel A's swimming pool was located outdoors and enclosed by an approximately 4-foot tall fence. The pool was filled with water from the public supply with a sand filtration system. The chemical feed equipment was located within the pool area and enclosed by its own 5-foot fence with a secure entrance. Pool chemicals were stored in this subarea and in direct sunlight. The pool was disinfected with chlorine (calcium hypochlorite tablets) and stabilized with cyanuric acid to minimize depletion of free available chlorine (FAC) by the sun's ultraviolet light. No signage was present within the pool area addressing maximum bather load or standard pool etiquette and hygiene measures. The hotel allowed pets in the pool area.

The pool was reportedly checked 3 times daily by employees to ensure no warning lights in the automatic monitoring system indicated an imbalance or low level of pool chemicals. Water sample testing results were reportedly transmitted to a third-party company for remote monitoring by telephone line; however, after further investigation, the telephone line was found to be unconnected, and no information had been transmitted for an indeterminate time period. Employees responsible for pool maintenance were not required to hold any specific certifications and they did not routinely log chemical levels or other monitoring information.

During assessment, the pool water had a pH of 7.2, and both total and FAC levels of 0.5 ppm (Table 2). Oxidation–reduction potential measured by the water chemistry monitor was 528 mV. Pool water tested positive for *E. coli* (20 most probable number [MPN]/100 mL) and total coliforms (365 MPN/100 mL); however, neither *Cryptosporidium* nor *Giardia* was detected in the water sample collected from the pressure release valve of the pool's sand filter. Of

TABLE **2**

Comparison of Results From Water Testing Conducted During Environmental Health Assessment of Pool at Hotel A to the Model Aquatic Health Code (MAHC) Recommendations

Test	Pool Result, Hotel A	MAHC Recommendations	MAHC Code
pH	7.2	7.2–7.8	5.7.3.4.1
Free available chlorine	0.5 ppm	1–3 ppm	5.7.3.1.1.2
Oxidation–reduction potential	528 mV	600–900 mV	4.7.3.3.4.6.2 4.7.3.3.4.6.3
E. coli	20 MPN/100 mL	—	—

ppm = parts per million; MPN = most probable number.

note, large volume, filtered water samples were not possible to collected, which may be preferable for detection of *Cryptosporidium* as the oocysts occur in low numbers in aquatic environments (Kaucner & Stinear, 1998). Based on these test results, the Shelby County Bureau of Environmental Health Services issued a health directive closing the pool at Hotel A on August 11, 2015. The pool remained closed until September 5, 2015, when it completed the required remediation procedures and was allowed to reopen under the guidance of local environmental health officials.

Discussion

A cryptosporidiosis outbreak identified among participants in a multistate baseball tournament was traced to a hotel swimming pool. Epidemiologic investigation determined that the risk factor most strongly associated with illness was swimming in the pool on July 23, 2015. No direct epidemiologic link with the baseball tournament was identified. Secondary transmission within households, a phenomenon that has been noted in published material, was reported (Ichinohe et al., 2005; Johansen et al., 2015). Molecular subtyping demonstrated *C. hominis* IfA12G1, a species and subtype that is primarily transmitted among humans and circulating in the U.S. since at least 2013 (D. Roellig, personal communication, September 2015). To prevent future outbreaks of this extremely chlorine-tolerant parasite, key stakeholders (e.g., swimmers, operators of pools and other treated recreational water venues, and public health officials) need to be engaged to understand risks, implement control and prevention measures, and participate in ongoing education.

A definitive determination of when each primary case-patient became infected cannot be made because persons swam during multiple days. *Cryptosporidium* oocysts are extremely chlorine tolerant and transmission could have occurred during multiple days. Although the majority of infectious pathogens are inactivated within minutes in treated recreational water with 1 part per million (ppm) FAC, *Cryptosporidium* oocysts are infectious immediately upon excretion and can survive for more than 10 days (Shields, Hill, Arrowood, & Beach, 2008).

After a diarrheal incident (i.e., a high-risk *Cryptosporidium* contamination event) or a treated recreational water-associated outbreak suspected to be caused by *Cryptosporidium*, CDC recommends 1) closing the involved venue to swimmers, 2) raising FAC levels to inactivate 99.9% *Cryptosporidium* oocysts (i.e., hyperchlorination), and 3) backwashing the filter thoroughly (CDC, 2016a). Hyperchlorination will achieve the concentration time inactivation value of 15, 300 mg-min/L (e.g., 20 ppm FAC for 12.75 hours or 10 ppm for 25.5 hours), which will inactivate *Cryptosporidium*. Of note, cyanuric acid prolongs the inactivation time of infectious pathogens, with inactivation times increasing with higher cyanuric levels. For example, at 20 ppm FAC, raising the cyanuric acid level from 16 ppm to 48 ppm decreases effectiveness of inactivation from 26.3 hours (99.9% inactivation) to 63.8 hours (90% inactivation) (Murphy et al., 2015).

Our investigation identified five case-patients who swam while ill with diarrhea, three during or just before the time period with the highest odds of infection. Swimmers who are ill can introduce 10^7–10^8 *Cryptosporidium* oocysts into the water with a single diarrheal contamination incident, and fewer than 10 oocysts can cause infection (Chappell et al., 2006; Goodgame, Genta, White, & Chappell, 1993; Okhuysen, Chappell, Crabb, Sterling, & DuPont, 1999). These characteristics, combined with evidence that children can unintentionally ingest as much as 150 mL of water during 45 minutes or more of swimming, are favorable conditions for the transmission of infectious pathogens (Dufour, Evans, Behymer, & Cantú, 2006).

The reported unhealthy swimming behaviors, which facilitate the transmission of infectious pathogens, underscore the need to educate the public (i.e., the primary source of *Cryptosporidium* contamination of treated recreational water) regarding healthy swimming practices. Healthy swimming messages include not swimming with diarrhea, not swallowing water while swimming, washing with soap and water before swimming, and keeping animals out of the pool area. Healthy swimming education campaigns can help the public understand potential risks associated with use of treated recreational water venues and their role in helping to keep themselves and others healthy (CDC, 2012; McClain, Bernhardt, & Beach, 2005), potentially decreasing the incidence of recreational water-associated illness outbreaks. In addition, to facilitate understanding of risks and to promote adoption of healthy swimming behaviors, healthy swimming education campaigns can dispel commonly held mistaken beliefs (e.g., chlorine instantly inactivates all infectious pathogens or waterborne disease occurs only outside the U.S.).

Cryptosporidium is the leading etiology of reported recreational water-associated illness outbreaks because of the number of outbreaks it has caused since 1988 (Sorvillo, Lieb, Kerndt, & Ash, 1994). This statistic calls for a better understanding of *Cryptosporidium* transmission. *Cryptosporidium* species are morphologically indistinguishable by traditional diagnostic tests; thus, molecular typing is needed to distinguish species and subtypes. To improve the ability to understand U.S. cryptosporidiosis epidemiology, CDC has established CryptoNet, a molecular-based surveillance program (CDC, 2015).

CryptoNet confirms outbreaks and types *Cryptosporidium* specimens from sporadic cases; however, the goal of CryptoNet is to molecular type *Cryptosporidium* specimens for every case reported to the National Notifiable Diseases Surveillance System and to integrate molecular typing data with traditional epidemiologic data. Communication between the Tennessee Department of Health and CDC CryptoNet laboratory during this outbreak investigation provided important context for this cluster within the national framework. Identifying *C. hominis* indicates transmission was limited to humans (i.e., no animal source). The specific subtype detected in this outbreak, IfA12G1, is the most common subtype currently associated with recreational water-associated illness outbreaks in the U.S. (D. Roellig, written communication, September 2015).

During 2011–2012, approximately 20% of all outbreaks associated with treated recreational water venues were in a hotel setting (Hlavsa et al., 2015). In addition, analysis of data collected during routine inspections conducted in 15 state and local jurisdictions during 2008 found the percentage of inspections resulting in immediate closure or in identifying particular violations (e.g., disinfectant level violations) to be among the highest for hotel and motel pools (CDC, 2010).

Although our environmental health assessment identified numerous points for potential intervention at Hotel A, none of the findings explicitly contributed to this cryptosporidiosis outbreak except possibly the use of cyanuric acid. The inadequate FAC level is less important for transmission of this extremely chlorine-tolerant parasite, but it is important for the transmission of chlorine-susceptible infectious pathogens (e.g., *Campylobacter,* or Shiga toxin-producing *E. coli*) and provides further evidence of overall poor pool maintenance.

Findings of our environmental health assessment indicate that operators of Hotel A's pool needed training. Studies have demonstrated that pools staffed by certified operators have improved water quality, which prevents transmission of chlorine-susceptible infectious pathogens (Buss et al., 2009; Johnston & Kinzinger, 2007); however, only 24 states and the District of Columbia require operator training to some degree (S. Wichmann, written communication, November 2015).

This variation among state and local codes for treated public recreational water venues is not limited to operator training requirements and cuts across every aspect of the design, construction, operation, and maintenance of public treated recreational water venues. In 2005, federal, state, and local public health officials and representatives of the aquatics sector met to address the increasing incidence of reported recreational water-associated illness outbreaks. Meeting attendees deemed variations in state and local codes across the U.S. to be a key barrier to preventing these outbreaks. Consequently, the Council of State and Territorial Epidemiologists requested CDC spearhead development of national guidance to prevent illness and injury associated with public treated recreational water venues.

During 2007–2014, CDC and the New York State Department of Health led a multistakeholder (public health, aquatics sector, and academic researchers) effort to develop a science-based and best practices-based model code, which addressed design, construction, operation, and maintenance of public venues. The first edition of the Model Aquatic Health Code (MAHC) was released in August 2014 and the revised second edition was released in July 2016 (CDC, 2016b). Multiple MAHC recommendations could improve overall operation and maintenance of Hotel A's pool.

MAHC calls for hotels like Hotel A to have an "on-site responsible supervisor," who is in charge of water treatment operations when a "qualified operator" is not present. MAHC defines responsibilities of the "on-site responsible supervisor" and includes knowledge of when to close the venue to swimmers (e.g., when FAC level is inadequate or the water is so cloudy the venue bottom is not visible). MAHC also calls for FAC levels to be 1 ppm when cyanuric acid is not used and 2.0 ppm when cyanuric acid is used. Table 2 summarizes water quality findings of the hotel pool environmental health assessment and compares them with MAHC guidance. Additionally, MAHC also calls for keeping pool chemicals away from direct sunlight, temperature extremes, and high humidity to prevent pool chemical-associated health events. Chemical storage spaces should be completely enclosed to prevent unauthorized access; signage should be posted addressing hours of operation, theoretical peak occupancy, and hygiene standards; and no animals should be allowed in the pool area except for service animals.

Some limitations to our investigation were noted. The response rate for our questionnaire was 48%, which might have impacted our ability to capture all cases. Our case definition was intentionally broad with regards to clinical symptoms, so cases of gastrointestinal illness other than cryptosporidiosis might have been included in our analysis. Given the significant *ORs*, laboratory confirmation, and biologic plausibility of the spread of *C. hominis*, we feel confident in our findings despite any potential misclassification bias. Lastly, we did not collect measurements of cyanuric acid levels during this outbreak; however, including them might have provided additional information regarding risk for delayed pathogen inactivation.

Conclusions

An outbreak caused by *C. hominis* among participants in a multistate baseball tournament was traced to the swimming pool of Hotel A. We found that a possible contamination event, substantial hotel pool use, and the use of cyanuric acid might have contributed to this outbreak and its magnitude. Aquatic facilities practicing proper operation and maintenance (e.g., following CDC's MAHC) can protect the public's health.

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Distribution and Evaluation of a Carbon Monoxide Detector Intervention in Two Settings: Emergency Department and Urban Community

Abstract **The objective of this study was to describe changes in carbon monoxide (CO) safety knowledge and observed CO detector use following distribution of a CO detector use intervention in two environments, a pediatric emergency department (Ohio) and an urban community (Maryland). A total of 301 participants completed the 6-month follow up (Ohio: *n* = 125; Maryland: n = 176). The majority of participants was female, 25–34 years of age, and employed (full or part time). We found that CO safety knowledge did not differ between settings at enrollment, but significantly improved at the follow-up visits. The majority of CO detectors observed were functional and installed in the correct location. Of those with CO detectors at follow up, the majority had not replaced the battery. The success of the intervention varied between settings and distribution methods. The majority of participants showed improved knowledge and behaviors. Improved device technology may be needed to eliminate the need for battery replacement.**

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Introduction

Carbon monoxide (CO) poisoning is a leading cause of poison-related death in the U.S. and is responsible for 450 deaths and 20,000 nonfatal injuries every year (Centers for Disease Control and Prevention [CDC], 2012). The U.S. does not have a comprehensive national system of CO surveillance (Graber, Macdonald, Kass, Smith, & Anderson, 2007), however, so these numbers likely are a vast underestimate of the CO-related deaths and injuries. The incidence of CO poisoning might also be underrepresented nationally due to misdiagnosis resulting from the nonspecific nature of its symptoms (Iqbal, Law, Clower, Yip, & Elixhauser, 2012; Raub, Mathieu-Nolf, Hampson, & Thom, 2000). Between 2000 and 2009, more than 68,000 CO exposures were reported to poison centers (Annest et al., 2008). In 2007, unintentional, nonfire-related CO poisoning accounted for more than 2,000 hospitalizations with the cumulative total for hospitalizations in 2007 costing over $26 million (Iqbal et al., 2012).

Poisonings caused by CO occur when CO—an odorless, colorless, and tasteless gas—escapes from fuel-burning appliances and becomes trapped in enclosed spaces. The installation of a CO detector is the most effective step for protecting household occupants. Detectors are effective in alerting occupants to the presence of CO and reducing the number of individuals who experience poisoning symptoms. Nationally, less than one half of households own a CO detector (Runyan et al., 2005), yet most are unsure where to place CO detectors or how many they should install. In a recent Baltimore study, 26% of 603 surveyed households were observed to have a functioning CO detector and less than 20% of surveyed households correctly identified the best place to install a CO detector (McDonald et al., 2013). Common misuses (which lead to false alerts, decrease the effectiveness of the devices, or render the devices inoperable) are incorrect placement and failure to replace batteries every 6 months. Thus, there is a critical need for interventions to increase correct use of residential CO detectors.

Numerous methods and interventions have been developed and tested to distribute and increase the adoption and use of safety products. Evidence from previous meta-analyses showed that interventions to promote use of smoke alarms are effective at increasing smoke alarm ownership (DiGuiseppi & Higgins, 2000, 2001) and the prevalence of func-

FIGURE 1

Fast Facts About Carbon Monoxide Educational Tool

tioning alarms (DiGuiseppi & Higgins, 2001; Kendrick et al., 2007). Cooper and coauthors (2012) in a network meta-analysis showed that "more intensive" interventions (e.g., education with low-cost or free equipment, installation of equipment, and home inspection), compared with "less intensive" interventions had a higher probability of increasing possession of functioning smoke alarms (Cooper et al., 2012). A study by Harvey and coauthors (2004) determined that direct installation of smoke alarms by program staff resulted in functioning smoke alarms in 90% of households that received direct installation intervention compared with 65% in a voucher intervention group. To our knowledge, no similar interventions (or interventions that combined the aforementioned components) have examined the effectiveness of CO detector interventions or various distribution methods to increase CO detector ownership, functionality, and placement.

The purpose of this study was to describe changes in CO safety knowledge and observed CO detector use (ownership, functionality, and placement) following distribution of the identical CO intervention, that is, an educational tool, *Fast Facts About Carbon Monoxide*, along with a CO plug-in detector with battery backup in an emergency department (ED) setting (Columbus, Ohio) and in an urban community setting (Baltimore, Maryland).

The specific aims of the current study were to describe the 1) sociodemographic characteristics of each sample, 2) changes in CO safety knowledge 6-months postintervention, and 3) changes in observed CO detector use (ownership, functionality, and placement) 6-months postintervention.

Methods

Participants were part of larger studies: a randomized controlled trial based in Columbus, Ohio, and a community intervention trial based in Baltimore, Maryland. Participants in each group received an educational tool, *Fast Facts About Carbon Monoxide*, a new CO detector, and completed a 6-month follow-up home visit.

Fast Facts About Carbon Monoxide was developed as part of the Columbus, Ohio-based randomized controlled trial, which aimed to increase the use of correctly installed and maintained CO detectors in a population of parents recruited in a pediatric ED. The tool guides the recipients through a presentation in which CO is defined; the dangers, symptoms, and causes of CO poisoning are described; and the instructions on CO detector installation and maintenance are explained. The tool was written at a seventh-grade reading level so as to suit the needs of a low literacy population. Images and messages were chosen to be appropriate for the target audiences (Figure 1). The last page of the educational tool contained a removable magnet that included emergency and nonemergency phone numbers relevant for the city in which the educational tool was distributed.

Data Collection: Ohio

The intervention was distributed to parents while their child was being treated in the ED for an injury or medical complaint. Eligibility criteria included English-speaking parents or guardians of children 18 years or younger residing in Franklin County, Ohio, who reported living with the child "at least some of the time," and self-identified as someone responsible for the child's safety. Parents completed a 15-minute survey on a portable tablet computer while in the ED examination room. Six months following enrollment, parents completed the same survey at a follow-up home visit. During the home visit, data collectors recorded the presence, location, and functionality of CO detectors in the home, including the "study" CO detector distributed at enrollment. Battery replacement was also recorded.

Data Collection: Maryland

Selected homes were visited as part of a community intervention trial in which the Baltimore City Fire Department entered homes, installed 10-year lithium battery smoke alarms, and provided education to residents about fire prevention. During the home visit, trained data collectors accompanied the fire department personnel and collected information about observed safety behaviors (e.g., presence of smoke and CO alarms, hot water temperature) and tested knowledge about fire, CO, and hot water safety. Residents were informed of the need to have a working CO detector and were alerted by fire department and study personnel if their home failed to meet these criteria. The intervention (educational tool and CO detector) was provided in homes with children 17 years of age or younger. At 6–9 months after the home visit, residents were contacted to participate in a follow-up home visit. Residents who agreed to a follow-up home visit were visited by pairs of data collectors who completed a structured questionnaire 60 minutes in length via a tablet computer. The follow-up interview collected information about safety knowledge and demographic data. Upon completion of the structured interview, data collectors observed home safety practices including the presence, location, and functionality of CO detectors, including the study CO detector. Battery replacement was also recorded.

Measures

Sociodemographic Characteristics

Participants were asked to report their age (years), sex (male/female), race/ethnicity (White, Black, other), employment status (employed/not employed), education (≤high school/GED, completed some college, ≥Bachelor's degree), time in current residence (<1 year, 1–2 years, >2 years), number of children in the home (≤18 years of age for Ohio and ≤17 years of age for Maryland), annual household income (Ohio: ≤$14,000, $14,001–$25,000, $25,001–$35,000, $35,001–$45,000, $45,001–$55,000, ≥$55,001; and Maryland: <$5,000, $5,000–$14,999, $15,000–$24,999, $25,000–$34,999, $35,000–$44,999, $45,000–$54,999, ≥$55,000), and number of individuals supported on that income (1 through ≥10). Annual household income and number of individuals supported on that income were used to calculate a per capita income variable by taking the midpoint of the annual household income and dividing by the number of individuals supported on that income.

Carbon Monoxide Safety Knowledge

To test CO safety knowledge, eight multiple choice and true/false items were developed and administered in both samples at enrollment and at the 6-month follow-up home visit. Correct responses were assigned one point and incorrect responses zero points. The points were summed to determine a total knowledge score for each participant at enrollment and at the 6-month follow-up home visit. The mean of the total knowledge score is reported for enrollment and the 6-month follow-up home visit.

Observed Carbon Monoxide Detector Use

Study team members observed the presence (whether or not the CO detector was installed), location/placement (proximity to sleeping areas), and functionality of the study CO detector provided at enrollment, as well as other CO detectors in the home. Study CO detectors and batteries were labeled (at distribution) to identify and distinguish them from other CO detectors that participants might have had or purchased during the study period, and to determine whether or not the battery had been replaced since enrollment.

The current study was approved by the institutional review boards at the Research Institute at Nationwide Children's Hospital in Columbus, Ohio, and at the Johns Hopkins Bloomberg School of Public Health in Baltimore, Maryland. Participants in both groups were compensated for their time with a $50 gift card following completion of the home visit.

Data Analysis

Descriptive statistics were generated for each sample and compared by chi-square analysis. Changes in percent correct for each knowledge item between baseline and follow-up visit were compared using McNemar's test. An independent *t*-test was used to test for a difference between differences in the Ohio and Maryland samples. A total knowledge score was generated for each time point by tallying each participant's number of correct responses. A paired *t*-test was used to test for differences in knowledge score between baseline and follow-up visits. An independent *t*-test was used to test for differences between Ohio and Maryland.

Chi-square analysis was used to compare households with and without a study CO detector and to assess differences between Ohio and Maryland on functionality, location, and battery replacement of study CO detectors. A general linear regression model was used to assess the difference in knowledge score at the 6-month home visit between Ohio and Maryland, adjusting for baseline knowledge score, potential confounding demographic characteristics, and other variables significantly associated with the outcome. A multivariate logistic regression model was used to compare the observed CO detector use at 6 months, adjusting for demographics characteristics significantly associated with the outcome and potential confounders. An α of < .05 was considered to be significant.

Results

A total of 125 participants in the Ohio sample and a total of 176 participants in the Maryland sample received the intervention and were included in our analysis. There were no differences on any single knowledge item or total knowledge score between those lost to follow up (that is, participants who did not complete the 6-month home visit in either study) and those who completed the 6-month follow-up home visit for the Ohio or Maryland sample.

The majority of participants was female (Ohio: 90.4%; Maryland: 85.8%), 25–34 years of age (Ohio: 41.6%; Maryland: 31.8%), and employed either full or part time (Ohio: 50.4%; Maryland: 61.2%). Most participants had a per capita income of $5,000 or less (Ohio: 43.2%; Maryland: 34.2%) or $5,001–$10,000 (Ohio: 26.4%; Maryland: 35.5%). The Maryland sample had significantly more participants who reported their race as Black ($p < .01$). Educational attainment differed significantly between the two samples ($p < .01$); Ohio participants were more likely to have completed some college (Ohio: 49.6%; Maryland: 23.9%), while Maryland participants were more likely to report completing high school or less (Ohio: 33.6%; Maryland: 61.9%).

The amount of time living in current residence significantly differed between samples ($p < .01$); Ohio participants were more likely to report living in their current residence less than 1 year, while Maryland residents reported living in their current residence more than 2 years (Table 1).

CO Knowledge Questions (Enrollment Versus 6-Month Home Visit)

Overall, participants in both Ohio and Maryland showed significant improvement in CO knowledge score from enrollment to the 6-month home visit (Ohio: $p < .01$; Maryland: $p < .01$); the Ohio sample made more knowledge gains overall compared with the Maryland sample ($p < .01$). Knowledge score at the 6-month follow-up visit was 0.384 units higher on average for the Ohio sample (mean = 5.84, 95% confidence interval [*CI*]: 5.61, 6.06) than the Maryland sample (mean = 5.46, 95% *CI*: 5.26, 5.66) ($p < .01$) after adjusting for baseline knowledge score and education level. The Ohio sample was more likely to correctly identify that electric heaters do not cause CO poisoning ($p = .02$) and that symptoms of CO poisoning are similar to the flu ($p = .03$). Improvement was documented in both groups: participants correctly reported that CO is a gas that cannot be seen (Ohio: $p < .01$; Maryland: $p = .03$) and the best place to install a CO detector is near a sleeping area (Ohio: $p < .01$; Maryland: $p < .01$), although the difference in knowledge gains between the two sites was not statistically different (for these items:

TABLE **1**

Sociodemographic Characteristics

Characteristic	Ohio (n = 125) # (%)	Maryland (n = 176) # (%)	p-Value
Respondent sex	125 (100)	176 (100)	.23
Female	113 (90.4)	151 (85.8)	
Male	12 (9.6)	25 (14.2)	
Race	125 (100)	167 (100)	<.01
White	59 (47.2)	23 (13.8)	
Black	56 (44.8)	132 (79.0)	
Other[a]	10 (8.0)	12 (7.2)	
Respondent age (years)	125 (100)	176 (100)	<.01
18–24	16 (12.8)	7 (4.0)	
25–34	52 (41.6)	56 (31.8)	
35–44	40 (32.0)	41 (23.3)	
45–54	14 (11.2)	40 (22.7)	
55–64	1 (0.8)	9 (5.1)	
Per capita income	122 (100)	152 (100)	.34
≤$5,000	54 (43.2)	52 (34.2)	
$5,001–$10,000	33 (26.4)	54 (35.5)	
$10,001–$25,000	32 (25.6)	42 (27.6)	
≥$25,001	3 (2.4)	4 (2.6)	
Employment	125 (100)	134 (100)	.08
Employed full or part time	63 (50.4)	82 (61.2)	
Not employed	62 (49.6)	52 (38.8)	
Education	125 (100)	176 (100)	<.01
≥Bachelor's degree	21 (16.8)	25 (14.2)	
Some college[b]	62 (49.6)	42 (23.9)	
≤High school (GED)	42 (33.6)	109 (61.9)	
Time in residence	125 (100)	176 (100)	<.01
>2 years	52 (41.6)	115 (65.3)	
1–2 years	34 (27.2)	50 (28.4)	
<1 year	39 (31.2)	11 (6.3)	
Number of children[c]			
Mean (*SE*)	2.3 (1.2)	1.96 (1.4)	
Range	1–7	0–9	

[a]Other includes Hispanic Latino, Asian/Pacific Islander, or other.
[b]Some college includes associate or technical degrees.
[c]Number of children includes children ≤18 years for Ohio and ≤17 years for Maryland.

Carbon monoxide is a gas that cannot be seen: p = .31; and Where is the best place to install a carbon monoxide alarm in your home?: p = .39) (Table 2).

Observed CO Detector Use

At the 6-month follow-up home visit, the majority of participants' homes (Ohio: 74.4%; Maryland: 71.6%) had at least one functional CO detector. These detectors, however, were not always consistently located, placed, or installed near the sleeping areas as recommended (Ohio: 48.8%; Maryland 64.3%) (Table 3). The presence of CO detectors, regardless of whether it was a study CO detector, differed significantly between Ohio and Maryland groups. Site location (Ohio or Maryland) ($p < .01$), age group ($p = .04$), race ($p < .01$), and number of years at current residence ($p < .01$) were significantly associated with having a functioning CO detector in the home in a multivariate logistic regression model. The odds of having a functioning CO detector were 2.781 times greater for the Ohio sample compared with the Maryland sample (95% *CI*: 1.386, 5.51) after adjusting for age group, race, and years at current residence ($p < .01$). The odds of having a functioning CO detector increased by increasing age group (overall $p = .04$) in the multivariate model. Participants identifying their race as White had 3.204 times greater odds of having a functioning CO detector than people identifying as Black (95% *CI*: 1.642, 6.252) after adjusting for the other variables in the model. Participants living in their current residence for 1–2 years had 4.969 times greater odds of having a functioning CO detector than people residing at their current residence for less than 1 year (95% *CI*: 1.987, 12.425).

Participants in Ohio were more likely ($p <$ .01) to have the study CO detector installed at the 6-month follow-up. The majority of the study CO detectors that were installed successfully passed testing protocols (i.e., detector signaled when test button was depressed by study data collector during the home visit) (Ohio: 97.7%; Maryland: 87.5%, $p = .01$) and were installed by sleeping areas (Ohio: 59.8%; Maryland: 52.5%, $p = .01$). For participants with study CO detectors at the 6-month follow up, the majority ($p < .01$) had not replaced the batteries (Ohio: 70.1%; Maryland: 88.8%) (Table 4).

Discussion

CO poisoning is a leading cause of poison-related death in the U.S. (CDC, 2012) and a significant public health concern. A properly installed and functioning CO detector is an effective tool to protect household occupants from residential, nonfire-related CO poisoning. The purpose of this study was to describe changes in CO safety knowledge and observed CO detector use following distribution of the

TABLE **2**

Carbon Monoxide Knowledge Outcomes at Enrollment and 6-Month Follow-Up Home Visit

Carbon Monoxide Knowledge Questions and *Correct Responses*	**Ohio (*n* = 125)**			**Maryland (*n* = 176)**			**Difference Between Differences**
	Enroll # (%)	**6-Month Home Visit # (%)**	***p*-Value**	**Enroll # (%)**	**6-Month Home Visit # (%)**	***p*-Value**	***p*-Value**
Carbon Monoxide is: *A gas that cannot be seen*	107 (85.6)	119 (95.2)	.002	151 (85.8)	161 (91.5)	.025	.308
You can smell carbon monoxide: *False*	99 (79.2)	105 (84.0)	.180	147 (83.5)	153 (86.9)	.239	.744
Which of the following does NOT cause carbon monoxide poisoning? *Electric Heaters*	40 (32.0)	66 (52.8)	<.0001	49 (27.8)	59 (33.5)	.189	.019
Only children and teens are at risk for carbon monoxide poisoning: *False*	120 (96.0)	122 (97.6)	.625	168 (95.5)	170 (96.6)	.317	.808
Symptoms of carbon monoxide poisoning are similar to: *The flu*	46 (36.8)	68 (54.4)	<.0001	40 (22.7)	50 (28.4)	.077	.030
Where is the best place to install a carbon monoxide alarm in your home? *Near all the sleeping areas*	20 (16.0)	51 (40.8)	<.0001	40 (22.7)	74 (42.1)	<.001	.390
What should you do FIRST if your carbon monoxide alarm goes off and you or someone in your home feels sick? *Get everyone out of the home and call 911*	105 (84.0)	109 (87.2)	.541	156 (88.6)	161 (91.5)	.317	.939
Your SMOKE ALARM will alert you when carbon monoxide levels are too high: *False*	87 (69.6)	94 (75.2)	.210	99 (56.3)	106 (60.2)	.336	.782
			Paired *t*-Test			Paired *t*-Test	
Mean score (*SD*)	5.0 (1.7)	5.9 (1.6)	<0.01	4.8 (1.4)	5.3 (1.5)	<0.01	.009

same CO intervention (educational tool *Fast Facts About Carbon Monoxide* plus a plug-in CO detector with battery backup) in an ED setting (Columbus, Ohio) and in an urban community setting (Baltimore, Maryland).

Overall, both groups significantly improved in knowledge scores and the majority of participating households was protected by a CO detector at follow up (>70% for Ohio and Maryland). The detectors were not consistently installed, however, in the correct recommended location, i.e., near sleeping areas in either sample. Differences in postintervention outcomes were detected between samples. The Ohio sample that had higher postintervention knowledge scores was more compliant on having a working CO detector than the Maryland sample. Other indicators of improved behavior were participants who lived at their current residence for 1–2 years, identified their race as White, and were older in age.

There are several differences in the target populations and delivery methods that may partially explain these differences; however, these differences were adjusted for in these analyses. First, there were key demographic differences between the two samples, namely, educational level (lower in Maryland sample) and minority composition (more Blacks in Maryland sample). Other significant differences were the age of participants and time living at current residence. Although the educational tool was written at a seventh-grade reading level and with a low literacy population in mind, perhaps the tool could be further refined in this manner (text shortened, lower reading grade level, etc.).

Second, the "intensiveness" of the intervention from a resource standpoint and from a content and information standpoint differed between the samples. The Maryland sample received the intervention as part of another study where smoke alarms and hot water temperature were also addressed. The Ohio sample received only information and intervention on the CO detector. The difference in the amount of information that participants had to process may have contributed to the Maryland sample's difficulty in following through on the recommendations. The CO intervention might be better as a stand-alone intervention, rather than combined with other safety messages and recommendations.

Third, the setting in which the interventions were distributed varied. The Maryland sample received the intervention in their homes (Baltimore City Fire Department staff and data collector were present); the Ohio sample received the intervention in a pediatric ED (study recruiter delivered the intervention). As the Ohio participants "had time to wait" in the ED, they might have had more time to read the tool, absorb the information, and were then motivated to install the device when they returned home.

Despite these differences, it is promising that the less-resource intensive distribution method in Ohio (i.e., simply delivering the tool and device in a clinical setting) had higher knowledge gains and more uptake of CO detectors. A positive note about the home distribution is that you can conserve resources by restricting distribution to homes in need or address other safety issues within the home.

Messaging around the importance and timing of battery replacement need improvement.

TABLE 3

Observed Carbon Monoxide (CO) Detectors Outcome of Total Detectors at 6-Month Follow-Up Home Visit

Presence of CO Detectors in the Home	Ohio (n = 125) # (%)	Maryland (n = 176) # (%)	p-Value
Homes protected by CO detectors	93 (74.4)	126 (71.6)	.59
≥1 Functional detector	69 (55.2)	85 (48.3)	.29
≥2 Functional CO detectors	24 (19.2)	41 (23.3)	
Homes not protected	32 (25.6)	50 (28.4)	.59
No CO detectors present	27 (21.6)	33 (18.7)	.07
CO detector present but not functional	5 (4.0)	17 (9.7)	
At least 1 functional CO detector near the sleeping area	61 (48.8)	81 (64.3)	.64

TABLE 4

Study Carbon Monoxide (CO) Detectors and Batteries Observed at 6-Month Follow-Up Home Visit

Presence of Study CO Detectors	Ohio (n = 125) # (%)	Maryland (n = 176) # (%)	p-Value
No study CO detector in the home	38 (30.4)	96 (54.6)	<.01
Study CO detector in the home	87 (69.6)	80 (45.4)	
Study CO detectors	87 (100)	80 (100)	<.01
Passed testing	85 (97.7)	70 (87.5)	.01
Failed testing	1 (1.1)	10 (12.5)	
Could not be tested	1 (1.1)	0	
Near the sleeping areas			
Yes	52 (59.8)	42 (52.5)	.01
No	35 (40.2)	38 (47.5)	
Battery replaced			
Yes	26 (29.9)	9 (11.2)	<.01
No	61 (70.1)	71 (88.8)	

Our results suggest that the educational tool and messages on battery replacement were not effective in motivating participants to change the battery, even when a replacement battery was provided. Methods to increase battery replacement should be further investigated in future studies.

Limitations

The two study samples (Maryland and Ohio) were derived from other larger studies and were not originally designed or selected to be comparable; it was timing and launching of both studies and convenience that drove the comparison. As such, these studies were not collectively powered for this comparison. Other limitations included minor variations in how the intervention was distributed and how follow-up home visits were conducted at each site, including: 1) how children were defined in each study (≤18 years in the Ohio sample and ≤17 years in the Maryland sample); 2) length of time between enrollment and 6-month follow up; 3) length of time to conduct follow-up home visit (average 30 minutes for Ohio and 60 minutes for Maryland); and 4) amount of information shared with participants. The groups received identical educational materials, CO detectors, and batteries. Both sites were assessed using the same survey items and observation criteria.

Conclusions

An intervention designed to improve CO safety knowledge and CO detector presence, functionality, placement, and battery replacement behaviors can be distributed successfully with positive results in a pediatric ED and/or door-to-door in an urban setting. The success of the intervention varied between settings and distribution methods, but both methods showed positive changes in knowledge and behavior. CO safety knowledge was better among the Ohio sample (more improvement in knowledge from enrollment to follow up) and CO detector use (installation, location, and functionality) was significantly better at follow up. All participants, regardless of setting or distribution method, would benefit from improved battery replacement messages or reminders. Future educational efforts around this topic should focus on the less well-known information about CO poisoning and prevention such as the causes of CO, symptoms of CO poisoning, and where CO detectors should be installed. Despite the differences in the improvement shown in knowledge and behaviors between the sites, both distribution methods (ED and community distribution) were promising for getting this life-saving technology into homes.

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Elevated Arsenic in Private Wells of Cerro Gordo County, Iowa: Causes and Policy Changes

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Abstract **Private wells are unregulated and often at risk for arsenic contamination. Research objectives included distribution of groundwater arsenic concentrations, identification of arsenic sources, and establishment of best practices for well construction to minimize risk for wells in Cerro Gordo County, Iowa. We sampled 68 wells over 3 years with 393 water samples and 79 rock samples. Geochemical modeling was used to better understand arsenic mobilization. Arsenic in groundwater ranged from 1.0 to less than 10.0 µg/L for 75 water samples and 31 water samples had arsenic concentrations greater than or equal to 10 µg/L. The arsenic source is naturally occurring sulfide minerals (typically pyrite) in the bedrock aquifers. The shallow (100–150 feet) Lime Creek Aquifer was most at risk for arsenic. Arsenic is likely mobilized from the rock into the water in the shallow aquifer under more oxidizing conditions, subject to water level changes. The study resulted in a policy change for arsenic testing and well completion in Cerro Gordo County to better protect domestic well users.**

Introduction

One of the most challenging environmental health problems today, known to affect millions of people worldwide, is arsenic-contaminated drinking water (Amini et al., 2008; Bhattacharya et al., 2007; Nordstrom, 2002; Smith, Lopipero, Bates, & Steinmaus, 2002). The World Health Organization (WHO, 2010, 2016) guideline for arsenic in drinking water is 10 micrograms per liter (µg/L). The U.S. Environmental Protection Agency has also set the maximum contaminant level (MCL) for arsenic at 10 µg/L (U.S. EPA, 2002). U.S. EPA regulates public water systems, but does not have the authority to regulate drinking water in private wells (U.S. EPA, 2016). Thus, many private wells are not tested for arsenic.

A complete literature review on arsenic contamination in groundwater and the resulting health effects is beyond the scope of this article. There are, however, some excellent review summaries on arsenic contamination in groundwater (Ahuja, 2008; Khan, Sakauchi, Sonoda, Washio, & Mori, 2003; Mukherjee et al., 2006; Ravenscroft, Brammer, & Richards, 2009; Welch, Lico, & Hughes, 1988). In addition, organic arsenic is not readily eliminated by the body, compounding chronic negative health effects (Bates, Smith, & Hopenhayn-Rich, 1992; Flora, 2015). In particular, chronic arsenic exposure can result in skin lesions, keratosis, peripheral neuropathy, gastrointestinal symptoms, renal system effects, high blood pressure, reproductive problems, cardiovascular disease, and cancer (Bhattacharya et al., 2007; Chen et al., 2009; Kapaj, Peterson, Liber, & Bhattacharya, 2006; Navas-Acien et al., 2005; Navas-Acien, Silbergeld, Pastor-Barriuso, & Guallar, 2008; Ng, Wang, & Shraim, 2003; Nordstrom, 2002; Smedley & Kinniburgh, 2002; WHO, 2010, 2016).

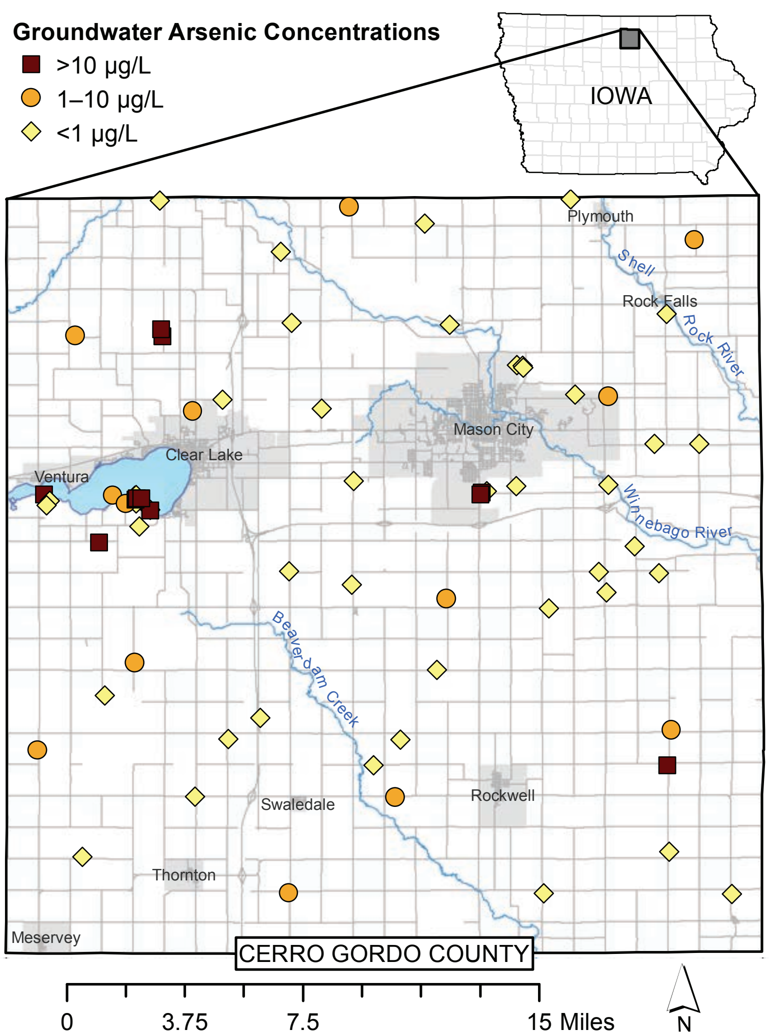
Arsenic in drinking water was initially discovered in Cerro Gordo County in the 1990s, with the extent of the problem becoming better known in recent years. Rural populations in the Midwest might be at higher risk, as they often tend to be less transient and families drink water from the same well source for many years. Arsenic in Iowa wells has been relatively unstudied (Schnoebelen & Walsh, 2014a, 2014b). The Iowa Statewide Rural Well Water Survey Phase 2 in 2005, however, showed that arsenic was present in 47% of the wells tested, with elevated arsenic levels found in 33 counties, including Cerro Gordo County (Center for Health Effects of Environmental Contamination, 2017).

Most private wells in the study area are open at depths between 100–400 feet and utilize the 1) Devonian Lime Creek Formation (Lime Creek Aquifer), the upper aquifer or 2) the Devonian Cedar Valley Group (Cedar Valley Aquifer), the lower aquifer. The limestone and dolostone formations of the aquifers are accompanied by minor shale deposits and pyrite (Iowa Department of Natural Resources [IDNR], 2013; Prior, Boekhoff, Howes, Libra, & VanDorpe, 2003). The Cedar Valley Aquifer exceeds 350 feet in thickness in places, is deeper, contains less shale, and yields more water than the Lime Creek Aquifer.

This 5-year study was funded through the Environmental Health Specialist Network (EHS-Net) Water Program at the Centers for Disease Control and Prevention (CDC) beginning in 2010 (CDC, 2014a, 2014b). The

FIGURE 1

Map of Cerro Gordo County, Iowa, With Well Sampling Locations and Areas Where Arsenic Was Detected in the Study



partners involved included the University of Iowa, Iowa Department of Natural Resources (IDNR), Iowa State Hygienic Laboratory (SHL), and Shawver Well Company. The diverse team had experts in public health and communication, analytical chemistry, geochemical modeling, geology, and well drilling.

The study objectives for Cerro Gordo County were to identify the source, mobilization, and distribution of arsenic in groundwater. In addition, the study team embarked on a strong education and outreach campaign to educate and inform private wells owners throughout the study.

Methods

Well Selection

Potential wells were selected using data from the IDNR GeoSAM database (IDNR, 2017). Criteria for selection included the most complete information for well identification number, location, depth, drilling date, owner, elevation, casing depth, casing into bedrock depth, bedrock elevation, total depth, static water level, pumped water level, well yield, drilling log, aquifer name, rock chip samples, and spatial distribution.

Several recruitment methods to engage participants in the study were employed including presenting at town hall meetings, using social media, and issuing a press release. Participant invitation packets were sent to 108 well owners who met the criteria. The response rate was approximately 60% positive to participate (65 positive responses initially), with three additional wells added throughout the study for a total of 68 wells. Figure 1 shows the final arsenic study well sampling sites.

Water Quality Sampling and Laboratory Analysis

Study protocol dictated sampling twice per year for any temporal variation in arsenic (wet period: May–September and dry period: October–April) over the 3-year period. Water quality collection methods followed those used by federal agencies (U.S. EPA Region 1, 2010; U.S. Geological Survey, 2006). The chemical analysis and arsenic speciation work was done at SHL facilities (standard U.S. EPA methods 200.7 and 200.8), in Ankeny, Iowa (Iowa State Hygienic Laboratory [SHL], 2016a). SHL is accredited by the National Environmental Laboratory Accreditation Program in conjunction with numerous other certifications (SHL, 2016b). The first column of Table 1 lists field parameters and laboratory analysis for each sample.

Sampled wells were pumped and monitored for approximately 25–30 minutes prior to sampling from a faucet or valve before any household water treatment equipment. New tubing was used for each well sampled to eliminate the chance of "carry over" of chemical species between sample sites. The sampling process involved the routine measurements of pH, temperature, specific conductance, and dissolved oxygen.

Approximately 9% of the total 393 samples collected (35 samples) were field replicate samples collected sequentially immediately after the regular environmental sample for quality control. Samples were shipped on ice by overnight express to SHL for analysis.

Data Analysis

The R statistical package was used for statistical analysis of the water quality results (R-Statistical Computing, version 3.2.1, 2015). Statistics included minimum, 25th percentile, median, mean, 75th percentile, and maximum, in addition to correlation and hypothesis test-

TABLE **1**

Water Quality Characteristics and Field Parameters of 68 Wells (350 Samples) in Cerro Gordo County, Iowa (2011–2013)

Compound	Units	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
Iron	mg/L	0.01	0.05	0.190	0.750	0.49	20.0
Magnesium	mg/L	0.25	27.0	32.0	30.76	36.0	47.0
Manganese	mg/L	0.01	0.01	0.01	0.030	0.02	0.4
Sodium	mg/L	3.0	12.0	18.0	20.83	23.0	170.0
Zinc	mg/L	0.01	0.01	0.01	0.027	0.03	0.19
Turbidity	NTU	0.5	0.5	1.6	8.34	5.8	230.0
Nitrate-N	mg/L as N	0.05	0.5	0.5	0.557	0.5	15.0
Sulfate	mg/L	0.5	2.02	7.45	13.47	17.0	89.0
Ammonia-N	mg/L as N	0.025	0.26	0.46	0.631	0.85	2.9
Bicarbonate	mg/L	0.5	330	355.0	341.8	380.0	460.0
Carbonate	mg/L as $CaCO_3$	0.5	0.5	0.5	3.42	0.5	370.0
Chloride	mg/L	0.5	1.3	2.7	5.93	6.5	90.0
Dissolved organic carbon	mg/L	0.25	0.9	1.3	1.39	1.7	6.1
Total alkalinity	mg/L	170	330	360.0	343.9	380.0	460.0
Arsenic	µg/L	0.5	0.5	0.5	0.516	1.0	110.0
Cadmium	mg/L	0.0005	0.0005	0.0005	0.00051	0.0005	0.004
Calcium	mg/L	0.5	66.0	72.0	72.57	77.0	150.0
Copper	mg/L	0.005	0.005	0.005	0.0068	0.005	0.05
Total dissolved solids	mg/L	210.0	330.0	360.0	361.6	390.0	730.0
Nickel	mg/L	0.025	0.025	0.025	0.025	0.025	0.025
Arsenic (III)*	mg/L	0.5	0.5	4.1	12.95	12.0	91.0
Arsenic (V)*	mg/L	0.5	1.95	3.9	12.68	15.5	95.0
Temperature	ºC	3.8	11.8	13.3	13.61	15.25	21.1
Specific conductance	µS/cm	317.3	531.7	609.2	604.1	669.0	1,059.0
pH	-	6.8	7.385	7.92	8.028	8.46	11.78
Eh	mV	-278.1	-104.6	-73.7	-76.56	-48.9	728.4
Dissolved oxygen	mg/L	0	0.07	0.12	0.6371	0.305	12.57

*If total arsenic was detected at or above 5 µg/L, arsenic speciation was performed.

ing. The pH-REdox-EQuilibrium geochemical program version 3.0 (PHREEQC) was used to simulate potential chemical reactions speciation, and the calculation of saturation indices (SI) for numerous mineral species (Parkhurst & Appelo, 2013).

Results

Arsenic Detections

Arsenic was detected in wells throughout the county (Figure 1). A total of 393 water samples were collected from 68 wells during 2011–2013. In quality control samples, the environmental and replicate samples matched closely as 32 of the 35 replicate samples were the same as the environmental samples with three replicate samples varying from the environmental sample by only 0.001 µg/L. These data indicate consistent repeatability of results. Only the environmental samples (i.e., no replicates) were used in computing final summary statistical water quality results. Additionally, eight water quality samples were not included in the final statistical analysis as these were missing some general chemical data (trace metal data, but not arsenic data). This exclusion left 350 total water quality samples for the final statistical water quality analysis and 358 samples for arsenic analysis.

Water Quality

Statistics (minimum, 25th percentile, median, mean, 75th percentile, and maximum) were calculated for 350 water quality samples (Table 1). In general, the water chemistry is dominated by a calcium-bicarbonate rich groundwater (calcium mean = 72.6 mg/L; bicarbonate mean = 341.8 mg/L), together

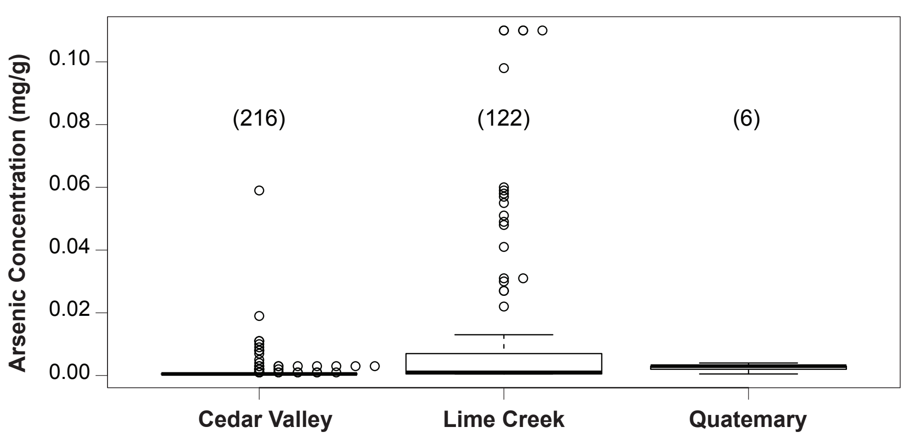
TABLE **2**

Total Arsenic Data for All Environmental Samples Collected and Analyzed for the Study With Subsets of Wet Period (May–September) and Dry Period (October–April) Samples

Arsenic Range	Total # of Samples	Wet Period Samples (May–September)	Dry Period Samples (October–April)
Arsenic ≥10 µg/L	31	20	12
1≤ Arsenic <10 µg/L	75	26	31
Arsenic <1 µg/L	252	137	132
Totals	358	183	175

FIGURE **2**

Arsenic Concentrations From Water Samples by Aquifer Type



Aquifer formation for all sampled wells. Total samples = 358: 14 without values and 344 with values.

with sodium (mean = 20.83 mg/L) and sulfate (mean = 13.47 mg/L). These results are typical of limestone and dolostone aquifers in Iowa where the bedrock groundwater is dominated by these ions (confirmed by total alkalinities that ranged from 170–460 mg/L and total dissolved solids ranged from 210–730 mg/L).

We found that 68 samples of the 358 total had detections of arsenic. Table 2 shows there were 31 samples with detections of arsenic at or above the MCL of 10 µg/L, 75 samples had arsenic detected between 1–10 µg/L, and 252 samples with arsenic below the detection level (<1 µg/L). The highest detected arsenic concentration in the study was 110 µg/L. There were 79 rock chip samples analyzed for arsenic in the Cedar Valley and Lime Creek aquifers.

Box plots of arsenic concentrations by aquifer formation (Figure 2) and those of rock chip samples from the Cedar Valley and Lime Creek aquifers (Figure 3) are provided. The results of the seasonal wet (May–September) and dry (October–April) sampling periods are shown in Table 2.

Discussion

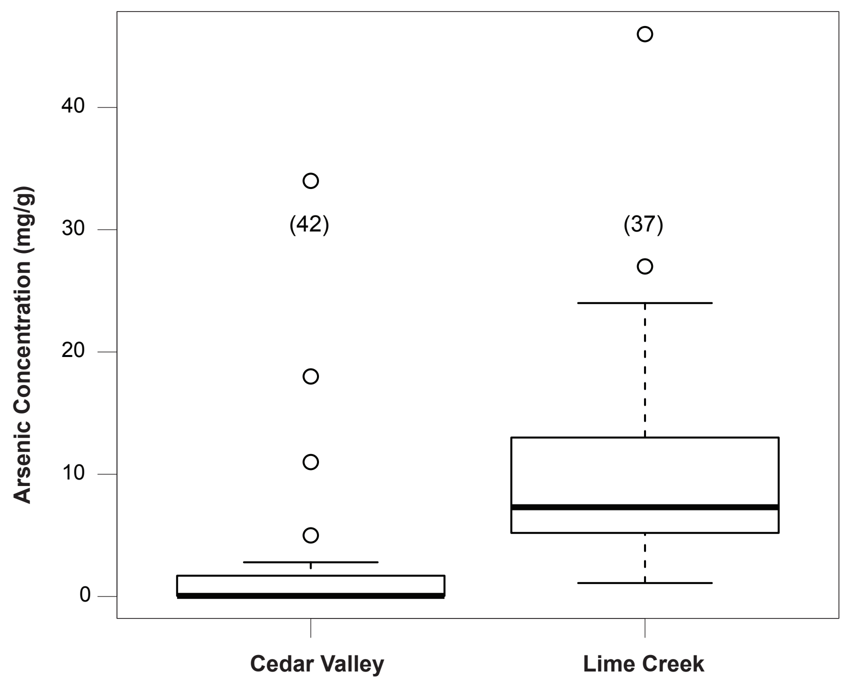
Understanding the source and mobilization of arsenic from rock into water was important for making future public health decisions in the county. Typically, arsenic can change oxidation state and As(III) is more toxic and mobile than As(V) (Welch, Westjohn, Helsel, & Wanty, 2000; WHO, 2011). During sample analysis, if total arsenic was detected at or above 5 µg/L, arsenic speciation was performed. On average there was a 50% split of arsenic as As(III) and As(V) when arsenic speciation was done for the total sample set. Variation of the speciation, however, for individual water samples was more pronounced with As(III) composing 6–100% of the total arsenic in some samples and As(V) composing 4–92% of total arsenic in other samples. This finding indicated that if homeowners detect arsenic they should run the speciation to see if they have the more toxic arsenic, As(III).

The Lime Creek Aquifer has more shale and pyrite than the Cedar Valley Aquifer. Indeed, pyrite (FeS_2) is one of the most common iron sulfide minerals and has been shown to incorporate large (up to 10.0 wt %) amounts of arsenic in its structure (Abraitis, Pattrick, & Vaughan, 2004). Pyrite and other sulfide minerals are often found in shales and carbonate bedrock as small (2–20 µm) framboids (Schieber, 2011; Smedley & Kinniburgh, 2002, 2005). Arsenic concentration in rock and well water samples were higher for the Lime Creek Aquifer than for the Cedar Valley Aquifer (Figures 2 and 3). Rock chip samples showed arsenic concentration in the Lime Creek bedrock at a mean of 11.4 mg/g compared with the Cedar Valley bedrock of 1.2 mg/g. The shales and pyrite were identified as a source of the arsenic in the Lime Creek Aquifer.

Initially, the arsenic detections (arsenic ≥10 µg/L and 1≤ arsenic <10 µg/L) were statistically compared between the water quality parameters listed in Table 1 to determine if there was any significance in a particular water quality parameter correlated with detectable arsenic concentrations using Pearson's product-moment correlation *r*, where *r* is a measure of strength of a linear association between two variables. Hypothesis testing using the *p*-value was completed as well. Potential correlations (or alternatively no correlations) are typically interpreted as numbers less than 0.05 or greater than 0.05, respectively. The hypothesis testing was completed for two sets: 1) arsenic equal to 10 µg/L or greater and 2) arsenic equal to 1.0 µg/L or greater but less than 10 µg/L. In general, the *p*-value hypothesis testing did not show any strong correlation with other chemical parameters that might have been used as a surrogate for arsenic in the future. Selected results are shown in Table 3. The *p*-value hypothesis tests, however, did indicate that shallower bedrock depth and increased change in water level did show statistical significance for arsenic >10 µg/L (p = .0015, r = 0.707 and p = .0009, r = 0.658, respectively) (Table 3). Similarly, for arsenic greater than 1.0 µg/L but less than 10 µg/L, increased dissolved oxygen and shallower bedrock depth were correlated with increased arsenic. Shallow wells in the Lime Creek Aquifer with oxic water were at risk for arsenic contamination (Table 3).

FIGURE **3**

Arsenic Concentration From Rock Chip Samples by Aquifer Type



SI and Potential Geochemical Reactions

The SI calculations by PHREEQC also indicated a dominance of more oxic iron sulfide minerals formation (i.e., hematite, magnetite, and goethite) expected in the mobilization of arsenic under more oxygen-rich conditions. These data were additionally confirmed by Eh values that were more oxic (less negative; mean = -76 mV, Table 1) compared with reducing conditions (i.e., Eh = -200 to -400 mV). Finally, iron and manganese were at relatively low concentrations in the groundwater samples (iron mean = 0.750 mg/L and manganese mean = 0.030 mg/L), again supporting more oxic water. Iron and manganese concentrations would typically be over 1.0 mg/L if the conditions were more reducing (Chapelle & Lovley, 1992). These geochemical data support the hypothesis of oxic conditions where arsenic could mobilize from the rock into the water. The PHREEQC SI calculations illustrated groundwater was dominated by calcium, manganese, sodium, and bicarbonate, which corresponded to actual water sample data, confirming that PHREEQC was yielding accurate results.

Pyrite was present in the aquifer and is known to contain arsenic in the Lime Creek Aquifer (Figure 3); thus, the oxidation of pyrite is a potential pathway for arsenic into water. In the presence of aerated (oxygenic) water, dissolved Fe(II), pyrite, and other Fe(II) sulfides containing arsenic can readily oxidize to Fe(III) (Gleisner & Herbert, 2002), releasing As into the water. Thus, in carbonate-dominated groundwater (Table 1), Fe(III) can readily react with water, oxygen, and/or hydroxides to become saturated in the groundwater (i.e., yielding saturation indices >1) to form (oxy)(hydr)oxides (shown in the PHREEQC data runs). These Fe hydroxides often cause "iron staining" in pumping fixtures as further confirmed by homeowners in Cerro Gordo County with untreated well water.

Finally, when examining the hydrologic properties of the Lime Creek Aquifer from drilling logs, it was found that often the pumped water levels in the Lime Creek aquifer could drop several feet below the static water level. In some instances, we noted a 60–100 feet of drop (hydraulic head difference). This drop has the potential to introduce oxygen into the aquifer through the wellbore. The Lime Creek Aquifer does not have as large of specific capacity (pumping rate or well yield divided by drawdown) under pumping as the Cedar Valley Aquifer due to the shales in this aquifer. This limited capacity means the Lime Creek Aquifer will have larger drawdowns under pumping (introducing more oxygen to the water) than the Cedar Valley Aquifer.

Communicating Results to Residents

Project participants, private well users, and the general public received regular project updates through multiple methods. Forming these strong community-based research partnerships was critical for communicating health effects (Israel, Schulz, Parker, & Becker, 1998). Participants received copies of all analyses completed on their wells along with education. One-on-one mentoring and easy-to-understand videos helped communicate results across all educational levels. We created three YouTube.com videos, including one that featured an interview with a woman who had suffered health effects from consuming arsenic in her groundwater (http://youtu.be/0ddWtA0M8Ks).

Health Policy Change

The results of our study were presented to the Cerro Gordo County Board of Supervisors in March 2015. Our study clearly showed that arsenic was a problem countywide, with the source and mobilization of arsenic in the Lime Creek Aquifer. The County Well Ordinance was rewritten based on the results of our study to include language that all new wells drilled must be cased through the upper Lime Creek formation (the aquifer with the

TABLE **3**

Hypothesis Testing Results for Arsenic Concentrations Versus Selected Parameters

Sets	Dissolved Oxygen	Eh	Bedrock Depth	Change in Water Level	Nitrate	Sulfate
Arsenic ≥10 µg/L	*p* = .245 *r* = 0.228 *n* = 31 NA = 3	*p* = .181 *r* = 0.251 *n* = 31 NA = 1	***p* = .0015** ***r* = 0.707** *n* = 31 NA = 14	***p* = .0009** ***r* = 0.658** *n* = 22 NA = 0	*p* = .114 *r* = 0.294 *n* = 31 NA = 1	*p* = .474 *r* = 0.133 *n* = 31 NA = 0
1≤ Arsenic <10 µg/L	***p* = .0012** ***r* = 0.374** *n* = 75 NA = 0	*p* = .989 *r* = 0.0016 *n* = 75 NA = 0	***p* = .044** ***r* = 0.236** *n* = 75 NA = 2	*p* = .68 *r* = 0.163 *n* = 73 NA = 0	*p* = .791 *r* = 0.031 *n* = 75 NA = 0	*p* = .117 *r* = 0.182 *n* = 75 NA = 0

NA = not available.
Note. Bolded text indicates statistical significance.

greatest source of arsenic) and that all future wells would be tested for arsenic when put in service. County health officials now had the correct information to provide to residents and could provide possible treatment options if wells were affected. In addition, results from this study influenced a statewide revision of rules to allow for arsenic testing in the Grants to Counties bacteria and nitrate private well testing program. Nationally, the team was involved in a U.S. EPA workgroup that wrote a report to Congress regarding potential rule changes for small public water systems and arsenic contamination.

Conclusions

We met our objectives within this study on determining the distribution of groundwater arsenic concentrations, identification of arsenic sources, and establishment of best practices for future well construction to minimize risk for wells in Cerro Gordo County, Iowa. A critical part of the study involved educating private well owners on the risks of arsenic in groundwater and providing good communication by team members on research results. The arsenic source was naturally occurring sulfide minerals (pyrite) containing arsenic commonly associated with the Lime Creek Aquifer. Geochemical analysis suggests that arsenic is most likely mobilized through oxidizing conditions, particularly in shallow aquifers that are subject to larger water level changes during pumping. Reducing conditions, however, could also mobilize arsenic in deeper parts of the aquifer system in places. The seasonal and long-term variations in arsenic were minimal for individual wells. Future studies are warranted to expand and fill known geographical, environmental, and public health sampling gaps for arsenic in groundwater, geochemistry, and biomarkers. The results of the study support other arsenic issues in the Midwest with similarities to private wells and arsenic in groundwater (Erickson & Barnes, 2005; Minnesota Department of Health, 2001, 2008, 2015; Wisconsin Department of Natural Resources, 2016a, 2016b), but not previously identified in Iowa.

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DIRECT FROM CDC ENVIRONMENTAL HEALTH SERVICES BRANCH

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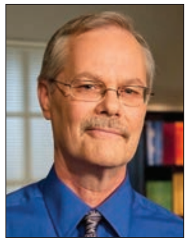

Michael J. Beach, PhD

Minimizing Risk of Illness and Injury at Public Aquatic Facilities by Maximizing the Power of Aquatic Facility Inspection Data

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 views of CDC.

Michele Hlavsa is chief of the Healthy Swimming Program in CDC's National Center for Emerging and Zoonotic Infectious Diseases (NCEZID). CDR Jasen Kunz serves as CDC liaison to the Council for the Model Aquatic Health Code (CMAHC) on behalf of CDC's National Center for Environmental Health. Michael Beach is associate director of the Healthy Water Program at CDC's NCEZID and president of the CMAHC board of directors.

More than two thirds (68%) of local health departments regulate, license, or inspect public aquatic facilities, defined as a physical place that contains one or more aquatic venues (e.g., pools) and supports infrastructure (e.g., a chemical pump room) (National Association of County and City Health Officials, 2013). When environmental health practitioners enforce state or local codes during inspections, they prevent illness and injuries at public aquatic facilities. But how exactly can the public and public health—two key healthy and safe swimming stakeholders—maximize the power of aquatic facility inspection data to minimize the risk of illness and injury? Just follow the inspection data.

The Public

A national convenience survey found that about two thirds of adults, who regularly participate in aquatics or whose children do, don't know that they can ask for inspection scores for individual public aquatic venues (Hlavsa, McClain, Collier, & Prue, 2014). If aware of inspection scores, almost 90% are somewhat or very interested in knowing the inspection scores. Conspicuously posting inspection scores online (e.g., on public health and aquatics Web sites) and on site (e.g., at the facility's entrance or waterside) can increase public awareness. It can also encourage the public to regularly check these inspection scores and use them to decide which facilities to use, much like how the public checks food service establishment inspection scores to decide where to eat.

Public Health

Data tell us that almost one in eight (12.3%) routine inspections conducted in 2013 in 16 local jurisdictions resulted in immediate closure because at least one violation that represented a serious threat to public health had been identified (Hlavsa et al., 2016). Violations (e.g., improper disinfectant concentration or missing safety equipment) indicate an increased risk of illness and injury associated with public aquatic facilities. Additionally, violations represent an opportunity for environmental health practitioners to be illness and injury prevention advisors, educating operators about how to properly operate and maintain public aquatic facilities and why these measures are necessary. Such interactions, at the waterside or in aquatic facility operator training, could prevent future or repeated violations, and more importantly, minimize risk of illness and injury associated with public aquatic facilities.

Environmental health aquatic inspection programs have finite resources, so they can't be everywhere all of the time. To help direct enforcement (e.g., risk-based inspections) and education efforts, programs can use data from their aquatic facility inspections to

- determine which identified violations resulted in immediate closures;
- examine quantitative water quality readings (e.g., chlorine and cyanuric acid concentrations, pH) collected by environmental health practitioners during inspections, which are particularly valuable when readings that are too low have different public

FIGURE **1**

Model Aquatic Health Code Aquatic Facility Inspection Report

Aquatic Facility Permit #: _______________ Aquatic Venue Identifier: _______________ Date: _____/_____/_________

Model Aquatic Health Code Aquatic Facility Inspection Report

Name of Aquatic Facility ____ Address ____ City ____ State ____ Zip Code ____ Time: In ______ / Out ______

Venue Type: ❏ Pool ❏ Hot tub/Spa ❏ Wading Pool ❏ Interactive water play venue ❏ Other_______

Risk Type*: ❏ 1 ❏ 2 ❏ 3

Item		Descriptions (Bold= critical violations)	Points	In	Out	N/A	N/O
1	Pool/ Spa Area	**Enclosure: fencing, walls, gates and doors in good repair**	**10**				
2		**Self-closing/Self-latching gates or doors operational**	**10**				
3		**Protected overhead electrical wires/GFCI electrical receptacles**	**10**				
4		Grab rails, ladders secured; shell, deck in good repair	5				
5		Float/safety line clearly present	5				
6		"Depth" & "no diving" markers; stair stripes; in good repair and visible	5				
7		Skimmers: Weirs and baskets installed; clean and operating; covers in good repair	5				
8		Recirculation inlets functional	5				
9		**Main drain grate secured in place & in good repair**	**10**				
10		**Water is clear, main drain visible**	**10**				
11		Starting blocks removed, covered, or access blocked	5				
12		Pool deck free from obstructions; emergency exit marked	5				
13		Emergency phone or other communication device available and well-marked	5				
14		First Aid Kit available	5				
15		**Appropriate safety equipment present & in good repair**	**10**				
16		**Adequate supervision of the aquatic facility**	**10**				
17		Signs: Bathing load/rules/chemicals/spa legible and in good repair	5				
18		Spa temperature ≤ 104°F (40°C)	10				
19	Water Chemicals	Approved NSF/ANSI Standard 50 DPD test kit	5				
20		**Proper disinfectant level**	**10**				
21		**pH between 7.2 and 7.8**	**10**				
22		Combined chlorine < 0.4 ppm	5				
23		Cyanuric acid ≤ 100 ppm	5				
24	Equipment/ Chemical Room	Automated feeder operable	10				
25		Automated controller operable	5				
26		Piping and valves identified and marked	5				
27		Flow meter present and operating	5				
28		**Recirculation pump: approved, good repair, operating**	**10**				
29		**Filter: approved, good repair, operating**	**10**				
30		Pump strainer: baskets in good condition, not clogged	5				
31		Filter gauges operable: filter inlet and outlet, strainer; sight glass	5				
32		Proper functioning UV system; ozone system	5				
33		**Chemicals: labeled, stored safely, secured**	**10**				
34		Appropriate Personal Protective Equipment (PPE) available	5				
35	Hygiene Facilities	Diaper-changing station present; sink, adjacent trash can, sanitizer	5				
36		Used equipment separated from cleaned equipment	5				
37		Toilets: clean, good repair, bathroom appropriately stocked	5				
38		Rinse showers: good repair, accessible	5				
39		Cleansing showers: Warm, non-scalding water available; good repair; soap	5				
40	Records Room	Operator training certification available onsite	5				
41		Lifeguard training certification available onsite	5				
42		Inspection report conspicuously posted at each entrance	5				
43		Operator inspection daily items: checklist used daily	5				
44		Operator inspection items: evidence of appropriate steps promptly taken	5				
45		Chemical records: filled out daily	5				
46		Chemical records: evidence of appropriate steps promptly taken	5				
47		Emergency Action Plan available on site	5				
48	General	**Substantial unauthorized alterations/equipment replacement**	**10**				
49		Other: Imminent Health Hazards are a 10-point **critical violation**	5 or **10**				
		Points: add points for all scored categories; for in (blue) and out of (red) compliance	TOTAL				

SCORE: _______ %

Letter Grade: ________

Previous Score: _______ %

Purpose of Visit (Check one)

_____Routine
_____Complaint
_____Follow-Up
_____Other

Water Quality Readings

Free clorine	ppm
Free bromine	ppm
pH	
Total alkalinity	ppm
Calcium hardness	ppm
Cyanuric acid	ppm
Water Temp	°F

Grading System: A= 95-100% B= 85-94% C=75-84 % F= 74% or less or critical item

Last updated 11/03/2016

http://www.cdc.gov/mahc/

health implications than those when readings are too high;

- characterize distribution of violations, closures, and out-of-range readings by setting (e.g, hotel/motel, waterpark), venue (i.e., pool versus hot tub/spa), and pool category (e.g., wading pool, interactive water play venue); and
- monitor trends in violations, closures, and out-of-range readings overall and by specific settings, venues, and pool categories.

Enabling regular analysis of aquatic facility inspection data requires collecting and storing the data so that they can be easily accessed and extracted. This requirement calls for a multidisciplinary effort led by environmental health across local, state, and federal public health agencies to increase efficiency in developing needed tools, and at the level of individual environmental health aquatic inspection programs. Environmental health practitioners have technical knowledge of the operation and maintenance of public aquatic facilities and inspection expertise, epidemiologists have data analysis expertise, and information technology specialists have database construction and maintenance expertise.

One key tool needed to facilitate regular analysis of aquatic facility inspection data is a model form to collect the data. As a starting point, the Centers for Disease Control and Prevention (CDC) drafted a model inspection form that state and local environmental health practitioners field tested and provided feedback on. The current form (Figure 1) includes about 50 of the top risk reduction elements in the Model Aquatic Health Code (MAHC). The MAHC is a set of CDC recommendations to prevent public aquatic facility–associated drownings, other injuries, and outbreaks (such as the 2014 Tennessee cryptosporidiosis outbreak associated with a hotel pool published in this issue; see page 16). Additionally, CDC is developing a free MAHC inspection iPad application (Figure 2). The application includes the model inspection form, a system to capture and run simple statistics on aquatic facility inspection data, and the complete 2016 MAHC (2nd Edition). A link to the app will be available on CDC's MAHC Web site.

Quick Links

- Centers for Disease Control and Prevention's (CDC) Model Aquatic Health Code: www.cdc.gov/mahc
- Network for Aquatic Facility Inspection Surveillance: www.cdc.gov/mahc/nafis.html
- Council for the Model Aquatic Health Code (CMAHC): www.cmahc.org
- Become a member of CMAHC: www.cmahc.org/become-a-member.php
- CDC's Environmental Health Services Branch: www.cdc.gov/nceh/ehs

The Council for the Model Aquatic Health Code (CMAHC) (www.cmahc.org), which supports the use of aquatic facility inspection and other data to optimize the MAHC and supports MAHC adoption, could, through its membership, facilitate the cross-agency multidisciplinary collaboration needed to develop a set of tools to maximize the power of aquatic facility inspection data. Be a part of this public health effort, become a CMAHC member. Also, help drive the use of data to shape the 2018 MAHC (3rd Edition) by participating in the second biennial CMAHC conference in Denver, Colorado, on October 17–18, 2017, and by voting on proposed MAHC change requests from October 17–November 19, 2017.

Acknowledgement: The authors thank their state and local partners in Arizona, California, Florida, New York, and Texas for collaborating on the Network for Aquatic Facility Inspection Surveillance and maximizing the power of aquatic facility inspection data to minimize the risk of illness and injury.

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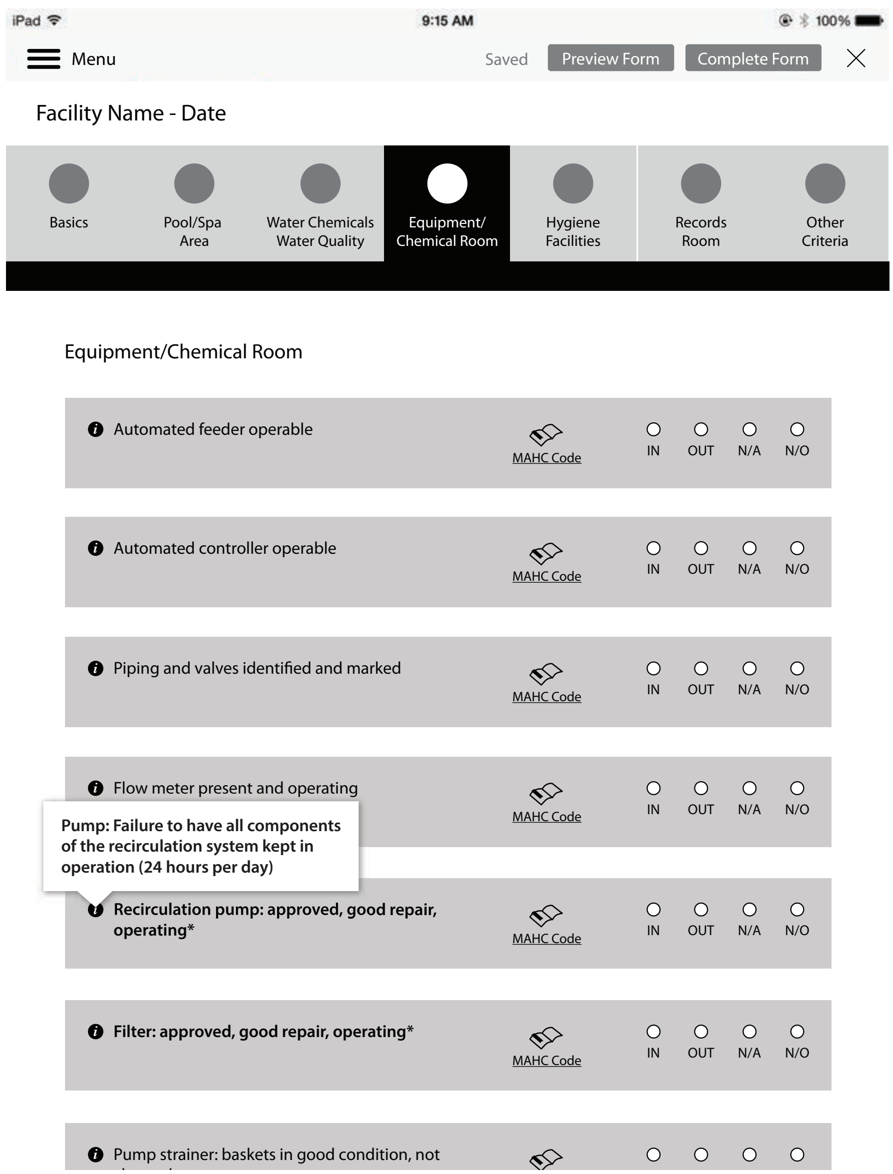
FIGURE **2**

Screenshot of the Model Aquatic Health Code iPad App



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www.achd.net

American Chemistry Council
www.americanchemistry.com

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www.arlingtonva.us

Association of Environmental Health Academic Programs
www.aehap.org

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City of Bloomington
www.bloomingtonmn.gov

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

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

Coconino County Public Health
www.coconino.az.gov

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

Denver Department of Environmental Health
www.denvergov.org/DEH

Digital Health Department, Inc.
www.dhdinspections.com

Diversey, Inc.
www.diversey.com

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DuPage County Health Department
www.dupagehealth.org

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

Ecobond Lead Defender
www.ecobondlbp.com

Ecolab
www.ecolab.com

EcoSure
adolfo.rosales@ecolab.com

Elite Food Safety Training
www.elitefoodsafety.com

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

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

GLO GERM/Food Safety First
www.glogerm.com

Health Department of Northwest Michigan
www.nwhealth.org

Hedgerow Software Ltd.
www.hedgerowsoftware.com

Hoot Systems, LLC
http://hootsystems.com

Industrial Test Systems, Inc.
www.sensafe.com

Inspect2GO Health Inspection Software
www.inspect2go.com/ehs

InspekPro, LLC
www.inspekpro.com

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

LaMotte Company
www.lamotte.com

Lenawee County Health Department
www.lenaweehealthdepartment.org

Macomb County Environmental Health Association
jarrod.murphy@macombgov.org

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

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

New Mexico Environment Department
www.env.nm.gov

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

NSF International
www.nsf.org

Otter Tail County Public Health
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www.swdh.org

Southwest Utah Health Department
www.swuhealth.org

Starbucks Coffee Company
www.starbucks.com

StateFoodSafety.com
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Stater Brothers Market
www.staterbros.com

Steritech Group, Inc.
www.steritech.com

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Texas Roadhouse
www.texasroadhouse.com

UL
www.ul.com

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

Waukesha County Environmental Health Division
www.waukeshacounty.gov/environmental_health

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www.findlay.edu

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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.

Georgia
June 5–7, 2017: Annual Education Conference, hosted by the Georgia Environmental Health Association, St. Simons Island, GA. For more information, visit www.geha-online.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.

Minnesota
May 10–12, 2017: Spring Conference, hosted by the Minnesota Environmental Health Association, Ruttger's Bay Lake, MN. For more information, visit www.mehaonline.org.

September 19–21, 2017: FDA Central Region Retail Food Protection Seminar and NEHA Region 4 Biannual Educational Conference, Minneapolis, MN. For more information, visit www.mehaonline.org.

North Dakota
October 18–19, 2017: Fall Education Conference, hosted by the North Dakota Environmental Health Association. For more information, visit http://ndeha.org/wp/conferences.

Rhode Island
October 4–5, 2017: 55th Annual Yankee Conference on Environmental Health, Newport, RI. For more information, visit www.cteha.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.

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

Washington
May 1–3, 2017: 65th Annual Education Conference, hosted by the Washington State Environmental Health Association, Wenatchee, WA. For more information, visit www.wseha.org.

West Virginia
May 9–11, 2017: Sanitarian's Mid Year Conference, hosted by the West Virginia Association of Sanitarians, Ripley, WV. For more information, visit www.wvdhhr.org/wvas/events/index.asp.

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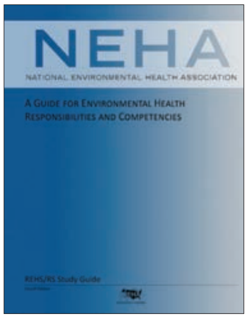
www.neha.org/store

REHS/RS Study Guide (4th Edition)

National Environmental Health Association (2014)

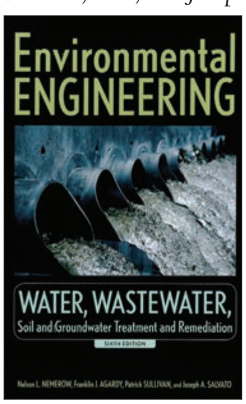


The Registered Environmental Health Specialist/Registered Sanitarian (REHS/RS) credential is NEHA's premier credential. This study guide provides a tool for individuals to prepare for the REHS/RS exam and has been revised and updated to reflect changes and advancements in technologies and theories in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

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.

384 pages / Hardback / Catalog #709
Member: $130 / Nonmember: $140

Certified Professional-Food Safety Manual (3rd Edition)

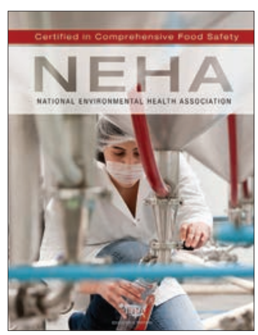
National Environmental Health Association (2014)

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.

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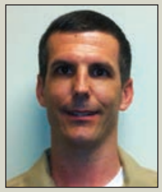

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DirecTalk
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the end of the seminar on how NEHA and CDC can partner more effectively. My response reflected the notion that throwing small amounts of money across the public health world in support of environmental health was reinforcing the balkanization of the profession. It is time to fund NEHA as the single, most effective partner that can reach and build the capacity of both the public and private environmental health sector.

The 2-day CDC Zika summit was thought provoking. The conference was invitation only and was convened adjacent to CDC's Emergency Operations Center. Speakers representing the pest control industry, U.S. and foreign public health officials, researchers, and funders such as the Bill & Melinda Gates Foundation delivered a wide range of presentations aimed at reducing Zika risk in the U.S.

The Zika situation in the U.S. is complex. An estimated 5,000 cases have been reported,

David Dyjack with CDC Acting Director Anne Schuchat. Photo courtesy of David Dyjack.

with 221 transmitted locally, primarily in Texas and Florida. The vector, the *Aedes* mosquito, is profoundly local. It loves to breed in very small vessels of water, making efforts to control breeding sites very difficult. Many innovative approaches to track, target, and act on juvenile and adult mosquitoes are under consideration. These approaches include the deployment of genetically modified sterile males, aerial spraying, and basic, good old fashion housekeeping measures that reduce breeding sites.

The resounding implications are that Zika is likely here to stay in the U.S. Thus, the message is clear: sustained financial investment in vector control programs is a strategic national priority. At this conference and in other venues, I have repeatedly advocated for the environmental health workforce and its valuable role in minimizing the risk associated with vectors. Who better to work on Lyme disease, Rocky Mountain spotted fever, or chikungunya?

All public health roads lead to Atlanta. Our commitment is to show up and speak up on behalf of you and the entire profession. February 2017 was a busy month indeed!

Dave

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Did You Know?

For the first time in its 80-year history, NEHA has released an Annual Report for fiscal year 2016. The progressive and interactive format of the Annual Report allows readers to view videos and click on links that take them directly to online content for a richer, in-depth experience. View the Annual Report at http://neha.org/sites/default/files/flipping_book/annual-report-2016/index.html.

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***Start planning the sessions you want to attend at the NEHA 2017 AEC!** We will once again be using our AEC meeting app rather than a printed program for session information. Be sure to register today so you can access the app and plan ahead. Here are just some of the AEC session highlights:*

Don't Miss the Great Restaurant Grading Debate

Is restaurant grading an effective practice or are we misleading ourselves and the public? Listen to the pros and cons of restaurant grading as Terri Williams, Director of Environmental Health for Los Angeles County, and Mick Miklos, Senior Manager at the National Restaurant Association, face-off to discuss this controversial issue.

Join an Interactive Panel Discussion on New Challenges and Responsibilities Facing Water Quality

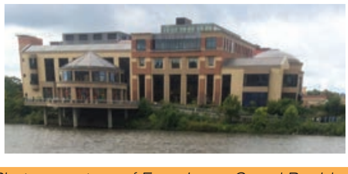
Contaminants, climate change, and aging infrastructure have had a great impact on water quality in the U.S. Many health departments are facing new challenges and taking on new responsibilities to protect our water supplies. This interactive panel discussion will focus on the increasing role of environmental health in keeping our water safe.

Learn How to Build Local Solutions in Climate Change

The Climate and Health Track will embody the AEC theme—Local Solutions. National Influence.—by featuring Michigan's success in building community partnerships and using local data to adapt to the effects of climate change. This session and others will demonstrate tools and resources for attendees to utilize in their own communities and provide steps to build resilience. CDC will present on how to communicate to policymakers and continue the discussion from the 2016 AEC.

Choose From Over 25 Hours of Food Safety Content

Participate in multiple educational lecture sessions, learning labs, and panel discussions on food safety and defense issues including food fraud, allergen labeling, breakthrough technology for the seafood industry, achieving conformance with FDA's Voluntary National Retail Food Regulatory Program Standards, emerging issues with wild foraged mushrooms, and a wide variety of many more food safety topics.



UL Event: Tuesday, July 11

Be sure to purchase your tickets in advance to attend this fun night at the Grand Rapids Public Museum! Visit neha.org/aec/events.

Photos courtesy of Experience Grand Rapids.

Build Your Personal Agenda From 25 Environmental Health (EH) Disciplines Conveniently Aligned in 11 Easy to Follow Tracks

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6) **Emergency Preparedness**
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9) **Workforce and Leadership**
   - Leadership & Management
10) **Climate and Health**
   - Climate Change
11) **Infectious and Vector Borne Diseases**
   - Pathogens & Outbreaks
   - Vector Control & Zoonotic Diseases

*Register and find details on sessions and events at **neha.org/aec.***

DirecTalk MUSINGS FROM THE 10TH FLOOR

David Dyjack, DrPH, CIH

Oh, Atlanta

There is nothing quite like the taste of a fresh Georgia peach. The fragrance and flavor have a way of clinging to you long after the fruit is devoured. This lasting impression is also true for Georgia's influence on environmental practice and public health. This reflection is particularly relevant for February 2017 when I represented your interests at two Atlanta-based conferences and a reverse site visit to the Centers for Disease Control and Prevention (CDC).

Allow me the privilege to provide you with a quick review of the key outcomes of my Georgia adventures, beginning with the most nationally visible event—the Climate and Health Summit sponsored by Al Gore. The 1-day program attracted national attention in large measure because Gore stepped in (and up) to host the Climate and Health Summit.

The Carter Center provided an appropriate venue for the conference, punctuated by an appearance and brief remarks from Jimmy Carter. But the star of the show was Gore, who provided the audience with a compelling rationale for convening the conference. The "who's who" of the climate research world presented scientific findings about the disturbing changes to our planet, the implications for our health and food supply, and the possible paths forward to address what is increasingly becoming a concern of global proportions.

While I was very pleased to represent you at the conference, I had heard most of the presentations at prior events and there was precious little in the way of new or emerging science presented. What was different, however, was the collective show of force from the allied health professions. The conference was widely covered in the national press, which demonstrated what we in the health sector can achieve if we search for areas to collaborate.

The message is clear: sustained financial investment in vector control programs is a strategic national priority.

Ironically, it was the last speaker who made the entire day worthwhile. The presenter was once employed by a conservative think tank, but had since joined the folds of those who are alarmed by the implications of growing environmental change. He encouraged the audience to stop talking to people who agree with the public health community and to increase efforts to engage the conservative political elite who are undecided about the implications of climate and health. He described what he perceived as effective approaches and strategies that might compel moderate political leaders. He went on to emphasize that we should not overstate the certainty of our science and importantly, how to frame our health messages in the context of risk management.

Shortly after the Climate and Health Summit, our Government Affairs Director Joanne Zurcher and I completed targeted appointments with pubic health officials on the CDC Roybal campus. We met individually with CDC Acting Director Dr. Anne Schuchat; Dr. Stephen Redd, director of the Office of Public Health Preparedness and Response; and the leadership of the National Center for Emerging and Zoonotic Infectious Diseases (NCEZID).

The appointments with Drs. Schuchat and Redd were impressive in that both professionals were attentive and inquisitive about how the environmental health profession creates and delivers value for the health enterprise. Both seemed genuinely surprised at the notion that we are the single largest and most geographically distributed segment of the public health workforce. Dr. Redd took note that in some places, especially in rural and frontier areas of the country, environmental health *is* the local health department. The importance of this realization is highlighted in the combat of Zika in the U.S.

The meeting with NCEZID leadership was followed by a center-wide "Value of Working With NEHA" seminar delivered by yours truly. I highlighted the critical role environmental health professionals play in protecting the American public against waterborne and foodborne diseases, and our profession's vital role in emerging infectious and vectorborne diseases. I received a question at

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INTERNATIONAL PERSPECTIVES

Pollution Characteristics and Potential Ecological Risk Assessment of Polycyclic Aromatic Hydrocarbons in Wastewater Irrigated Soil

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Abstract **Soil contamination by polycyclic aromatic hydrocarbons (PAHs) is an increasing problem. We wanted to determine the characteristics and ecological risk of PAHs in wastewater-irrigated soil, provide a theoretical basis for the prevention of PAH contamination in soils, and inform the formulation of guidelines and standards for critical limits of PAHs. We collected soil samples from two typical wastewater-irrigated farmlands, Farmlands A and B, in Tangshan, China, and used a clean-water irrigated farmland, Farmland C, as the control area. A total of 15 samples were analyzed for 16 PAHs by high-performance liquid chromatography. The results showed that the total amount of PAHs in samples from Farmlands A and B were 1,046.2 µg/kg and 1,308.1 µg/kg, respectively—significantly higher than Farmland C's 189.1 µg/kg. The PAHs from wastewater-irrigated soil mainly consisted of PAHs of 4-rings or higher, accounting for 83.1% and 60.2% of total PAHs for Farmlands A and B, respectively. The evaluation of the ecological risk of PAHs using the single-factor index method and Nemerow comprehensive index (P_n) method revealed the main PAHs exceeding the critical limits were pyrene, dibenz[a,h]anthracene, and benzo[g,h,i]perylene. The P_n for the two wastewater-irrigated soils were 3.05 and 3.16, respectively, for Farmlands A and B, reaching a heavy pollution level versus Farmland C's 0.34, classified as a clean level. We conclude that wastewater irrigation has led to ecological risk, and the wastewater-irrigated soil is carcinogenic, teratogenic, and mutagenic.**

Introduction

Polycyclic aromatic hydrocarbons (PAHs) are organic substances that contain two or more benzene rings. Due to their ring-shaped structure, PAHs have relatively high chemical stability and are rarely affected by photochemical and biological oxidation. They are persistent and bioaccumulative. Thousands of different kinds of PAHs exist, and most of them are strongly carcinogenic, teratogenic, and mutagenic (Chen & Liao, 2006; Ifegwu & Anyakora, 2015). The U.S. Environmental Protection Agency (U.S. EPA) lists 16 PAHs as priority pollutants (Keith & Telliard, 1979).

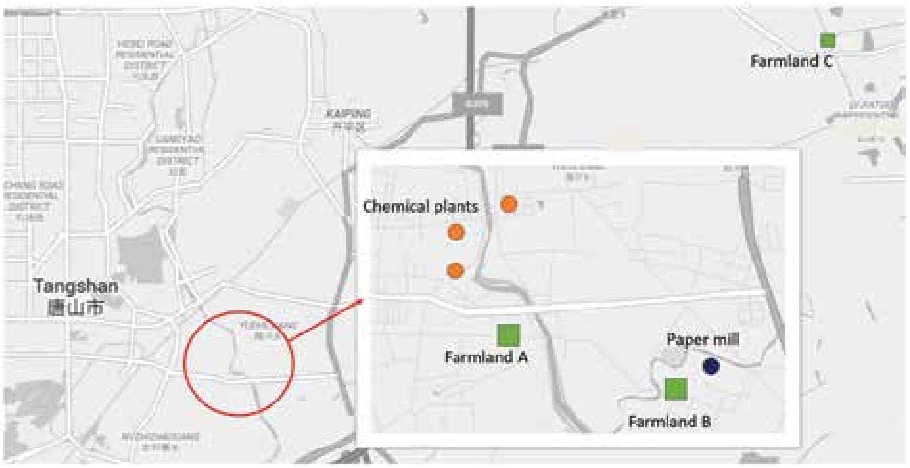
The soil is an important environmental medium and is rich in organic matter. PAHs are lipophilic in nature, and thus show high affinity to the soil. Soil bears more than 90% of the environmental load of PAHs, and is therefore a storage and transfer station for PAHs (Wang et al., 2007). Studies show that the amount of PAHs entering human bodies from the soil is significantly higher than that from air and water (Feng, Fu, Zhao, & Gao, 2011). Moreover, the PAHs in soil can affect human health indirectly via the soil-groundwater-atmosphere connection and endanger human health directly via the soil-plant-food chain (Aleem & Malik, 2003; Zohair, Salim, Soyibo, & Beck, 2006).

With industrial development and a rising living standard, the amount of industrial water and urban sewage increases year by year, resulting in the increasingly prominent problem of surface water pollution and the contamination of clean irrigation water. To solve the problem of irrigation water shortages, more areas are forced to use wastewater for irrigation, leading to deterioration of soil quality. The contaminants in wastewater include not only heavy metals but also many organic compounds such as PAHs (Hao, Wang, & Li, 2010; Zhang et al., 2012).

Currently in many countries including China, requirements on the limit of heavy metals have been included in the standards of agricultural land use, but the evaluation and monitoring of PAHs have not yet been incorporated in these standards (Tang, Tang, Zhu, Zheng, & Miao, 2005), leading to a lack of control for PAHs in soil. Therefore, it is critical to investigate the level of PAHs in different types of soil, and develop appropriate standards for level of PAHs in soil as soon as possi-

FIGURE **1**

Map of Sampling Area Locations



ble. We collected soil samples from two typical wastewater-irrigated farmlands, Farmlands A and B, in Tangshan, China, and a clean-water irrigated farmland, Farmland C, was used as the control area. PAHs in the soil were analyzed and evaluated to determine their characteristics and ecological risk, and to provide a theoretical basis for the prevention and treatment of PAHs, as well as derive a critical limit for PAHs for standards and guidelines.

Materials and Methods

Equipment and Reagents

The chromatographic analysis was performed with Aglient 1200 high-performance liquid chromatography (HPLC). An ultrasonic oscillation water bath was purchased from Kunshan Ultrasonic Instrument (KQ5200DB).

The primary reagents were acetone, petroleum ether, cyclohexane, and methanol. All solvents were of HPLC grade. Silica gel, purchased from Tianjin Chemical Reagent Plant, was activated at 130 °C for 16 hours, and water was added before usage (silica gel/water = 95/5). Anhydrous ammonium sulfate, purchased from Tianjin Chemical Reagent Plant, was heated at 650 °C for 4 hours before usage and stored in a desiccator. PAHs were purchased from Supelco Technical Service, and consisted of the 16 PAHs listed by U.S. EPA as priority pollutants, namely naphthalene (NAP), acenaphthylene (ACY), acenaphthene (ACE), fluorine (FLU), phenanthrene (PHE), anthracene (ANT), fluoranthene (FLA), pyrene (PYR), benzo[a]anthracene (BaA), chrysene (CHR), benzo[b]fluoranthene (BbF), benzo[k]fluoranthene (BkF), benzo[a]pyrene (BaP), dibenz[a,h]anthracene (DahA), benzo[g,h,i]perylene (BghiP), and indeno[1,2,3-cd]pyrene (IcdP).

Sample Collection and Treatment

The area of study is Tangshan, China. Tangshan (latitude 39°37'51.12"N and longitude 118°10'48.7"E) is a heavily industrialized city in northeastern Hebei Province. Two typical wastewater-irrigated farmlands from Tangshan, China, were selected for investigation. There are several chemical plants upstream of Farmland A, and a paper mill upstream of Farmland B. Both farmlands are irrigated with water from the river, whose water quality is categorized as below class V, exceeding the Standards for Irrigation Water Quality according to the Environmental Protection Agency of China (GB3838-2002), and is categorized as a wastewater irrigation area. The main parameter exceeding the standard limit is NH_3-N and chemical oxygen demand. Farmland C is irrigated by groundwater and lies 15 km away from A and B; it was chosen as the control area. The irrigation water quality for Farmland C satisfies the Standard for Drinking Water (GB 5749-2006). The locations of Farmlands A, B, and C can be seen in Figure 1. Following the Technical Specification for Environmental Monitoring (State Environmental Protection Administration of China, 2004), surface soils up to a depth of 20 cm were collected and mixed for each farmland. Five sampling spots were selected for each of Farmlands A, B, and C. Samples were collected at the four corners and at the midpoint of each sampling spot. All samples were mixed, and each mixture of sample weighed 1–2 kg.

We removed any stones and leaves from the sample before letting the sample dry naturally. Samples were sieved through a 2-mm mesh nylon sieve and crushed until the soil passed through the 40-mesh sieving screen. Each sample was then blended and stored at -20 °C.

The method for extraction and purification was performed as described by Gao and coauthors (2010), with slight modification. A sample of 10 g of the soil was mixed with 10 g of anhydrous sodium sulfate. A mixture of acetone, petroleum ether, and cyclohexane (1:1:1, v/v/v) was added, and the mixture was allowed to sit for at least 10 hours. The mixture was extracted by the ultrasonic oscillator for 30 min, and the supernatant was decanted after the mixture was centrifuged at 2,000 rpm for 10 min. The supernatant was then collected. The precipitate was extracted 3 times using the extracting reagent. All the supernatant was put into K-D concentrator, with 70 °C water bath until volume decreased to 1 ml.

Glass fiber, 4 g of silica gel (water content 5%), and 4 g of anhydrous sodium sulfate were filled into the glass chromatography column (150 mm x 10 mm) sequentially. The chromatography column was eluted with 10 ml of cyclohexane to remove organic impurities. The concentrated sample was transferred into the chromatography column and eluted with 20 ml cyclohexane continuously. The resultant eluent was collected and put into a K–D concentrator and concentrated to dry. Lastly, 0.5 ml of benzene was added as the solvent and stored for HPLC analysis.

The extracts were analyzed with Agilent Eclipse XDB-C18 (250.0 mm × 4.6 mm, 5 µm) at column temperature 25 °C. The injection volume was 20 µl. The ratio of methanol increased from 60–100% during the first 20 min, and stayed 100% during the second 20-min interval, with detected wavelength

TABLE 1

Concentrations of Polycyclic Aromatic Hydrocarbons (PAHs) in Soils Among Different Areas (µg/kg)

PAH Name	Rings	Farmland A		Farmland B		Farmland C	
		$\bar{x}$	*s*	$\bar{x}$	*s*	$\bar{x}$	*s*
NAP	2	3.3	1.4	12.5	5.3	5.4	1.9
ACY	3	67.4	21.1	119.4	30.8	44.1	11.6
FLU	3	3.1	1.2	152.5	45.9	3.9	1.6
PHE	3	65.2	35.3	49.5	20.2	14.2	5.6
ACE	3	19.8	4.7	172.5	50.3	6.5	3.1
ANT	3	18.1	6.2	13.8	4.7	ND	ND
BaA	4	37.4	12.1	12.2	3.2	2.6	1.1
CHR	4	16.8	5.3	11.9	3.5	3.9	1.3
FLA	4	37.5	12.9	7.7	2.8	4.2	1.5
PYR	4	88.7	22.6	77.2	24.1	13.8	3.2
BaP	5	19.5	4.8	8.3	3.7	5.7	2.1
DahA	5	417.8	92.9	134.6	30.8	46.6	12.9
BbF	5	53.6	18.9	19.6	6.2	4.9	2.1
BkF	5	12.9	5.1	23.2	6.8	12.7	3.6
BghiP	6	171.2	41.4	436.3	90.7	13.5	4.3
IcdP	6	13.9	3.2	56.9	9.5	7.1	2.7
ΣPAHs	–	1,046.2	–	1,308.1	–	189.1	–

NAP = naphthalene; ACY = acenaphthylene; FLU = fluorine; PHE = phenanthrene; ACE = acenaphthene; ANT = anthracene; BaA = benzo[a]anthracene; CHR = chrysene; FLA = fluoranthene; PYR = pyrene; BaP = benzo[a]pyrene; DahA = dibenz[a,h]anthracene; BbF = benzo[b]fluoranthene; BkF = benzo[k]fluoranthene; BghiP = benzo[g,h,i]perylene; IcdP = indeno[1,2,3-cd]pyrene; ND = not detected.

254 nm, flow rate at 1 ml/min. The wavelength of the fluorescence detector was Ex 340 nm, Em 425 nm.

Quality control was carried out according to the method by Ma and coauthors (2011), with slight modification. Soil samples were extracted repeatedly. The extracts were first dried and used as the soil matrix. Then 10 soil matrices were extracted, purified using the aforementioned method, and analyzed by HPLC. Limit of detection for this group was set at 3 times the standard deviation. The results showed that for 16 PAHs, the minimum detection limit was 0.01–0.16 µg/kg. Then, seven soil matrices were taken, and a mixture of the standard samples of 16 PAHs was added. The new mixture was extracted, purified using the aforementioned method, and analyzed by HPLC. Finally, the recovery and relative standard deviation were calculated for this group. We found that the average recovery of the 16 PAHs group was 85–110.2% and relative standard deviation was 2.6–5.1%, showing that the result meets the requirements of PAH trace analysis.

Results and Discussion

PAH Contamination Levels in Soils

The concentration of 16 PAHs detected and their total PAH contents (∑PAHs) are presented in Table 1. It can be seen that the PAH concentrations of wastewater-irrigated farmlands were significantly higher than that found in the control area. Sixteen kinds of PAHs were observed in Farmland A, and the ∑PAHs was 1,046.2 µg/kg. Sixteen kinds of PAHs were observed in Farmland B, with ∑PAHs of 1,308.1 µg/kg. Fifteen kinds of PAHs were present in Farmland C, and the ∑PAHs was 189.1 µg/kg. Edwards (1983) found that the level of endogenous PAHs in the soil should be around 1–10 µg/kg, and they mainly come from the degradation of vegetation and natural fire. It can, therefore, be inferred that the PAH concentrations observed in this research were above normal natural values, and the soil under investigation was affected by human behavior.

Presently no uniform standard for the evaluation of PAHs in soils exists. To evaluate the contamination level of PAHs, this study used the criterion proposed by Maliszewska-Kordybach (1996), which is widely used and referenced. Maliszewska-Kordybach classified the contamination of PAHs in soils into four levels according to the PAH content in soil in Europe: no contamination (<200 µg/kg), slight contamination (200–600 µg/kg), moderate contamination (600–1,000 µg/kg), and heavy contamination (>1,000 µg/kg). According to this classification, the PAH content in Farmlands A and B both reached a level of heavy contamination, and the control area can be classified as a level of no contamination.

Studies on residual concentrations of PAHs in soil in some cities show that different cities and different regions display very different residual concentrations. PAH content in Fuzhou, China, is 100.2–1,215.1 µg/kg (Han, Yang, Yang, & Ni, 2008); in Cixi, Zhejiang, it is 70.4–325.0 µg/kg (Li et al., 2007); in Hong Kong it is 21.1–544.0 µg/kg (Chung, Hu, Cheung, & Wong, 2007); and in South Korea it is 23.3–2,834 µg/kg with a mean of 236 µg/kg (Nam, Song, Eom, Lee, & Smith, 2003). Compared with these regions, the soil investigated in this research showed a very high level of PAHs. The concentration of PAHs near typical farmlands irrigated by wastewater exceeds previous values found by other researchers elsewhere. Urgent attention and further investigation should be focused on PAHs in wastewater-irrigated farmlands.

Distribution Characteristics of PAH Rings

The environmental behavior of PAHs is related to their chemical and physical properties (Douben, 2003; Luo, Liu, & He, 2014).

PAHs can be divided into two categories according to their physical and chemical properties, namely low molecular weight aromatic benzene with 2–3 rings and high molecular weight aromatic hydrocarbons with 4–6 phenyl rings. Low molecular weight

TABLE 2

Grading Standard for Soil Contamination

Pollution Index (P_i or P_n)	Pollution Grade
P ≤0.7	Clean
0.7≤ P <1	Warning limit
1≤ P <2	Slight pollution
2≤ P <3	Moderate pollution
P >3	Heavy pollution

TABLE 3

Single-Factor Index and Nemerow Comprehensive Index for Polycyclic Aromatic Hydrocarbons in Different Sampling Areas

Sampling Area	Single-Factor Index (P_i)								Nemerow Comprehensive Index (P_n)
	NAP	PHE	PYR	BaA	BbF	BaP	DahA	BghiP	
Farmland A	0.03	0.65	0.89	0.37	0.54	0.20	4.18	1.81	3.05
Farmland B	0.13	0.50	0.77	0.12	0.20	0.08	1.35	4.36	3.16
Farmland C	0.05	0.14	0.14	0.03	0.05	0.06	0.48	0.13	0.34

NAP = naphthalene; PHE = phenanthrene; PYR = pyrene; BaA = benzo[a]anthracene; BbF = benzo[b]fluoranthene; BaP = benzo[a]pyrene; DahA = dibenz[a,h]anthracene; BghiP = benzo[g,h,i]perylene.

PAHs have low boiling points. They are volatile and their distribution is affected by environmental factors (air movement, temperature, and lighting). Such low molecular weight PAHs show acute toxicity. On the contrary, high molecular weight PAHs have high boiling points and are less volatile. They tend to remain in the soil and many such PAHs are carcinogenic, muagenic, and teratogenic (Chen & Liao, 2006; Douben, 2003).

In this research, analysis of the results show that PAHs in the wastewater-irrigated areas mainly consist of 4–6 rings. We found fewer 2–3 rings. High-ring PAHs contents were 83.1% and 60.2% for Farmlands A and B, respectively.

Past studies show similar results on the concentration of PAHs in soil. Li and coauthors (2007) investigated the spatial distribution and sources of PAHs in soils from typical oil-sewage irrigation areas in Northeast China and found out that 47% of the PAHs present were 4-ring PAHs. Ge and coauthors (2005) analyzed the wastewater-irrigated soil near a steel mill; the detection rate of PAHs was 100% and mainly consisted of 4-ring and higher PAHs. Such high dominance of higher-ring PAHs in soil was also observed by Peng and coauthors (2011). They studied PAHs in the urban soil of Beijing and found that 4–6 ring PAHs accounted for 83% of the total PAH content of the soil.

Our results echo these findings and further show that wastewater-irrigated soils have mainly 4-ring and above PAHs. These higher-ring PAHs are highly carcinogenic, teratogenic, and mutagenic. Our research suggests that in developing national standards and guidelines, the relevant authority could place an initial control and limits over the allowable concentration of 4-ring and above PAHs in the soil. This suggested process can be the most effective way to monitor PAHs in soil, as the majority of the PAHs will be regulated and therefore most harm could be potentially reduced.

Evaluation of Ecological Risk of PAHs

This research used the single-factor index method and Nemerow index comprehensive method to evaluate the ecological risk of PAHs. Single-factor index method can effectively reflect the degree of individual contaminant and is often used to evaluate the level of contamination of one specific pollutant. The mathematical expression is as follows:

$$P_i = \frac{C_i}{S_i}$$

where P_i is the single-factor index of one specific pollutant i, C_i is the value of pollutant i as measured, and S_i is the evaluation standard value for pollutant i.

When evaluating the effect of combined contamination of several pollutants, single-factor index method is combined with comprehensive index method to determine the level of contamination. Nemerow comprehensive index method is widely used in the evaluation of PAH contamination. Its mathematical expression is:

$$P_n = \sqrt{\frac{P_{max}^2 + P_{sav}^2}{2}}$$

where P_n is the Nemerow comprehensive pollution index, P_{max} is the maximum value in the single-factor pollution index, and P_{sav} is the average value in the single-factor pollution index. It can be seen from the formula that for the Nemerow compresensive index method, the pollutant with the highest single-factor index is considered favorably in the computation of P_n, therefore reflecting the degree of pollution with the severity of the most dominant pollutant. The grading standards for both single-factor index and Nemerow index are presented in Table 2.

As there are no uniform standard values for the evaluation of PAHs in soil, this study used the standard value for PAH management for agricultural soils in the Netherlands (Annokkée, 1990). This method is straightforward, relatively widely used, and generally accepted. The indicators include NAP, PHE, PYR, BaA, BbF, BaP, DahA, and BghiP. Their standard values are all 100 µg/kg. The single-factor index and Nemerow comprehensive index for PAHs in different sampling areas are shown in Table 3.

Table 3 indicates that in the single-factor index, mainly PYR, DahA, and BghiP had a high pollution index. PYR, DahA, and BghiP in Farmland A were 0.89, 4.18, and 1.81, respectively, reaching the warning limit of pollution grade, moderate pollution, and slight pollution, respectively; PYR, DahA, and BghiP in Farmland B were 0.77, 1.35, and 4.36, respectively, reaching the warning limit, slight pollution, and heavy pollution level, respectively. Other indicators of single-factor index were less than 0.7, belonging to the clean grade. Farmland C had a single-factor index less than 0.7, belonging to the clean grade.

PYR, DahA, and BghiP have 4-, 5-, and 6-rings, respectively, and they are all highly carcinogenic, teratogenic, and mutagenic. Our research shows that the wastewater-irrigated soil contains these toxic properties, which is confirmed by the results discussed earlier.

The Nemerow comprehensive index shows that P_n in Farmlands A and B were 3.05 and 3.16, respectively, graded as heavy pollution. P_n in Farmland C was 0.34, graded as clean limit. This result is consistent with the evaluation of the ∑PAHs according to Maliszewska-Kordybach (1996). These results indicate that soils in wastewater-irrigated soil are under ecological risk—mainly the risk of carcinogenic, teratogenic, and mutagenic effects.

Conclusion

The PAH concentrations detected in wastewater-irrigated areas were significantly higher than PAH concentrations found in the control area: ∑PAHs were 1,046.2 µg/kg and 1,308.1 µg/kg for Farmlands A and B, respectively, reaching a level of heavy pollution. Based on the distribution characteristics of numbers of rings of PAHs, wastewater-irrigated soil contains mainly higher-ring PAHs (4 and above). They are strongly carcinogenic, teratogenic, and mutagenic.

The ecological risk assessment showed that in wastewater-irrigated soil, the PAHs exceeding the standard value are mainly PYR, DahA, and BghiP, whose Nemerow comprehensive indices are greater than 3, reaching a level of heavy pollution. This finding indicated that there is an ecological risk of wastewater irrigation of agricultural soil. Given the ecological risks associated with PAHs in wastewater-irrigated soils, the management of agricultural irrigation water quality should be urgently strengthened and standard limits for PAHs for different types of soil should be developed as soon as possible in order to facilitate the monitoring, prevention, and remediation of contamination in soil. Our research methods, including the evaluation criteria of using single-factor index and Nemerow comprehensive index, could be a potential reference for developing guidelines and standards on PAH control in wastewater-irrigated soil.

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