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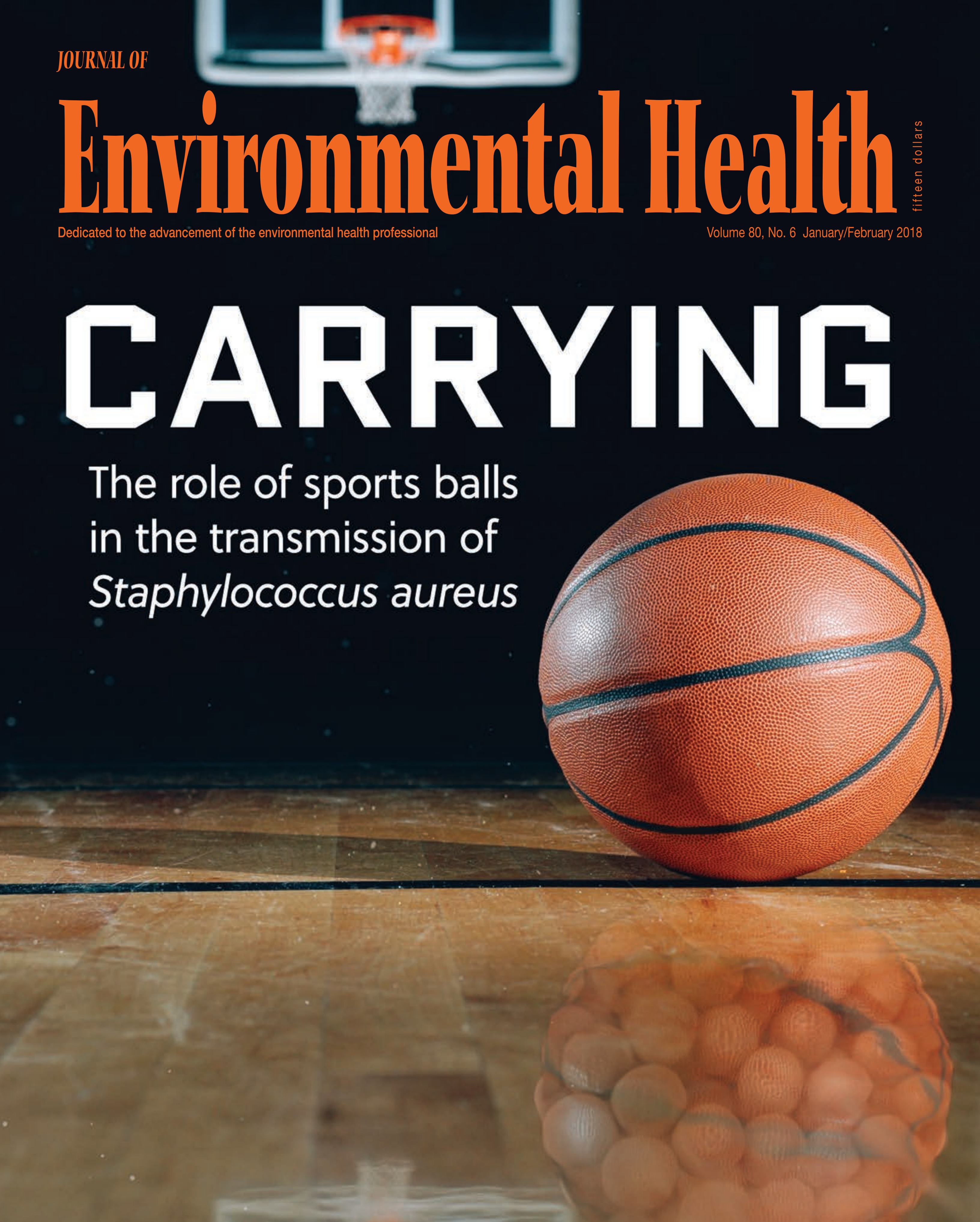

CARRYING

The role of sports balls in the transmission of *Staphylococcus aureus*

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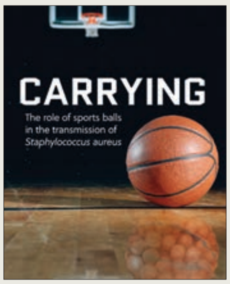

Carrying: to support and move (someone or something) from one place to another; a violation in the game of basketball that occurs when the dribbling player continues to dribble after allowing the ball to come to rest in one or both hands. Considering this issue's cover article, "The Sports Ball as a Fomite for the Transmission of *Staphylococcus aureus*," carrying was an excellent word to represent the context and findings of the article. The study described in the article explores the prevalence and transmissibility of *S. aureus* in three surfaces commonly encountered in the gymnasium setting: the court floor, the sports ball, and the athlete's hands. The study demonstrates the significance of the sports ball as a vector for pathogen transmission and advocates for interventions aimed at reducing athletic outbreaks to include routine disinfection of sports balls during and after play.

See page 8.

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Ozark River Portable Sinks® Kicks Off Their 2017/18 Hardship & Hope Program

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Ozark River Portable Sinks kicked off their 2017/18 Hardship & Hope Program at the 2017 World Food Championships in November 2017 in Orange Beach, Alabama. Two recipients were selected and honored for their dedication to food safety and the focused attention to the importance of hand washing while serving or handling food.

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Ozark River Portable Sinks will continue receiving nominations for the 2017/18 Hardship and Hope annual give-back to businesses and civic organizations. They are sending a special invitation to all NEHA Members to participate in the nominations.

> *"This give-back program was born out of our business culture", said Martin Watts, CEO of Ozark River Portable Sinks. "We believe clean hands lead to healthier people and businesses, and everyone deserves that."*

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Right to Left: Chef Chris Sherrill, Braswell McMeans, Martin Watts, CEO of Ozark River Portable Sinks.

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Ozark River PORTABLE SINKS

PRESIDENT'S MESSAGE

Adam London,
MPA, RS, DAAS

Staying Great in the 21st Century

I frequently teach health and public administration courses as an adjunct professor at a couple local universities. As a conversation starter during one of my lectures, I ask my students, "What do you think was the greatest achievement of the 20th century?" As you can imagine, they have suggested countless accomplishments ranging from the obvious (space exploration, flight, skyscrapers, television, and the Internet) to the less obvious (cartoons, microwave ovens, rock music, and video games). I had a student once tell the class that 30-minute pizza delivery was the greatest accomplishment. To my great surprise, the student supported this claim by arguing that it is the crowning glory of so many other innovations such as modern agriculture, telecommunications, transportation systems, GPS navigation, utility systems, and more. While there is, of course, no right or wrong answer to this question, I usually conclude the conversation with my students by sharing my opinion—separating people from their sewage was one of the greatest accomplishments of the last century.

The evolution of the environmental health profession has been greatly influenced by our nation's recognition that drinking water and food contaminated by microorganisms are bad things. This recognition would not have been possible without one of the greatest accomplishments of the 19th century: the germ theory of disease transmission. The average life expectancy at birth in 1900 was a mere 48 years. Of course, very few 48-year old Americans were dying at that time relative to other age segments of the population. Infant and maternal mortality rates were many times greater than they are now and gastrointestinal illnesses ranked high among the top 10 causes of mortality at that time. Other acute causes of death related to environmental health, such as occupational accidents, also ranked high. The epidemiology of those times motivated legislation and funding that would significantly boost the development of our profession.

> *We should welcome opportunities to demonstrate the ongoing value of environmental health in the 21st century.*

By the end of the 20th century, the average American lifespan had gained approximately 30 years. Most articles on this topic attribute the majority of those years of gained life to public health interventions. Separating people from their sewage saved and lengthened many more lives than moon landings, pizza deliveries, and most everything else combined.

This history is something we should consider as we plot a path forward. The development of legislation and funding required at least two things. First, it needed epidemiological data to demonstrate that a problem existed. Second, it required the science of germ theory, as described by Koch and others, to demonstrate causation. The recognition of causation eventually empowered the development of appropriate interventions. Once the problems and solutions were understood, nothing stood in the way of progress, right? Wrong. There was at least one other critical ingredient essential for separating people from their sewage: public will. Our health educator colleagues might suggest that this situation is all very similar to the health belief model of behavior. In sum, humans need to see that a problem is serious, that they are susceptible to it, and that they have the means to reduce its risk before they act differently.

The National Environmental Health Association respects and celebrates all the tremendous work that has been accomplished over the decades to keep people separated from their sewage. Millions of Americans have experienced longer, healthier lives thanks to you and your predecessors, and most will never know what was done on their behalf. This association also recognizes that maintaining a healthy separation between people and their sewage is always going to be a priority for our profession. To that end, I assure you that our training materials and products related to this issue will continue to improve. I also think it's important that we watch the epidemiology and developing theories regarding illness causation to identify new opportunities to serve our communities. As I am sure you know, cancer is one of the leading causes of death in the 21st century.

As I write this column, I am serving as the public health incident commander in response to developing knowledge of per- and polyfluoroalkyl substances contamination of groundwater in a rural/suburban township. Cancer is one of the health conditions associated with exposure to this family of chemicals. This contamination appears to have been caused in the 1950s, 1960s, and 1970s by the practice of dumping waste, including industrial waste, in unlined and largely unregulated landfills. Our local health department's response to this situation came shortly after unrelated emergency public health responses to problems with chemical vapors intruding into residential and commercial buildings. Those chemical vapors are part of the environmental legacy resulting from a long gone dry cleaning operation.

What is evident during these responses is that environmental health professionals are being expected to have answers and solutions to an expanding array of issues. It is also clear to me that many communities are recognizing the severity of these problems, they are feeling susceptible, and they are looking for solutions.

While we do not welcome these problems, we should welcome these opportunities to demonstrate the ongoing value of environmental health in the 21st century. By doing so, we can create the public will necessary to support future interventions. I encourage all of you to become familiar with these issues.

Let's begin a larger dialogue about the role of environmental health as it relates to cancer (and other illnesses and injuries) and exposure to persistent chemical waste products in the environment. Wouldn't it be great if reducing the incidence of illness by separating people from harmful industrial waste could be listed as one of the greatest accomplishments of this century? If that is going to happen, I am confident that you are going to be part of that success story.

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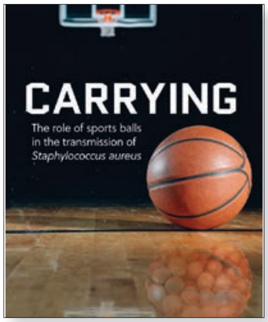

The Sports Ball as a Fomite for Transmission of *Staphylococcus aureus*

Brandon A. Haghverdian, MD
Hospital of the University of Pennsylvania

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Touro University College of Osteopathic Medicine in California

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Abstract **Outbreaks of methicillin-resistant *Staphylococcus aureus* (MRSA) are becoming increasingly frequent in the athletic community. Skin–fomite contact represents a putative mechanism for transmission of MRSA. The objective of this study was to demonstrate the prevalence and transmissibility of *S. aureus* in three surfaces commonly encountered in the gymnasium setting: the court floor, the sports ball, and the athlete's hands. Three sports scenarios were simulated by dribbling a sports ball within a designated area; the surfaces were cultured before and after play using media selective for *S. aureus*. There was significant transfer of *S. aureus* from the native, contaminated surface towards two disinfected surfaces. In a fourth experiment, survival of *S. aureus* on sports balls was evaluated over time. *S. aureus* was found to be viable on the ball for at least 72 hr. This study demonstrates the significance of the sports ball as a vector for pathogen transmission. Interventions aimed at reducing athletic outbreaks should therefore include routine disinfection of sports balls during and after play.**

Introduction

Methicillin-resistant *Staphylococcus aureus* (MRSA) has received growing attention because of its widespread prevalence and virulence in healthcare and sports environments (Cohen & Kurzrock, 2004). Community-associated MRSA (CA-MRSA) infections are commonly distinguished from other staphylococcal infections by the absence of predisposing patient risk factors or recent attendance at a healthcare institution. CA-MRSA infections are often aggressive, necrotizing, antibiotic-resistant, and sometimes fatal (Centers for Disease Control and Prevention, 2016). MRSA is genetically characterized by the presence of the arginine catabolic mobile element, the SCC*mec* IV gene complex, and the gene encoding Panton–Valentine leukocidin. The latter element is a recognized cytotoxic virulence factor implicated in a number of severe infections and necrotic cutaneous lesions (Lina et al., 1999).

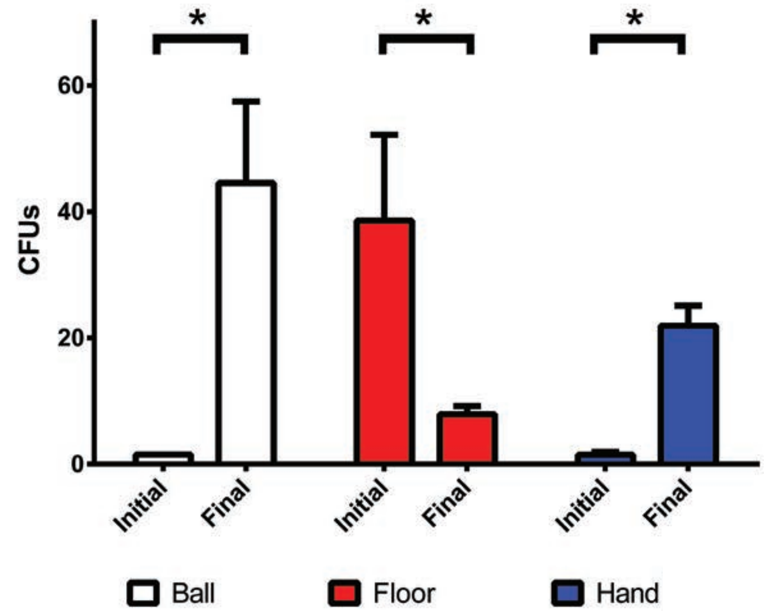
Athletes are at particular risk of skin infection due to a high degree of skin maceration (breaking down of skin resulting from prolonged exposure to moisture) and abrasive contact between players. Over one quarter of the academic literature concerning sports infections describes outbreaks of MRSA, suggesting a growing recognition of MRSA as an epidemic risk to players (Grosset-Janin, Nicolas, & Saraux, 2012). While the environmental prevalence of MRSA appears to vary widely between surfaces and institutions, athletic environments pose a considerable risk to active athletes and their trainers (Oller, Province, & Curless, 2010). In one study, nearly 90% of wrestling mats in rural high schools were found to harbor MRSA isolates (Stanforth, Krause, Starkey, & Ryan, 2010).

The first outbreak of MRSA infection in the athletic community was reported in 1998 (Stacey, Endersby, Chan, & Marples, 1998). Since then, numerous investigations of CA-MRSA outbreaks have been documented in participants of football, wrestling, rugby, soccer, and other sports (Turbeville, Cowan, & Greenfield, 2006). The financial, clinical, and emotional ramifications of these infections cannot be overemphasized; for example, in one professional U.S. football team, a total of 17 missed days of game or practice were accumulated due to a single outbreak (Kazakova et al., 2005).

Skin-to-skin contact among players with traumatic lesions or abscesses has tentatively emerged as the primary mechanism of CA-MRSA transmission between athletes, although equipment sharing and poor hygiene have also been implicated in the spread of contagions (Cohen, 2005; Turbeville et al., 2006). Regardless, the risk of CA-MRSA transmission through an intermediary fomite is not well understood (Benjamin, Nikore, & Takagishi, 2007). Given the relative uncertainty underlying the mechanisms of CA-MRSA transmission, we sought to investigate the role of the sports ball as a potential reservoir and vector in the communication of *S. aureus*.

FIGURE 1

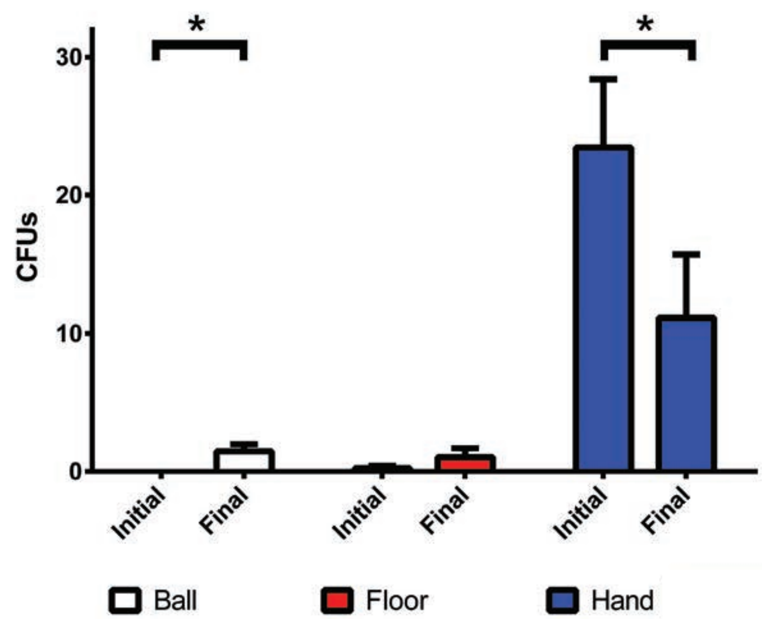
***Staphylococcus aureus* Transfer From Floor to Ball and Hand for Simulation #1**



*$p < .05$.

FIGURE 2

***Staphylococcus aureus* Transfer From Hand to Ball and Floor for Simulation #2**



*$p < .05$.

The purpose of this study is twofold: 1) to demonstrate the prevalence of *S. aureus* on sports balls circulating through a university gym that was open to student athletes, and 2) to establish that sports balls can act as vehicles for the transmission of *S. aureus* between the gym floor and athlete's hands. We elected to study the transmission of *S. aureus* as a model for CA-MRSA, as the greater environmental prevalence of *S. aureus* provides a more abundant reservoir from which large-scale microbial transmission can be studied. To our knowledge, this study is the first designed to explore in situ transmission between sports surfaces through simulated play. The elucidation of in-play transmission dynamics could be a vital factor in the design of future prevention efforts aimed at ameliorating infectious outbreaks in organized sports.

Methods

This study was conducted in the Anteater Recreation Center (ARC), the student gymnasium at the University of California, Irvine. All protocols were approved by the university institutional review board. The contact transfer of *S. aureus* between three surfaces—the gym floor, the sports ball, and the athlete's hands—was measured by means of simulated play in three different scenarios. In each scenario, two of the three surfaces were disinfected prior to play, while one was left in its native state. Each simulation was repeated 6 times with a basketball and 6 times with a volleyball for a total of 12 independent trials. In a fourth experiment, the viability of *S. aureus* on 6 sports balls was evaluated by serial cultures over a period of 72 hr.

Specimen Sampling

In each scenario, the following surfaces were sampled before and after play: the volar (or palm) surfaces of each hand, two random sites within a designated area of the gym floor, and two random sites on the sports ball. Sampling was carried out by means of contact "stamping" of the designated surface with an agar plate consisting of Baird-Parker agar (Hardy Diagnostics), a medium selective for *S. aureus*. All sample sites were subsequently marked to avoid sampling the same region twice in a single simulation. In each scenario, trials were excluded if either of the two disinfected surfaces cultured more than 10 CFUs

Sampled sports balls on disinfection stands. Photo courtesy of Brandon Haghverdian.

before play (as a means of controlling for inadequate pre-simulation disinfection).

Simulation #1: Transfer From Floor to Ball and Hand

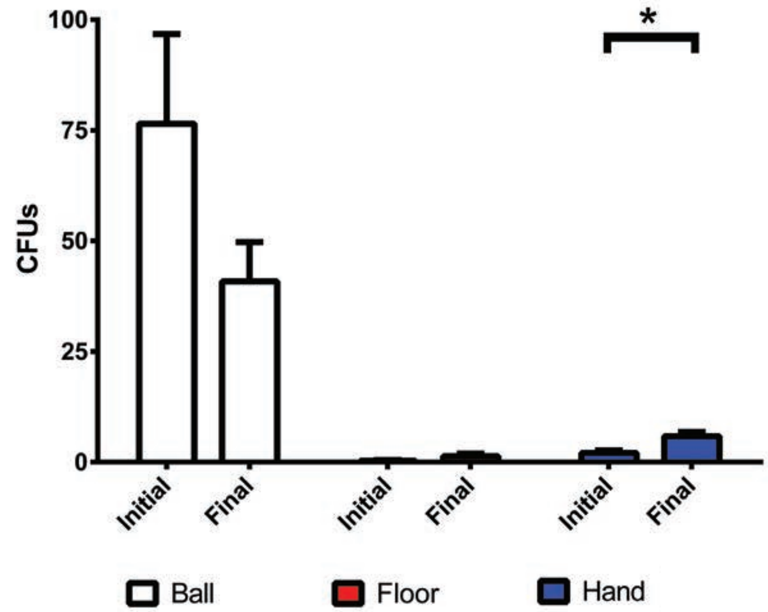
A 2 x 2 ft (0.6 x 0.6 m) zone within the free throw lane of an indoor basketball court was sectioned off immediately after a student basketball pick-up game (a spontaneous game as compared with a scheduled team game). The hands of a volunteer athlete were disinfected with commercial antimicrobial soap and warm water for 30 s. A leather basketball or volleyball, which was disinfected off site by 10 min of exposure to germicidal ultraviolet C (UV-C) light using a commercially available sports ball cleaner (GermNinja, Jaypro Sports), was handed to the player using a sterile surgical drape to avoid contamination. The participant was then instructed to stand stationary with his or her feet outside the designated area and dribble the ball inside the designated area for 5 min, alternating hands with each bounce.

Simulation #2: Transfer From Hand to Ball and Floor

Student athletes were recruited after at least 30 min of basketball or volleyball practice. A 2 x 2 ft (0.6 x 0.6 m) zone within the gym floor was sectioned off and disinfected using 70% ethyl alcohol. The floor was allowed to air dry for 10 min before simulated play. A leather basketball or volleyball, previously disinfected using UV-C light, was delivered to the participant using a sterile surgical drape to avoid contamination. The participant was then instructed to stand stationary with his or her feet outside the designated area and dribble the ball inside the designated area for 5 min, alternating hands with each bounce.

FIGURE **3**

***Staphylococcus aureus* Transfer From Ball to Floor and Hand for Simulation #3**



*$p < .05$.

Simulation #3: Transfer From Ball to Floor and Hand

A leather basketball or volleyball was checked out from the ARC's ball rental center within one hr following use in a student pick-up game. The hands of a volunteer athlete were disinfected with commercial antimicrobial soap and warm water for 30 s. A 2 x 2 ft (0.6 x 0.6 m) zone within the gym floor was sectioned off and disinfected using 70% ethyl alcohol. The floor was allowed to air dry for 10 min before simulated play. The participant was then instructed to stand stationary with his or her feet outside the designated area and dribble the ball inside the designated area for 5 min, alternating hands with each bounce.

Survival of *S. Aureus* on a Sports Ball

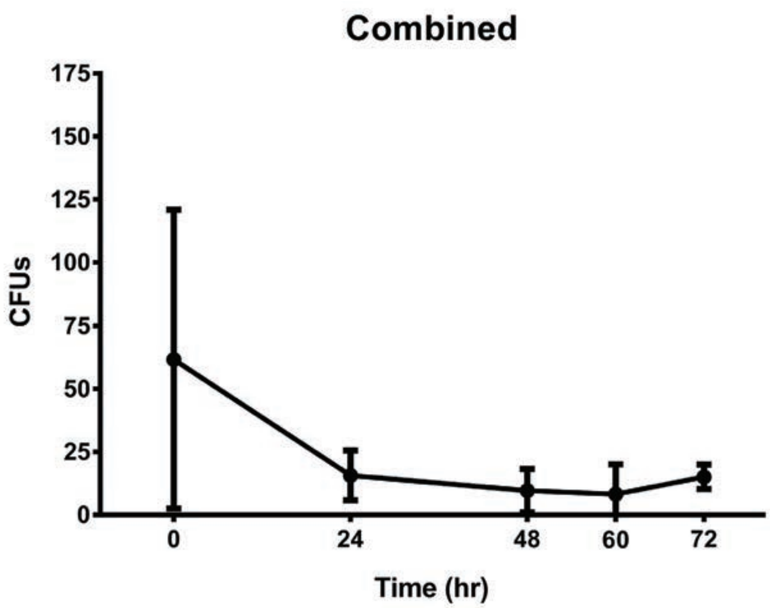
Three basketballs and three volleyballs were sequestered from the ARC's ball rental center within one hr following use in a student pick-up game. Each ball was sampled three times for the presence of *S. aureus*. The balls were then situated on disinfected stands in a ventilated equipment storage room adjacent to the ball rental center (see photo above). The sports balls were not disturbed and were not allowed to touch any other surface. Serial cultures were subsequently obtained at two locations in different regions of the ball at 24 hr, 48 hr, 60 hr (basketball only), and 72 hr. Ambient room temperature (20–25 ˚C) was maintained for the duration of the experiment.

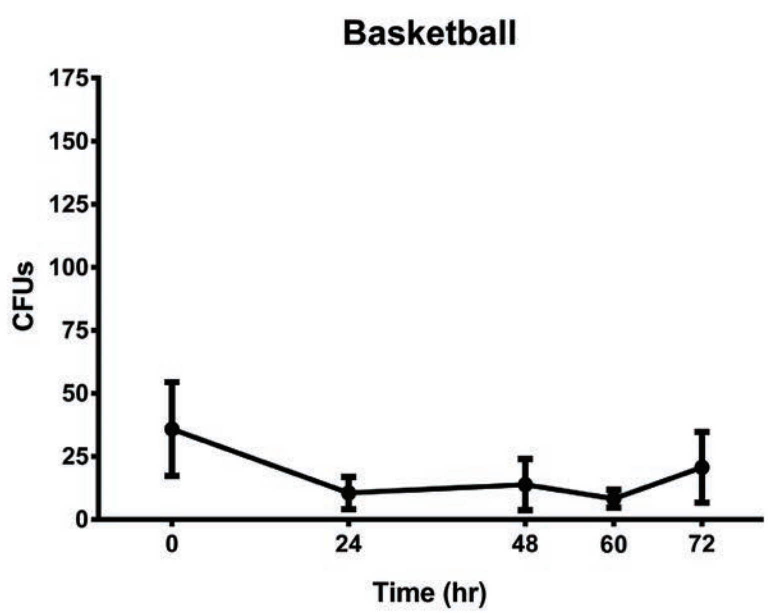
Specimen Incubation, Colony Identification, and Statistical Analysis

Culture plates used in sample collection were incubated aerobically using room air at 35 ˚C for 48 hr, consistent with manufacturer guidelines. The plates were checked for growth and counted by two different observers, with each individual observer counting the plate twice for accuracy. If the colony counts varied by more than 10% between observers, the plate was counted an additional time by a third observer; the three counts were then averaged. We assessed transmission between surfaces by comparing the average number of CFUs counted on the plate before and after play. Two-tailed, paired *t*-tests ($p < .05$) were used to statistically compare CFUs. Data were analyzed using IBM SPSS Statistics 23.

FIGURE **4**

Survival of *Staphylococcus aureus* on the Sampled Sports Balls





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Results

Simulation #1: Transfer From Floor to Ball and Hand

Two trials (one basketball, one volleyball) were excluded due to high CFU counts cultured on disinfected surfaces before play. The number of CFUs cultured from the floor significantly decreased following play, while the number of CFUs significantly increased in both the sports ball and the athlete's hand (Figure 1). The average change in CFUs following play was greatest in the sports ball (44.5 CFUs), followed by the floor (-32 CFUs), and the hand (20 CFUs). Interestingly, the average change in CFUs in the hand was significantly greater following play with basketballs compared with volleyballs (basketball: 27.3 ± 9.3 CFUs; volleyball: 15.3 ± 10.0 CFUs; $p = .041$).

Simulation #2: Transfer From Hand to Ball and Floor

Two trials (one basketball, one volleyball) were excluded due to high CFU counts cultured on disinfected surfaces before play. The number of CFUs cultured from the athlete's hand significantly decreased after the simulation, whereas the number of CFUs significantly increased in the ball (Figure 2). There was no significant change in CFUs sampled from the floor after play, although both the pre- and post-simulation counts were relatively low when compared with the hand. The average change in CFUs following the simulation was greatest in the hand (-14 CFUs) compared with the sports ball (1.5 CFUs). The average change in CFUs in the sports ball was also significantly greater in the volleyball compared with the basketball (basketball: 0.5 ± 0.7 CFUs; volleyball: 2.1 ± 2.9 CFUs; $p = .043$), although the practical importance of this comparison likely is not substantial.

Simulation #3: Transfer From Ball to Floor and Hand

Three trials (two basketball, one volleyball) were excluded due to high CFU counts cultured on disinfected surfaces before play. There was a significant increase in CFUs cultured from the hand following the simulation, although there was no significant effect of play on either the sports ball or the floor (Figure 3). The average change in CFUs was greatest in the ball (-44 CFUs) compared with the floor

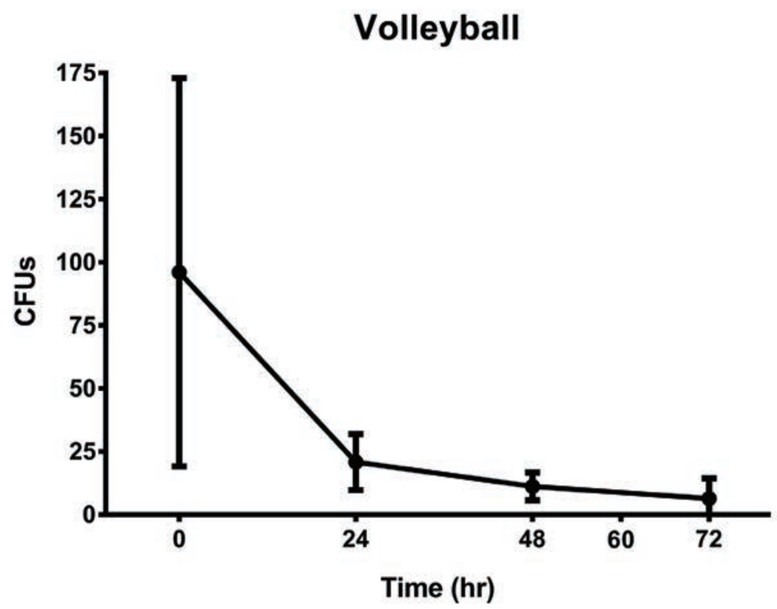
(1.6 CFUs) and the hand (4.8 CFUs). There were no significant differences between the volleyball or the basketball with respect to colony transmission before and after play.

Survival of *S. aureus* on a Sports Ball

Six standard rental basketballs and volleyballs were serially cultured over a period of 72 hr. Baseline cultures (time = 0 hr) yielded significantly more CFUs on the volleyball than on the basketball (volleyball: 96 ± 76.9 CFUs; basketball: 35.9 ± 19.4 CFUs; $p = .02$). Although cultures on both the basketball and volleyball decreased over the ensuing time points (time = 24, 48, 60, 72 hr), none of these cultures differed significantly compared with baseline (Figure 4). At the final time point (time = 72 hr), the average number of CFUs did not differ significantly between the volleyball and basketball (volleyball: 9.5 ± 7.9 CFUs; basketball: 20.7 ± 14.0 CFUs; $p = .29$).

FIGURE **4** *continued*

Survival of *Staphylococcus aureus* on the Sampled Sports Balls



Discussion

This study set out to demonstrate both the prevalence and transmissibility of *S. aureus* on sports surfaces commonly encountered in a university recreation center. Our results successfully affirmed both characteristics in several ways. First, in each of the three play scenarios, one surface was left in its native state (e.g., not disinfected). This surface was subsequently found to culture a substantial amount of *S. aureus* before any play took place, establishing a baseline prevalence of *S. aureus* on each of the tested sites. Following play, we demonstrated a transmission of bacteria away from the native surface and towards the remaining two interactive surfaces. For instance, in simulation #1, bacteria were found to transfer from the floor (the native surface) to the ball and hands (the previously disinfected surfaces).

Moreover, our study demonstrated the viability of *S. aureus* on sequestered sports balls for 72 hr. Although the population of bacteria declined substantially in this time frame, it was not eradicated. Our results are consistent with prior work demonstrating persistent survival of *S. aureus* for up to 12 days on inanimate surfaces (Boa, Rahube, Fremaux, Levett, & Yost, 2013). Rotation of the balls out of circulation and away from handling is therefore insufficient to fully eliminate the organisms subsisting on sports balls. It has been the experience and observation of the authors that, whereas weight rooms are typically equipped with disinfectant cleaners for use by patrons, the same materials are not supplied to the athletes seeking to rent sports balls.

Nonporous materials like sports balls and gym floors have a greater capacity to transfer CA-MRSA on contact, increasing the risk of spread in both the athlete and the casual gym-goer alike (Stanforth et al., 2010). As such, interventional programs have emerged to reduce transmission of CA-MRSA in the athletic community (Sanders, 2009). Interventional programs have proved to be efficacious and cost-effective by targeting the conditions that promote bacterial spread including contact, contaminated surfaces, and lack of cleanliness. Moreover, the combined cost of secondary, tertiary, and rehabilitative care for a single episode of CA-MRSA can total several hundreds of thousands of dollars (O'Laughlin & Cook, 2009). By comparison, the cost of a realistic, practical prevention program for an athletic team likely amounts to less than $50 (O'Laughlin & Cook, 2009).

Based on this study's results, the sports ball is an important vector for transmission of infectious organisms between the athlete's hands and the gym floor. While efforts are being made to improve sanitation for the athlete, to our knowledge there are few programs that routinely disinfect sports balls that players use (Fritz et al., 2012). It is conceivable that the addition of such an intervention would add minimal cost to the facility and require nominal staff involvement. Frequent disinfection of sports balls, and intermittent removal from circulation for at least 24 hr, might reduce the incidence of infectious outbreaks in athletic teams.

This study was limited in several respects. First, the media used to culture the gym surfaces was selective for *S. aureus* but not MRSA. This was intentionally done to maximize culture yield and, in turn, better study the transmissibility of *S. aureus*. As a result, little can be concluded from our study regarding the prevalence of CA-MRSA in the gym, although prior efforts have successfully demonstrated the existence of MRSA on a variety of athletic surfaces (Kazakova et al., 2005; Stanforth et al., 2010). It is also likely that the physical transmission characteristics of antibiotic-susceptible *S. aureus* are similar to CA-MRSA. Second, only two sites were sampled from each athletic surface before and after play. The resultant sampling error could account for some of the variability in culture yield, but is unlikely to discount the consistent transmission trends observed across the play simulations.

Conclusion

Over the last 20 years, the role of the nonclinical environment in transmission of MRSA has become increasingly recognized (Cohen & Kurzrock, 2004; Kassem, 2011). The community strain of MRSA, in particular USA 300, now accounts for between 8–20% of hospital-reported MRSA infections (McKenna, 2008). The consequences of skin–fomite contact are gaining attention, and this type of contact likely accounts for a significant proportion of CA-MRSA outbreaks, especially in the athletic setting (Miller & Diep, 2008). Our study demonstrated the prevalence of *S. aureus* on various athletic surfaces, as well as the effect of sports play in the transmission of pathogens from one surface to another. The sports ball, in particular, was identified as a principal vector for transmission between athlete hands and the gym floor. Future efforts to reduce the incidence of infectious sports epidemics should therefore include interventions with routine disinfection of the sports ball during and following play.

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References

Benjamin, H.J., Nikore, V., & Takagishi, J. (2007). Practical management: Community-associated methicillin-resistant *Staphylococcus aureus* (CA-MRSA): The latest sports epidemic. *Clinical Journal of Sport Medicine*, *17*(5), 393–397.

Boa, T.T., Rahube, T.O., Fremaux, B., Levett, P.N., & Yost, C.K. (2013). Prevalence of methicillin-resistant staphylococci species isolated from computer keyboards located in secondary and post-secondary schools. *Journal of Environmental Health*, *75*(6), 50–58.

Centers for Disease Control and Prevention. (2016). *Methicillin-resistant* Staphylococcus aureus *(MRSA)*. Retrieved from http://www.cdc.gov/mrsa/index.html

Cohen, P.R. (2005). Cutaneous community-acquired methicillin-resistant *Staphylococcus aureus* infection in participants of athletic activities. *Southern Medical Journal*, *98*(6), 596–602.

Cohen, P.R., & Kurzrock, R. (2004). Community-acquired methicillin-resistant *Staphylococcus aureus* skin infection: An emerging clinical problem. *Journal of the American Academy of Dermatology*, *50*(2), 277–280.

Fritz, S.A., Long, M., Gaebelein, C.J., Martin, M.S., Hogan, P.G., & Yetter, J. (2012). Practices and procedures to prevent the transmission of skin and soft tissue infections in high school athletes. *The Journal of School Nursing*, *28*(5), 389–396.

Grosset-Janin, A., Nicolas, X., & Saraux, A. (2012). Sport and infectious risk: A systematic review of the literature over 20 years. *Médecine et Maladies Infectieuses*, *42*(11), 533–544.

Kassem, I.I. (2011). Chinks in the armor: The role of the nonclinical environment in the transmission of *Staphylococcus* bacteria. *American Journal of Infection Control*, *39*(7), 539–541.

Kazakova, S.V., Hageman, J.C., Matava, M., Srinivasan, A., Phelan, L., Garfinkel, B., . . . Jernigan, D.B. (2005). A clone of methicillin-resistant *Staphylococcus aureus* among professional football players. *The New England Journal of Medicine*, *352*(5), 468–475.

Lina, G., Piémont, Y., Godail-Gamot, F., Bes, M., Peter, M.O., Gauduchon, V., . . . Etienne, J. (1999). Involvement of Panton–Valentine leukocidin-producing *Staphylococcus aureus* in primary skin infections and pneumonia. *Clinical Infectious Diseases*, *29*(5), 1128–1132.

McKenna, M. (2008). The many faces of MRSA: Community-acquired infection knows no bounds. *Annals of Emergency Medicine*, *51*(3), 285–288.

Miller, L.G., & Diep, B.A. (2008). Clinical practice: Colonization, fomites, and virulence: Rethinking the pathogenesis of community-associated methicillin-resistant *Staphylococcus aureus* infection. *Clinical Infectious Diseases*, *46*(5), 752–760.

O'Laughlin, D.M., & Cook, J. (2009). Financial analysis of methicillin-resistant *Staphylococcus aureus* in a high school wrestler. *Pediatric Nursing*, *35*(2), 130–136.

Oller, A.R., Province, L., & Curless, B. (2010). *Staphylococcus aureus* recovery from environmental and human locations in 2 collegiate athletic teams. *Journal of Athletic Training*, *45*(3), 222–229.

Sanders, J.C. (2009). Reducing MRSA infections in college student athletes: Implementation of a prevention program. *Journal of Community Health Nursing*, *26*(4), 161–172.

Stacey, A.R., Endersby, K.E., Chan, P.C., & Marples, R.R. (1998). An outbreak of methicillin resistant *Staphylococcus aureus* infection in a rugby football team. *British Journal of Sports Medicine*, *32*(2), 153–154.

Stanforth, B., Krause, A., Starkey, C., & Ryan, T.J. (2010). Prevalence of community-associated methicillin-resistant *Staphylococcus aureus* in high school wrestling environments. *Journal of Environmental Health*, *72*(6), 12–16.

Turbeville, S.D., Cowan, L.D., & Greenfield, R.A. (2006). Infectious disease outbreaks in competitive sports: A review of the literature. *The American Journal of Sports Medicine*, *34*(11), 1860–1865.

Analysis of Food Service Operation Risk Classification and Associated Food Safety Violation Frequency

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Abstract **Though local health department performance of restaurant inspections plays an important role in preventing foodborne illness, restaurant inspection quality and uniformity often varies across local health department jurisdictions and among employees. In 2012, the Cincinnati Health Department initiated a food safety staff quality improvement initiative. This initiative, part of a Food and Drug Administration national training standards grant initiative, featured standardized training and food safety workforce practices, defined food safety program data collection standards, and refined reporting protocols. The aim of this article was to explore the relationship between the Ohio food safety code violations incurred and the risk classifications to which a Cincinnati food service operation belongs (ranked I–IV based upon potential threat to public safety). A random intercept model was selected to quantify the difference in odds between risk classification categories of incurring violations. Additionally, longitudinal data analysis tracked violation trends across the three years of the study. Main findings were 1) the odds of receiving a food safety violation increased with each year and 2) food establishments categorized as risk class IV had a higher odds of receiving a food safety violation compared with the other risk classifications.**

Introduction

Within the U.S., the retail food industry serves an estimated 70 billion meals annually and nearly 50 million people in the U.S. are diagnosed with a foodborne illness over that same period of time, approximately 50–70% of which can be attributed to failures in food service operation (FSO) safety (Fraser & Nummer, 2010; Mathe, 2012). Infections by enteric pathogens result in thousands of deaths and hospitalizations per year, making food safety a prominent challenge that requires the concerted attention of multiple public health entities (Centers for Disease Control and Prevention [CDC], 2015). State and local health departments typically play the largest role in actively enforcing compliance with safe food-handling practices via licensing and inspection programs. Federal agencies, however, such as the Food and Drug Administration (FDA) are likewise responsible for public health through regulatory action and the establishment of national standards and models that local health departments may wish to adopt (Bekemeier, Yip, Dunbar, Whitman, & Kwan-Gett, 2015).

In an effort to meet FDA Voluntary National Retail Food Regulatory Program Standards (VNRFRPS), the Cincinnati Health Department (CHD) in 2012 instituted a staff training program for improving food safety within restaurant operations under its jurisdiction (National Environmental Health Association, 2007). The VNRFRPS initiative encourages use of a continuous improvement system for participating health departments by cooperating with state and local partners and offering a basic framework upon which a modernized food safety program can be built (Food and Drug Administration, 2015). To improve on VNRFRPS Standard 2 “Trained Regulatory Staff,” CHD field sanitarians met with a certified training officer to ensure adequate understanding of the Ohio Uniform Food Safety Code and its food protection plan (Sharkey, Alam, Mase, & Ying, 2012). Through homogenous staff training, the CHD sanitarian workforce is expected to have a more consistent methodology for conducting inspections of FSOs and other retail food establishments within the Cincinnati area (Kaml et al., 2013).

Sharkey and coauthors (2012) provide an assessment of the CHD’s food protection program prior to the implementation of the standardization process, specifically in regard to the Centers for Disease Control and Prevention (CDC) Foodborne Illness Risk Factors and their association with FSO risk classifications. The advantages of this article’s access

TABLE **1**

Ohio Safety Code Violation Types

Code #	Violation Description
3701.21-0	Display of food service operation license
3717.1-02	Management and personnel (employee health, personal cleanliness, hygienic practices, etc.)
3717.1-03	Food (sources, protection from contamination, destruction of organisms, etc.)
3717.1-04	Equipment, utensils, and linens (location and installation, maintenance and operation, etc.)
3717.1-05	Water, plumbing, and waste (sewage, other liquid wastes, refuse, etc.)
3717.1-06	Physical facilities (design, construction, installation, maintenance, etc.)
3717.1-07	Poisonous or toxic materials (labeling and identification, operational supplies, storage, etc.)
3717.1-08	Special requirements (fresh juice production, bulk water machine criteria, etc.)
3717.1-09	Criteria for reviewing facility layout and equipment specifications
3717.1-20	Existing facilities and equipment
3717.41	License required for food service operation
901	Embargo

to more recent data are threefold: 1) having records from 2013–2015 provides renewed insight into code violations following the implementation of CHD's standardized training program, 2) introduction of a time component allows for violation trend tracking and contributes valuable knowledge on how the inspection program has affected violation issuance over the course of the three yearly review cycles, and 3) separation of violation types is naturally more inclined toward specific investigation of which violations are most heavily associated with FSOs with certain characteristics. With that in mind, the chief objective of this analysis is to determine whether FSOs vary in their odds of incurring a food safety violation dependent upon risk classification in hopes of adding to the scientific literature that guides the decisions and practices of health department FSO inspecting staff.

Methods

Data Source

This analysis used FSO inspection data obtained from the CHD records for three separate review periods beginning July 2013 and ending June 2015. The inspection dataset itself contained relevant variables such as business name, inspector name, address, and census tract. The most notable variable of interest, however, pertained to the type of FSO safety violation issued. While there are several Ohio Uniform Food Safety Code categories (Table 1) such as water safety, personnel training, or equipment maintenance, this analysis was limited to an examination of food-related violations (3717.1-03) that encompass sourcing, protection from contamination, complete destruction of organisms, and the like.

The classification schema (Table 2) set forth by Ohio Administrative Code 3701-21-02.3 (Ohio Department of Health, 2010), which serves as an independent variable in the model, divides Cincinnati FSOs into four categories of increasing potential hazard to the public based upon the types of foods served and preparation methods employed. As risk classification is inherently defined by these factors, its inclusion as a covariate asks a reasonable question of interest: Are higher risk-class FSOs truly at greater risk of incurring a safety violation?

For the sake of longitudinal study regarding the trend of violation issuance across the three review cycles, the datasets were match-merged into a single document spanning the entire observation period. Without an individual restaurant identifier, address and business name were concatenated to create a unique variable and each instance was assigned an identification number by which violations could be compiled into a binary format. For each violation type, so long as a business was given a citation at least once that year, the variable was coded as 1. Those that had not received a citation for that specific violation during the year were otherwise coded as 0 (Table 3). Over the 3-year time span of 2012–2015, it was found that 2,191 unique Cincinnati FSOs underwent inspections. Not every FSO was inspected all three years, though, as businesses naturally may have opened and closed over the course of the data-gathering period (Table 4).

Data Analysis

Given that the response variable is binary in nature (violation versus no violation) and that the time variable can be considered continuous within the context of the data, multilevel modeling was applied to assess whether there was a significant difference in the instances of food-based violations being issued between the different risk class categories. Statistical analysis was conducted using the PROC GLIMMIX procedure in SAS version 9.3 in order to fit the most parsimonious model. Three mixed effects models were run: 1) random intercept, 2) random slope, and lastly, 3) random slope and intercept (Browne & Rasbash, 2004). The general forms of the models are as follows:

Model 1: Random Intercept

$$Y_{ij} = \beta_{0i} + \beta_1 t_{ij} + \epsilon_{ij}$$
$$\beta_{oi} = \beta_o + b_{0i}$$

Model 2: Random Slope

$$Y_{ij} = \beta_0 + \beta_{1i} t_{ij} + \epsilon_{ij}$$
$$\beta_{1i} = \beta_1 + b_{1i}$$

Model 3: Random Slope and Intercept

$$\begin{aligned} Y_{ij} &= \beta_{0i} + \beta_{1i} t_{ij} + \beta_2 Risk\ class + \epsilon_{ij} \\ &= \beta_0 + b_{oi} + (\beta_1 + b_{1i}) t_{ij} + \beta_2 Risk\ class + \epsilon_{ij} \\ &= \beta_0 + b_{oi} + \beta_1 t_{ij} + b_{1i} t_{ij} + \beta_2 Risk\ class + (\epsilon_{ij} + b_{oi}) \end{aligned}$$

Using the likelihood ratio test, the random intercept was found to be the best fit out of the three models (Table 5). This model fixes the predictive slope for each individual observation, but allows for variation in intercept between them to model the differences between risk classifications (Pinheiro & Bates, 2000).

Results

Statistical Analysis

The analysis reveals two key findings. First, time was found to be a significant factor in

TABLE **2**

Risk Class Descriptions

Risk Class	Definition	Food Examples	Food Service Operation (FSO) Examples*
I	Poses potential risk to the public in terms of sanitation, food labeling, sources of food, storage practices, or expiration dates.	• Coffee • Self-serve fountain drinks • Prepackaged non-TCS** foods	• Shell Food Mart • CVS Pharmacy • Family Dollar Store
II	Poses a higher potential risk to the public than risk level I because of hand contact or employee health concerns, but minimal possibility of pathogenic growth exists.	• Holding TCS foods at same temperature at reception	• Starbucks • Smoothie King • Bonomini Bakery
III	Poses a higher potential risk to the public than risk level II because of proper cooking temperatures, cooling procedures, contamination issues, etc.	• Hamburgers • Deli sandwiches • Ready-to-eat meats/cheeses	• Kroger • Little Caesar's • McDonald's • Jimmy John's Subs
IV	Poses a higher potential risk to the public than risk level III because of concerns associated with reheating, multiple temperature controls, high-risk clientele, etc.	• Soups • Sushi • Reheated foods • Catered foods • Food transported by FSOs	• Applebee's • IHOP • Kentucky Fried Chicken • Red Lobster • Subway

Source: http://codes.ohio.gov/oac/3701-21-02.3.
*It should be noted that not all FSOs of a particular franchise fall entirely into a single individual risk class category. The majority, however, often are primarily associated with one more than any other.
**TCS = temperature control for safety. TCS is the time and temperature control required to prevent growth of microorganisms.

TABLE **3**

Frequency of Food Service Operations With Violations and Nonviolations by Risk Class, July 2012–June 2015

Risk Class	Food Violation	No Food Violation
I	160	204
II	219	420
III	1,148	542
IV	1,661	319

TABLE **4**

Number of Food Service Operations (FSOs) by Review Cycle

Review Cycle	# of FSOs
July 2012–June 2013	1,592
July 2013–June 2014	1,608
July 2014–June 2015	1,641
Total unique	2,191

the model, with the odds of incurring a food-related safety violation increasing across the three review cycles (p = .0099). More precisely, the odds of receiving a violation in a more current review cycle compared to the last increases by 0.1193 (Table 6).

Second, referenced against risk class IV (the classification with the most potential risk), the odds of incurring a food-related safety violation is, in fact, lower for all other risk classifications I–III. Individually, the odds of receiving a violation in a risk class III FSO is compared with a risk class IV FSO is lower by 0.01478 (p < .0001). Risk class II compared with risk class IV yields a lower odds by 2.7236 (p < .0001) and risk class I compared with risk class IV is lower by 2.2103 (p < .0001).

Discussion

For both time and risk class, the results determined by the statistical analysis bring a number of noteworthy considerations to light. As was seen in the results, the odds of incurring a food-safety related violation increased across time. At a glance, one might conclude that Cincinnati FSOs, as a whole, are becoming less capable of adhering to food-handling protocols. Within the framework of CHD's newly adopted VNRFRPS initiative, however, a more plausible interpretation would suggest that the trained sanitarian is more adept at detecting food violations and, as a result, is issuing more citations with accuracy that reflects FDA standards. Of course, neither this article nor its analysis is capable of speaking comprehensively on the efficacy of CHD's new training program. Our analysis might, however, contribute toward understanding trends in the department's inspection practices post standardization (Waters et al., 2015).

With regard to the risk class findings, they are logically consistent with the health department's assignment of categories. Risk class IV is indeed experiencing a higher rate of violation incurrence compared with the other risk classes. An FSO that serves foods that pose a greater potential threat to the public inherently requires more stringent food-handling procedures, and CHD's sanitarian workforce is correct in maintaining greater attention to detail when inspecting risk class IV establishments.

As opposed to the use of a traditional regression model, which would require inclusion of several dummy variables to model differences between groups, the use of multilevel modeling in this analysis allowed for a more concise mathematical representation of the research question at hand. In addition to a favorable reduction in parameters, multilevel modeling serves as a framework for more convenient analysis of repeated measures. The combination of these advantages yields a conclusion that is more easily generalizable to wider populations.

Avenues for pursuing future research related to these data are numerous, as this article analyzes only food-related safety code

TABLE **5**

Model Comparison

Model	-2 Log L	*p*-Value
Intercept only	5,110.28	.0672
Trend only	5,113.82	.0087
Intercept and trend	5,106.93	–

TABLE **6**

Solutions for Fixed Effects

Effect	Estimate	*SE*	*df*	*t*-Value	Pr > |t|
Intercept	1.6726	0.1237	2,031	13.52	<.0001
Time	0.1193	0.0463	2,637	2.58	.0099
Risk class I	-2.2103	0.1666	2,637	-13.27	<.0001
Risk class II	-2.7236	0.1459	2,637	-18.66	<.0001
Risk class III	-0.0148	0.1051	2,637	-9.65	<.0001
Risk class IV	Reference	–	–	–	–

violations. Poor employee training, equipment maintenance, and the state of facilities are all culprits behind FSO-related foodborne illness. There is ample reason to believe that occurrence of any other Ohio Uniform Safety Code violation type could differ dependent upon risk class, temporal patterns, or even geographical disparities. Further exploration of FSO characteristics and how they might increase the incidence of unsafe food industry conditions provides scientific support for health departments to optimally allocate attention and resources to the food safety threats impacting the health of the public.

Conclusion

One of the primary functions of the U.S. local public health system is to assure safe conditions through the assurance function. As such, the responsibilities of the environmental health division within local public health departments are central to assuring a safe food supply. The potential for foodborne illness outbreaks poses a tremendous threat to the health of communities, the financial stability of community businesses, and to national security as demonstrated by past terrorist attacks whereby food supplies have been compromised. The importance of measurement within our local public health system demonstrates that through the quantification of daily operations, health departments can and do become increasingly enlightened as to what patterns and system-level operations are occurring. Ultimately, only by developing increased awareness of underlying patterns can better strategies be sought in order to maximally achieve overarching goals.

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References

Bekemeier, B., Yip, M.P., Dunbar, M.D., Whitman, G., & Kwan-Gett, T. (2015). Local health department food safety and sanitation expenditures and reductions in enteric disease, 2000–2010. *American Journal of Public Health*, *105*(Suppl. 2), S345–S352.

Browne, W., & Rasbash, J. (2004). Multilevel modelling. In M. Hardy & A. Bryman (Eds.), *Handbook of data analysis* (pp. 469–478). Thousand Oaks, CA: Sage Publications.

Centers for Disease Control and Prevention. (2015). *Surveillance for foodborne disease outbreaks, United States, 2013: Annual report.* Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention. Retrieved from https://www.cdc.gov/foodsafety/pdfs/foodborne-disease-outbreaks-annual-report-2013-508c.pdf

Food and Drug Administration. (2015). *Voluntary National Retail Food Regulatory Program Standards*. Retrieved from http://www.fda.gov/Food/GuidanceRegulation/RetailFoodProtection/ProgramStandards/ucm245409.htm

Fraser, A.M., & Nummer, B.A. (2010). Surveying the food safety training needs of environmental health specialists in the U.S. *Journal of Environmental Health*, *72*(8), 18–23.

Kaml, C., Fogarty, K.J., Wojtala, G., Dardick, W., Bateson, A., Bradsher, J.E., & Weiss, C.C. (2013). The development of standards-based national curriculum framework for regulatory food safety training in the United States. *Journal of Environmental Health*, *76*(2), 38–42.

Mathe, K. (2012). Food safety, labor costs, and the effects on quick service restaurant revenues. *Journal of Foodservice Business Research*, *15*(4), 398–410.

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References *continued from page 17*

National Environmental Health Association. (2007). FDA reports high enrollment in Voluntary National Retail Food Regulatory Program Standards. *Journal of Environmental Health*, *70*(1), 68.

Ohio Department of Health, Ohio Administrative Code, License Fees and Categories, 3701-21-02.1. (2010). Retrieved from http://codes.ohio.gov/oac/3701-21

Pinheiro, J.C., & Bates, D.M. (2000). *Mixed-effects models in S and S-PLUS*. New York, NY: Springer-Verlag.

Sharkey, K.W., Alam, M., Mase, W., & Ying, J. (2012). An investigation to determine association between foodborne illness and number of citations in a food establishment. *Journal of Environmental Health*, *75*(2), 8–11.

Waters, A.B., VanDerslice, J., Porucznik, C., Kim, J., Durrant, L., & DeLegge, R. (2015). The effect of follow-up inspections on critical violations identified during restaurant inspections. *Journal of Environmental Health*, *77*(10), 8–12.

Did You Know?

NEHA has recently launched a new credential! The Certified Foodborne Outbreak Investigator credential is for individuals who utilize environmental health principles and food safety knowledge in collaboration with outbreak response partners to assess foodborne illness risks. This credential will also prepare individuals to perform environmental assessments, identify contributing factors and antecedents, and implement control measures to prevent the spread of foodborne illness and protect the public. Learn more at www.neha.org/credentials.


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DRINKING WATER
Residential Point-of-Entry/ Point-of-Use Treatment Units
Municipal Treatment Chemicals
Distribution System Components
Plumbing and Devices

Predictors of Radon Testing Among Utah Residents Using a Theory-Based Approach

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Abstract **Exposure to radon continues to be a leading cause of lung cancer despite the availability of effective testing and mitigation options. This study examined differences in beliefs about radon testing among radon testers (n = 110) and a comparison sample of residents (n = 198) in Utah County, Utah, which is a high radon area. Structural equation modeling was used to analyze relationships between radon testing status and self-efficacy, knowledge, behavioral modeling, and risk perception. Risk perception (0.20, $p < .04$), self-efficacy (0.30, $p < .01$), and knowledge (0.40, $p < .001$) were positively associated with testing. Behavioral modeling was indirectly associated with testing through intervening pathways of self-efficacy ($z = 1.97$, $p < .05$) and knowledge ($z = 2.57$, $p = .01$). The results imply that increasing radon knowledge and self-efficacy, along with traditional intervention efforts focusing on risk perception, might be important factors to increase radon testing in residential areas.**

Introduction

Inhalation of radon (^{222}Rn) and its radioactive decay products (radon progeny) is associated with increased risk of developing lung cancer (Darby et al., 2005; Krewski et al., 2005). Worldwide, radon is the second leading cause of lung cancer behind smoking, accounting for 3–14% of all cases, depending on geographical location (World Health Organization [WHO], 2009). The dose-response relationship between radon and lung cancer is linear, where each increase in 100 Bq/m^3 (2.7 pCi/L) of air, measured as an individual's estimated residential exposure over several decades, is associated with approximately a 10% increase in lung cancer risk when controlling for smoking and other factors (Darby et al., 2005; Krewski et al., 2005, 2006; WHO, 2009).

With the exception of those with high occupational exposures, the residential environment is the most important source of radon exposure for the majority of people (Pershagen et al., 1994). Radon gas results from the radioactive decay of uranium (^{238}U) in soil. As a gas, radon can move through soil and infiltrate into homes through openings in foundation walls and floors. On average, people spend approximately 70% of their time indoors at home (Farrow, Taylor, & Golding, 1997). Furthermore, most residences in temperate and cold climates use recirculating heating and cooling systems, resulting in little fresh air exchange in the home (Yamamoto, Shendell, Winer, & Zhang, 2010). Low air exchange rates allow radon to concentrate indoors, increasing the potential for long-term exposure to ionizing radiation from the decay of radon and its progeny. Indoor radon levels can be reduced significantly using established mitigation methods (WHO, 2009); the only way to determine the presence and concentration of radon, however, is to test for it.

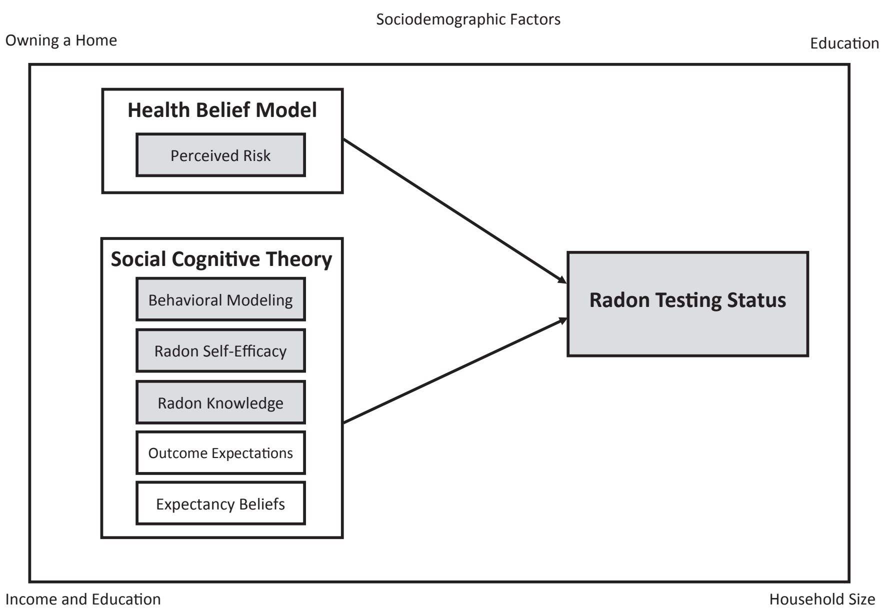
Despite the availability of effective mitigation strategies, reported testing rates often are below 25%, even in high radon areas (Duckworth, Frank-Stromborg, Oleckno, Duffy, & Burns, 2002; Kennedy, Probart, & Dorman, 1991; Larsson, Hill, Odom-Maryon, & Yu, 2009; Wang, Ju, Stark, & Teresi, 2000). Furthermore, not much is understood about the behavioral theory-based factors that influence radon testing. A few prior studies have explored relationships between individual risk perceptions and radon testing or intentions to test (Duckworth et al., 2002; Rinker, Hahn, & Rayens, 2014; Weinstein, Sandman, & Roberts, 1990, 1991). Additional knowledge of how other theory-based factors influence individual radon testing behaviors could help guide future interventions aimed at improving testing rates, warranting the need for more research in this area.

Theoretical Framework

We applied social cognitive theory (SCT) as the theoretical framework for this study (Bandura, 1986). Key SCT constructs included behavioral capability, self-efficacy, behavioral modeling, outcome expectations, and expectancy beliefs. We also incorporated risk perception from the Health Belief Model (HBM)

FIGURE 1

Theoretical and Analytic Framework



Note. Shaded boxes specify variables tested in the final model.

in order to evaluate relationships between multiple theoretical variables (Figure 1) (Janz & Becker, 1984; Rosenstock, 1974).

Behavioral capability refers to whether an individual possesses the knowledge and skills required to perform a behavior. Having general knowledge of radon shows up as a key prerequisite for testing in several previous studies (Halpern & Warner, 1994; Kennedy et al., 1991; Wang et al., 2000), and was used to measure behavioral capability in this study. Self-efficacy is defined as one's confidence to successfully perform a behavior. Studies show 30–39% of homeowners report "not knowing how" as one of the most common reasons for not testing for radon (Kennedy et al., 1991; Nissen, Leach, Nissen, Swenson, & Kehn, 2012). Thus, we posited that higher self-efficacy for testing would be predictive of radon testing. Behavioral modeling refers to a form of vicarious learning where individuals acquire behaviors by watching others. The role of behavioral modeling in radon testing is not well understood; however, previous studies show that knowing others who have tested for radon is positively associated with one's intentions to test (Rinker et al., 2014; Weinstein et al., 1991). Outcome expectations refer to one's beliefs about the anticipated consequences of performing a behavior, which can be social, physical, or self-evaluative in nature. Expectancy beliefs refer to the value one places on these anticipated outcomes. A better understanding of the relationships between SCT constructs and radon testing could provide valuable knowledge. This knowledge could be used in future interventions to improve testing rates.

Studies show that perceived risk (from HBM) is positively associated with testing (Weinstein et al., 1990, 1991), and intentions to test (Duckworth et al., 2002; Rinker et al., 2014; Weinstein et al., 1990, 1991). Previous interventions that increased participants' perceived risk to radon, however, failed to improve test kit orders across treatment levels and compared with controls (Weinstein et al., 1990, 1991). These prior studies are limited in that most did not include other theory-based constructs, making it difficult for us to evaluate theoretical relationships.

Several demographic factors are positively associated with testing, also. In general, studies show that increased education and income are positively associated with testing (Halpern & Warner, 1994; Hill, Butterfield, & Larsson, 2006; Nissen et al., 2012; Wang et al., 2000; Weinstein, Lyon, Sandman, & Cuite, 1998), as is home ownership compared with renting (Hill et al., 2006; Larsson et al., 2009; Wang et al., 2000). Prerequisites for testing include having knowledge of radon, incentive to test, and the financial means to perform the test and mitigate for radon if necessary. Individuals with higher socioeconomic status (SES) who are homeowners are more likely to meet these criteria. Conversely, those with low SES are more likely to rent, have limited financial resources, and might feel powerless to change environmental threats (e.g., lead paint, radon) related to their housing situation (Butterfield, Hill, Postma, Butterfield, & Odom-Maryon, 2011; Harnish, Butterfield, & Hill, 2006).

The purpose of this study was to evaluate theory-based and demographic differences between individuals who purchased a radon test kit from the Utah County Health Department (UCHD) compared with a control group comprised of individuals exiting the UCHD Vital Records office. Based on data from the Utah Department of Health (Utah Department of Environmental Quality, 2017), approximately 44% of homes in Utah County, Utah, have radon levels ≥148 Bq/m^3 (4 pCi/L), but only 12–18% of Utah residents report having tested for radon (Akerley et al., 2011; Utah Department of Health, 2017).

To our knowledge, this study is the first to assess SCT-based characteristics associated with radon testing. Furthermore, we built on prior studies by analyzing the data using a structural equation modeling (SEM) framework. SEM allowed us to account for measurement error and to assess multiple relationships simultaneously.

Methods

Sample

Two distinct groups were recruited at the UCHD using convenience sampling. Radon testers consisted of individuals who visited the UCHD Division of Environmental Health for the purpose of purchasing a radon test kit for $10. Two trained UCHD staff members recruited individuals into this sample. Participants completed the consent form and the 10–15-min radon testing survey at UCHD. Study personnel recruited the comparison sample from among individuals exiting the UCHD Vital Records office. We chose this sample as a comparison group assuming they would demographically represent the general Utah County population. Participants in the comparison group completed the consent form and the radon testing survey while at UCHD.

Radon testers who completed the survey from May 2014–February 2015 received $5 off the price of the radon test kit, after which the compensation increased to $10 for the remainder of the study. The compensation amount was changed to increase study enrollment, and to compensate this group for an additional follow-up survey regarding radon mitigation behaviors (data not reported). Participants in the comparison sample received $5 cash for completing the survey. The institutional review board of Brigham Young University approved this study.

TABLE **1**

Frequencies, Percentages, and *p*-Values of Demographic Variables

Variable	Radon Testers (*N* = 110)		Comparison Group (*N* = 198)		*p*-Value
	Frequency	%	Frequency	%	
Demographic characteristics					
Gender					
Male	58	55.24	71	36.98	<.02
Female	47	44.76	121	63.02	
Age (years)					
18–24	1	0.91	38	19.69	<.001
25–34	17	15.45	66	34.02	
35–44	9	8.18	48	24.87	
45–64	43	39.09	30	15.54	
65+	40	36.36	11	5.70	
Race					
White	104	95.41	164	84.97	<.02
Non-White	5	4.59	29	15.03	
Education					
High school or less	6	5.50	28	14.51	<.001
Some college	26	23.85	76	39.38	
Bachelor's degree or more	77	70.64	89	46.11	
Housing status					
Own	102	93.58	99	51.30	<.001
Rent/other	7	6.42	94	48.70	
Relationship status					
Married	96	89.72	141	73.44	<.001
Other	11	10.28	51	26.56	

continued ▸

Measures

A 51-item paper survey was developed to assess risk perceptions and SCT-based predictors of radon testing, sources of radon information, participant attitudes toward proposed radon policies in Utah, and demographic and housing variables. Participant attitudes toward proposed radon policies and sources of radon information are not reported in this article. Both radon testers and participants in the comparison group received the same survey.

Theory-Based Constructs

We used five multiple-choice questions to measure participant knowledge about radon. Questions were developed a priori, but were similar to those used in previous studies (Kennedy et al., 1991; Wang et al., 2000). Each of the five questions was coded as 1 = correct response, 0 = otherwise. Questions included:

- What is radon?
- Which of the following is the major health concern caused by exposure to radon?
- What is the main way that radon enters your body?
- According to the U.S. Environmental Protection Agency, radon levels in your home should not be above what level?
- What percentage of homes in Utah County have high radon levels?

A 20-item scale was developed to measure SCT-based predictors and radon risk perceptions (Rosenstock, 1974). Theory-based constructs included outcome expectations; outcome values; self-efficacy; behavioral modeling by family members, friends, and neighbors; and perceived radon risk. Theory-based predictors were developed a priori and measured on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Negatively worded items were reverse coded so that for all items, higher scores indicated greater agreement with the hypothesized constructs. Sample items included "I know how to test my home for radon" and "At least one of my friends has encouraged me to test my home for radon."

Demographic and Housing Variables

We included the following demographic and housing variables as controls: age, gender (1 = male, 2 = female), race/ethnicity (1 = White, 2 = non-White), relationship status (1 = married, 2 = other), educational attainment (1 = high school or less, 2 = some college, 3 = bachelor's degree or more), and annual household income. Housing and household characteristics were measured using five items, including length of time participants lived in their current residence, number of people in the home, number of children in the home, home ownership (1 = own, 2 = rent), and type of home (1 = single family, 2 = other).

TABLE **1** *continued*

Frequencies, Percentages, and *p*-Values of Demographic Variables

Variable	Radon Testers (*N* = 110)		Comparison Group (*N* = 198)		*p*-Value
	Frequency	%	Frequency	%	
Income					
<$15,000–$24,999	4	3.92	44	22.92	<.001
$25,000–$44,999	14	13.72	48	25.01	
$45,000–$64,999	22	21.57	37	19.28	
$65,000–$84,999	21	20.59	31	16.15	
$85,000–>$95,000	41	40.19	32	16.67	
Housing characteristics					
Type of home					
Single family home	95	87.16	114	59.38	<.001
Other	14	12.84	78	40.63	
Time in residence (months)					
≤12	13	12.04	57	29.53	<.001
13–36	12	11.11	45	23.32	
37–96	15	13.89	43	22.28	
≥97	68	62.96	48	24.87	
# of household members					
1–2	43	40.19	35	18.13	<.001
3–4	34	31.78	98	50.78	
≥5	30	28.04	60	31.09	
# of children in the household					
1	53	50.00	52	26.94	<.02
2	16	15.09	43	22.28	
≥3	15	14.15	44	22.80	

Data Analysis

Descriptive Analysis and Bivariate Comparisons

Survey data were double entered into two separate spreadsheets by study personnel. The "compare" procedure in SAS was used to compare the spreadsheets and any discrepancies between the two databases were compared against the original surveys and adjudicated by the lead author. Frequencies, percentages, and means were used to describe the data. The chi-squared test for the difference of proportions was used to identify differences between the two study samples. Descriptive analyses and bivariate comparisons were conducted in SAS version 9.4.

Measurement Model

We conducted exploratory factor analysis (EFA) on the 20-item scale measuring risk perceptions and SCT. EFA is appropriate when quantitative research on a measure is limited (Bandalos & Finney, 2010). We ran sequential one-, two-, three-, four-, and five-factor EFA models to assess the scale dimensionality using a GEOMIN or oblique rotation. For each estimation, we examined factor loadings and model fit indices. A priori, we determined to retain items that were strongly related to the underlying construct and to sequentially remove items that were weakly related (e.g., with a factor loading <0.40 or a cross-loading on a second factor >0.30). To assess model fit, we used the following fit indices and cut-offs: comparative fit index (CFI) ≥0.95 indicated good fit and <0.90 indicated poor fit; root mean square error of approximation (RMSEA) ≤0.06 indicated good fit and >0.10 indicated poor fit (Hu & Bentler, 1999). For the resulting factors that fit our theoretical model based on EFA plus the five items relating to radon knowledge, we conducted confirmatory factor analysis (CFA) using the same model fit indices and factor loading requirements as we used for EFA.

Structural Model

Structural equation models were fit regressing radon testing status on the constructs of interest (relating to SCT and risk perception variables). Control variables (gender, age, income, race, marital status, education, housing status, type of home, number of years lived in current residence, number of household members, and number of children) were included in the models by regressing the independent and dependent variables on the controls. Finally, we tested for intervening effects by assessing the significance of indirect effects using 5,000 bootstraps.

EFA, CFA, and SEM were performed in Mplus version 7 (Muthén & Muthén, 2010) using the robust weighted least squares estimator, which is appropriate for data with categorical indicators. Missing data were minimal and addressed in Mplus using full information maximum likelihood.

Results

The final sample included 110 and 198 participants in the radon testing and comparison groups, respectively. A total of 19 (17.43%) of the current radon testers had tested their home previously, as had 10 (5.18%) of those in the comparison group. The majority of previous testers in both groups completed those tests more than two years ago (data not shown). Sample demographics are presented in Table 1. The two samples were significantly different on all demographic characteristics. Radon testers were generally older and more educated than those in the comparison sample. Additionally, a higher proportion of radon testers

TABLE **2**

Item Means for Total Sample, Radon Testers Subsample, and Comparison Group Subsample (*N* = 308)

Variable	Total (*N* = 308)		Radon Testers (*n* = 110)		Comparison Group (*n* = 198)		Difference Between Groups
	% or *M*	*SD*	% or *M*	*SD*	% or *M*	*SD*	*p*-Value
Radon knowledge (average % correct out of 4 items)[a]	48.62	32.66	75.23	19.89	33.84	28.79	<.001
What is radon? (%)	63.64	48.18	91.82	27.53	47.98	50.01	<.001
Which of the following is the major health concern caused by exposure to radon? (%)	44.48	49.78	82.73	37.97	23.23	42.34	<.001
What is the main way that radon enters your body? (%)	69.16	46.26	92.73	26.09	56.06	49.76	<.001
According to the U.S. Environmental Protection Agency, radon levels in your home should not be above what level? (%)	17.21	37.81	33.64	47.46	8.09	27.32	<.001
Behavioral modeling (*M*)[a]	2.17	1.12	2.76	1.15	1.84	0.96	<.001
At least one of my family members has encouraged me to test my home for radon. (*M*)[b]	2.35	1.40	3.05	1.51	1.95	1.15	<.001
At least one of my friends has encouraged me to test my home for radon. (*M*)[b]	2.14	1.31	2.71	1.57	1.82	1.00	<.001
At least one of my neighbors has encouraged me to test my home for radon. (*M*)[b]	2.03	1.22	2.53	1.48	1.75	0.94	<.001
Radon self-efficacy (*M*)[a]	2.92	1.07	3.75	0.81	2.45	0.90	<.001
I do not know where to buy a radon testing kit. (*M*)[b]	2.92	1.55	4.32	1.00	2.13	1.20	<.001
I know who to contact to learn more about radon testing. (*M*)[b]	2.79	1.46	3.62	1.34	2.32	1.30	<.001
I know how to test my home for radon. (*M*)[b]	2.36	1.33	3.07	1.34	1.96	1.15	<.001
I can find help to test my home for radon. (*M*)[b]	3.63	1.07	4.02	0.98	3.41	1.06	<.001
Risk perception (*M*)[a]	4.20	0.64	4.55	0.50	4.00	0.62	<.001
It is important to me that I know if there are unseen health risks in my home. (*M*)[b]	4.71	0.52	4.88	0.32	4.61	0.59	<.001
It is important to me that I know the radon levels in my home. (*M*)[b]	4.30	0.77	4.75	0.48	4.06	0.79	<.001
I am not worried about radon making me sick. (*M*)[b]	3.57	1.11	4.02	1.10	3.31	1.04	<.001

[a]Scale score, items averaged.
[b]Scale response ranges: 1 (strongly disagree) to 5 (strongly agree).

owned rather than rented a home, and lived in single family as opposed to multifamily dwellings or manufactured housing.

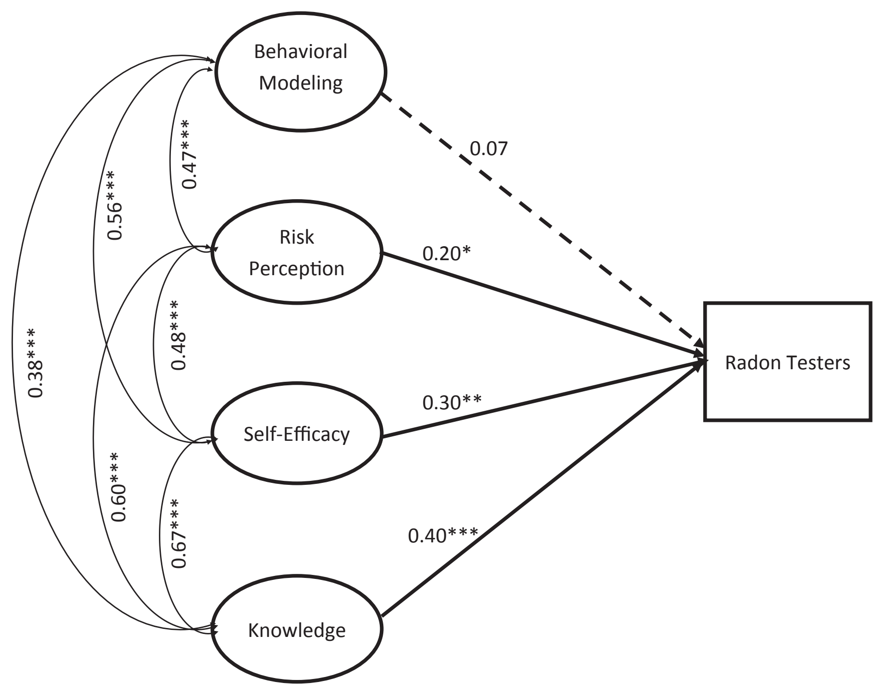
Measurement Model

A 4-factor model fit the data best during EFA. We dropped seven items with low factor loadings (<0.40) or a factor loading on more than one factor (>0.30). Model fit was good based on CFI (0.995) and adequate based on RMSEA (0.077). Factor loadings ranged from 0.47–0.99. Factor 1 related to behavioral modeling, factor 2 related to social ambivalence, factor 3 related to risk perception, and factor 4 measured radon self-efficacy. For our final model, we elected to retain the 3-item behavioral modeling, 4-item radon self-efficacy, and 3-item risk perception constructs. Social ambivalence was essentially the opposite of behavioral modeling, and we elected not to retain it in the final model due to concerns of model power.

We next conducted CFA using the behavioral modeling, self-efficacy, risk perception, and 5-item knowledge latent variables. During CFA, one item was dropped from the knowledge construct due to a low factor loading. Model fit for the final CFA model was good based on CFI (0.984) and RMSEA (0.058). Factor loadings ranged from 0.68–0.94 for the behavioral modeling construct, from 0.58–0.87 for radon self-efficacy, from 0.56–0.97 for risk perception, and from 0.60–0.88 for the 4-item knowledge construct. Table 2 contains the means for all items retained in the final model for the full

FIGURE **2**

Social Cognitive Theory and Radon Testing (*N* = 308)



Model fit: Root mean square error of approximation = 0.04; Comparative fit index = 0.98.

Model controls for respondent gender, age, income, race, relationship status, education, housing status, type of home, number of years lived in current residence, number of household members, and number of children in the household.

Intervening pathways: behavioral modeling → self-efficacy → radon testing status: $z = 1.97$, $p = <.05$; and behavioral modeling → knowledge → radon testing status: $z = 2.57$, $p = <.01$.

*$p < .05$.

**$p < .01$.

***$p < .001$.

sample and for the subsamples of radon testers and nontesters.

Structural Model

Figure 2 is the final SEM, regressing radon-testing status on the three SCT constructs and risk perception controlling for individual and family demographic variables. Model fit was good (CFI = 0.978, RMSEA = 0.044). Higher radon self-efficacy, radon knowledge, and risk perception were associated with buying a radon test kit (respectively, $\beta = 0.30$, $p < .01$; $\beta = 0.40$, $p < .001$; $\beta = 0.20$, $p < .05$). Behavioral modeling was not directly associated with radon testing status. We tested for direct effects using 5,000 bootstraps and found that behavioral modeling was indirectly associated with radon testing through self-efficacy ($z = 1.97$, $p < .05$) and through knowledge ($z = 2.57$, $p = .01$). Not being married and having more children in the home were associated with decreased likelihood to test. No other demographic factors were directly associated with radon testing.

Discussion

Our findings show that self-efficacy, radon knowledge, and risk perception were directly associated with testing. Furthermore, social modeling significantly and positively influenced radon testing, albeit indirectly through self-efficacy and knowledge. These findings offer insight into previous study results, and provide possibilities for future intervention strategies.

Similar to our study, previous studies show an association between risk perception and radon testing. When used as a stand-alone intervention strategy, however, raising individuals' perceived risk to radon has failed to produce significant results (Weinstein et al., 1990, 1991). Conversely, interventions incorporating self-efficacy show positive associations with testing behaviors (Butterfield et al., 2011; Weinstein et al., 1998).

In our study, self-efficacy and risk perception were highly correlated, but self-efficacy was more strongly associated with radon testing than risk perception. From a theoretical viewpoint, self-efficacy likely helps balance individual heightened risk awareness regarding radon with a sense of control over the threat (Bandura, 1997). This finding is consistent with prior studies that showed that increasing one's risk awareness without a concomitant increase in one's ability to exercise control over the risk can lead to avoidance (Bandura, 1997; Beck & Frankel, 1981).

In our study, renting one's home was associated with lower self-efficacy, perceived risk, behavioral modeling, and radon knowledge. Renters are at a significant disadvantage to homeowners because they do not have control over the property in which they live, and might not have the financial resources necessary to test for radon and mitigate if radon is found, which might lead to avoidance of information about radon risks and testing. Policy-level interventions requiring testing and mitigation of rental units could provide the best strategy to protect renters.

Behavioral modeling often is reported as an influential factor in individual occupational health-related behaviors (Johnston, Merrill, Zimmerman, Collingwood, & Reading, 2016; Lusk, Kerr, Ronis, & Eakin, 1999). Our findings support previous studies showing an association between knowing others who have tested for radon and one's own intention to test (Rinker et al., 2014; Weinstein et al., 1991). In our study, behavioral modeling did not directly influence testing, but did influence testing indirectly through the routes of knowledge and self-efficacy.

This study was limited to a relatively homogenous population and small sample size, and might not be generalizable to other locations. A comparison of the Vital Records group with data from the 2010 Utah County Decennial Census and American Community Survey showed a higher percentage of the Vital Records group was female, concentrated in the middle age ranges, married, and more highly educated as compared with Utah County generally. We controlled for these factors statistically in our models. In the absence of validated tools for measuring risk perception and SCT-based predictors, a scale was developed and factor analysis was performed to create constructs that can be used in future studies assessing radon testing in homes. An additional strength of our study was the use of SEM, which allowed us to assess several relationships simultaneously and to account for measurement error through our use of latent variables.

Conclusion

Considering that many adults report not testing because they do not know how (Kennedy et al., 1991; Nissen et al., 2012), self-efficacy promoting strategies should be a main focus of future interventions, coupled with educational strategies to inform people about radon.

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References

Akerley, W., Keyser, C., Edwards, S., Wilson, R., Van Duren, T., Akerley, D., . . . Sharry, S. (2011). Awareness of radon-associated health risks in Utah. *Utah's Health: An Annual Review*, *16*, 58–60. Retrieved from http://cdmbuntu.lib.utah.edu/utils/getfile/collection/uu-uhr/id/2/filename/6.pdf

Bandalos, D.L., & Finney, S.J. (2010). Factor analysis: Exploratory and confirmatory. In G.R. Hancock & R.O. Mueller (Eds.), *The reviewer's guide to quantitative methods in the social sciences* (pp. 93–114). New York, NY: Routledge.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York, NY: W.H. Freeman.

Beck, K.H., & Frankel, A. (1981). A conceptualization of threat communications and protective health behavior. *Social Psychology Quarterly*, *44*(3), 204–217.

Butterfield, P.G., Hill, W., Postma, J., Butterfield, P.W., & Odom-Maryon, T. (2011). Effectiveness of a household environmental health intervention delivered by rural public health nurses. *American Journal of Public Health*, *101*(Suppl. 1), S262–S270.

Darby, S., Hill, D., Auvinen, A., Barros-Dios, J.M., Baysson, H., Bochicchio, F., . . . Doll, R. (2005). Radon in homes and risk of lung cancer: Collaborative analysis of individual data from 13 European case-control studies. *BMJ*, *330*(7485), 223.

Duckworth, L.T., Frank-Stromborg, M., Oleckno, W.A., Duffy, P., & Burns, K. (2002). Relationship of perception of radon as a health risk and willingness to engage in radon testing and mitigation. *Oncology Nursing Forum*, *29*(7), 1099–1107.

Farrow, A., Taylor, H., & Golding, J. (1997). Time spent in the home by different family members. *Environmental Technology*, *18*(6), 605–613.

Halpern, M.T., & Warner, K.E. (1994). Radon risk perception and testing: Sociodemographic correlates. *Journal of Environmental Health*, *56*(7), 31–35.

Harnish, K.E., Butterfield, P., & Hill, W.G. (2006). Does Dixon's Integrative Environmental Health Model inform an understanding of rural parents' perceptions of local environmental health risks? *Public Health Nursing*, *23*(5), 465–471.

Hill, W.G., Butterfield, P., & Larsson, L.S. (2006). Rural parents' perceptions of risks associated with their children's exposure to radon. *Public Health Nursing*, *23*(5), 392–399.

Hu, L.T., & Bentler, P.M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55.

Janz, N.K., & Becker, M.H. (1984). The Health Belief Model: A decade later. *Health Education Quarterly*, *11*(1), 1–47.

Johnston, J.D., Merrill, R.M., Zimmerman, G.C., Collingwood, S.C., & Reading, J.C. (2016). Factors associated with biosafety level-2 research workers' laboratory exit handwashing behaviors and glove removal compliance. *Journal of Occupational and Environmental Hygiene*, *13*(4), 254–264.

Kennedy, C.J., Probart, C.K., & Dorman, S.M. (1991). The relationship between radon knowledge, concern and behavior, and health values, health locus of control and preventive health behaviors. *Health Education Quarterly*, *18*(3), 319–329.

Krewski, D., Lubin, J.H., Zielinski, J.M., Alavanja, M., Catalan, V.S., Field, R.W., . . . Wilcox, H.B. (2005). Residential radon and risk of lung cancer: A combined analysis of 7 North American case-control studies. *Epidemiology*, 16(2), 137–145.

Krewski, D., Lubin, J.H., Zielinski, J.M., Alavanja, M., Catalan, V.S., Field, R.W, . . . Wilcox, H.B. (2006). A combined analysis of North American case-control studies of residential radon and lung cancer. *Journal of Toxicology and Environmental Health, Part A, 69*(7), 533–597.

Larsson, L.S., Hill, W.G., Odom-Maryon, T., & Yu, P. (2009). Householder status and residence type as correlates of radon awareness and testing behaviors. *Public Health Nursing*, *26*(5), 387–395.

Lusk, S.L., Kerr, M.J., Ronis, D.L., & Eakin, B.L. (1999). Applying the health promotion model to development of a worksite intervention. *American Journal of Health Promotion*, *13*(4), 219–227.

Muthén, L.K., & Muthén, B.O. (2010). *Mplus statistical analysis with latent variables, user's guide* (6th ed.). Los Angeles, CA: Muthén & Muthén.

References

Nissen, M.J., Leach, J.W., Nissen, J.A., Swenson, K.K., & Kehn, H. (2012). Radon testing and mitigation: An intervention in a primary care setting. *Journal of Cancer Education*, *27*(3), 566–572.

Pershagen, G., Åkerblom, G., Axelson, O., Clavensjö, B., Damber, L., Desai, G., . . . Swedjemark, G.A. (1994). Residential radon exposure and lung cancer in Sweden. *New England Journal of Medicine*, *330*(3), 159–164.

Rinker, G.H., Hahn, E.J., & Rayens, M.K. (2014). Residential radon testing intentions, perceived radon severity, and tobacco use. *Journal of Environmental Health*, *76*(6), 42–47.

Rosenstock, I.M. (1974). Historical origins of the Health Belief Model. *Health Education & Behavior*, *2*(4), 328–335.

Utah Department of Environmental Quality, Division of Radiation Control. (2017). *Short term radon test results by county and ZIP code as of July 2017*. Retrieved from https://documents.deq.utah.gov/waste-management-and-radiation-control/planning-technical-support/radon/DRC-2017-002164.pdf

Utah Department of Health. (2017). *Public health indicator based information system (IBIS): Health indicator report of radon*. Retrieved from https://ibis.health.utah.gov/indicator/view/Radon.HomeTest.html

Wang, Y., Ju, C., Stark, A.D., & Teresi, N. (2000). Radon awareness, testing, and remediation survey among New York State residents. *Health Physics*, *78*(6), 641–647.

Weinstein, N.D., Lyon, J.E., Sandman, P.M., & Cuite, C.L. (1998). Experimental evidence for stages of health behavior change: The precaution adoption process model applied to home radon testing. *Health Psychology*, *17*(5), 445–453.

Weinstein, N.D., Sandman, P.M., & Roberts, N.E. (1990). Determinants of self-protective behavior: Home radon testing. *Journal of Applied Social Psychology*, *20*(10), 783–801.

Weinstein, N.D., Sandman, P.M., & Roberts, N.E. (1991). Perceived susceptibility and self-protective behavior: A field experiment to encourage home radon testing. *Health Psychology*, *10*(1), 25–33.

World Health Organization. (2009). *WHO handbook on indoor radon: A public health perspective*. Geneva, Switzerland: Author. Retrieved from http://apps.who.int/iris/bitstream/10665/44149/1/9789241547673_eng.pdf

Yamamoto, N., Shendell, D.G., Winer, A.M., & Zhang, J. (2010). Residential air exchange rates in three major U.S. metropolitan areas: Results from the Relationship Among Indoor, Outdoor, and Personal Air Study 1999–2001. *Indoor Air*, *20*(1), 85–90.

DIRECT FROM CDC ENVIRONMENTAL HEALTH SERVICES BRANCH

Gregory Miao, MS, JD
ChangeLab Solutions

Christine Fry, MPP

Improving Safe Drinking Water Programs One Essential Service at a Time: Closing the Water Quality Gap

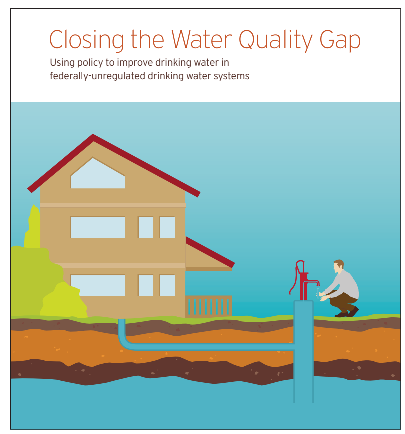
Editor's Note: **NEHA strives to provide up-to-date and relevant information on environmental health and to build partnerships in the profession. In pursuit of these goals, we feature a column from the Environmental Health Services Branch (EHSB) of the Centers for Disease Control and Prevention (CDC)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

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

Gregory Miao is a staff attorney at ChangeLab Solutions, where he works on issues related to active living, alcohol control, healthy housing, and water quality. Christine Fry is the former vice president of organizational learning at ChangeLab Solutions.

FIGURE **1**

Closing the Water Quality Gap



In 2015, the Centers for Disease Control and Prevention's (CDC) Environmental Health Services Branch (EHSB) reviewed past cooperative agreements with state and local public health agencies that had worked on safe drinking water programs. EHSB determined that the essential environmental public health services of developing policy and enforcing regulations were addressed less frequently than other service areas (Sabogal & Hubbard, 2015). There were instances, however, where local efforts to work on feasible, community-supported policy were effective at expanding service delivery, preventing exposure to drinking water contaminants, and protecting health (Cerro Gordo County Department of Public Health, 2015).

In 2016, EHSB entered into a cooperative agreement with ChangeLab Solutions to define the spectrum of approaches taken by state and local health departments when using policy in their safe drinking water programs. ChangeLab Solutions is a group of public health lawyers and professionals that "work with neighborhoods, cities, and states to transform communities with laws and policies that create lasting change" (ChangeLab Solutions, 2017a). In working with EHSB, ChangeLab Solutions focused solely on safe drinking water programs that had addressed policy for federally unregulated drinking water systems (e.g., household wells, springs). The intent of the agreement was not to create policy, but rather to understand the elements and best practices used by health agencies to enact feasible, community-driven solutions for drinking water problems.

ChangeLab Solutions reviewed information from state and local environmental public health agencies previously funded by EHSB to

- understand the influence of water projects on policy;
- identify challenges the agency personnel encountered when asked to provide data for policy efforts, and outline the strategies the agencies used to overcome those challenges;
- understand the type of partnerships the agencies needed to facilitate policy development;

FIGURE **2**

Federal Definition of a Public Water System

The Safe Drinking Water Act only regulates water systems that meet the federal definition of a public water system.

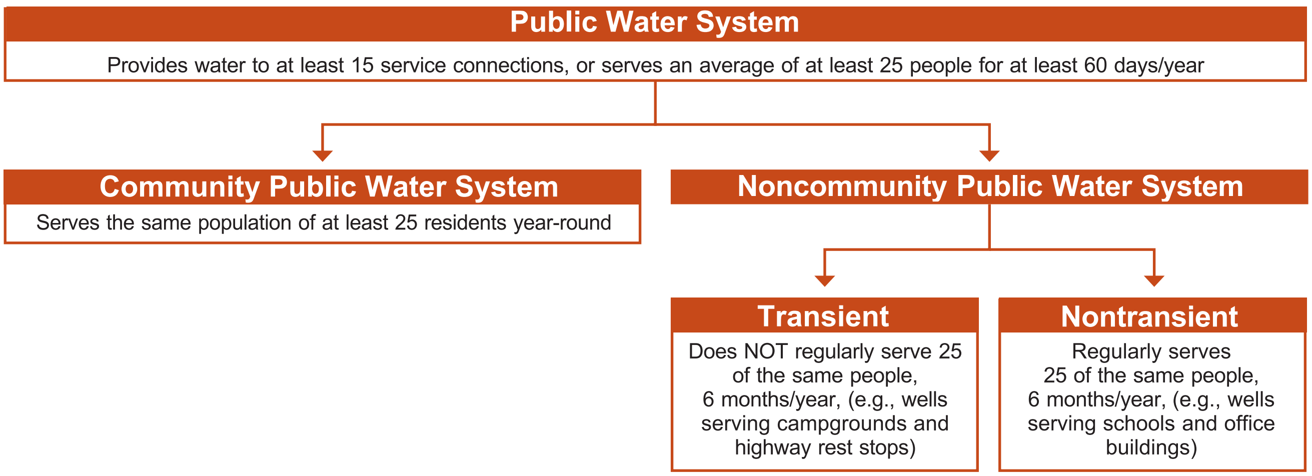


TABLE **1**

Steps for Working on Policy

1	Identify potential new policy or policy change based on available data, including gaps in existing policies, problems recognized in the field, health inequities, and health risks.
2	Clearly articulate to management the problems identified and how policy change will address those problems.
3	Advocate to managers within the agency chain of command for the proposed policy change. This advocacy should be supported by data showing how the new policy or policy change would reduce health risks and provide health benefits to the public.
4	Meet with groups, professions, organizations, and individuals who might be impacted by the new policy or policy change.
5	Work to educate the impacted community as to why the new policy or policy change is important and necessary.
6	Seek input and if possible, support from stakeholders who might be impacted by the new policy or policy change.
7	Be the leader or part of the team that drafts the new policy or policy change.
8	Serve as a resource for agency leadership, the board of health, and policy makers to answer questions and provide necessary information as requested.

- identify how communities benefit from water policies; and
- identify training and resource needs of state and local health agency staff working on water projects.

After reviewing materials, ChangeLab Solutions prioritized 10 agencies that worked on issues related to policy. Next, they conducted discussions with the 10 public health agencies, and then prioritized 6 of the 10 to learn more about their safe drinking water work. ChangeLab Solutions used in-person interviews to collect information from public health staff and partners that addressed policy issues. They used qualitative thematic analysis to compile responses and summarize their results.

ChangeLab Solutions analyzed the information collected from the six public health agencies to understand the differences and nuances of how policy is developed and used by state and local health departments. Additionally, the information collected was used broadly to

- inform the development of guidance to improve the delivery of essential environmental public health services for state and local safe drinking water programs and
- develop examples of how state and local health department personnel contributed to the development of policy.

At no time were the data used to develop a national approach to policy. On the contrary, ChangeLab Solution's activities were meant to capture what state and county public health agencies had accomplished in the local context that was feasible, sustainable, and supported by the community being served.

In July 2017, ChangeLab Solutions released the guidance document, *Closing the Water Quality Gap: Using Policy to Improve Drinking Water in Federally-Unregulated Drinking Water Systems* (ChangeLab Solutions, 2017b) (Figure 1). The guidance provides environmental and public health practitioners with current information outlining how policy has been used to address federally-unregulated drinking water, and focuses on some of the potential issues. Concepts such as the difference between public water systems and federally-unregulated drinking water systems and sources are presented in easy to understand charts (Figure 2). Likewise, policy and types of policies are defined with easy to understand examples. The guidance provides useful historical references of effective public health policies that have made vast improvements in the health and well-being of Americans. The document also provides clear examples of the roles and activities that environmental health practitioners took when supporting policy efforts (Table 1).

Most important, the guidance document reflects the best available science and practice and describes how policy has been used in various state and local environments to achieve improved water quality for consumers, including

- adopting water quality and testing standards for water sources not covered by the Safe Drinking Water Act,
- ensuring proper well construction,
- establishing consistent well identification systems, and
- assuring well driller certifications are in place.

The guidance has already been used by local health departments to support and educate local boards of health and other drinking water stakeholders engaged in policy work.

Current and future efforts by EHSB and ChangeLab Solutions will be the development of detailed case stories describing efforts by state and local agencies to strengthen policy. Case stories will address how outreach and educational efforts and work with nontraditional stakeholders were used to support policy compliance.

To learn more about CDC's Safe Water for Community Health program, visit www.cdc.gov/nceh/ehs/safe-watch/index.html.

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E-mail: gmiao@changelabsolutions.org.

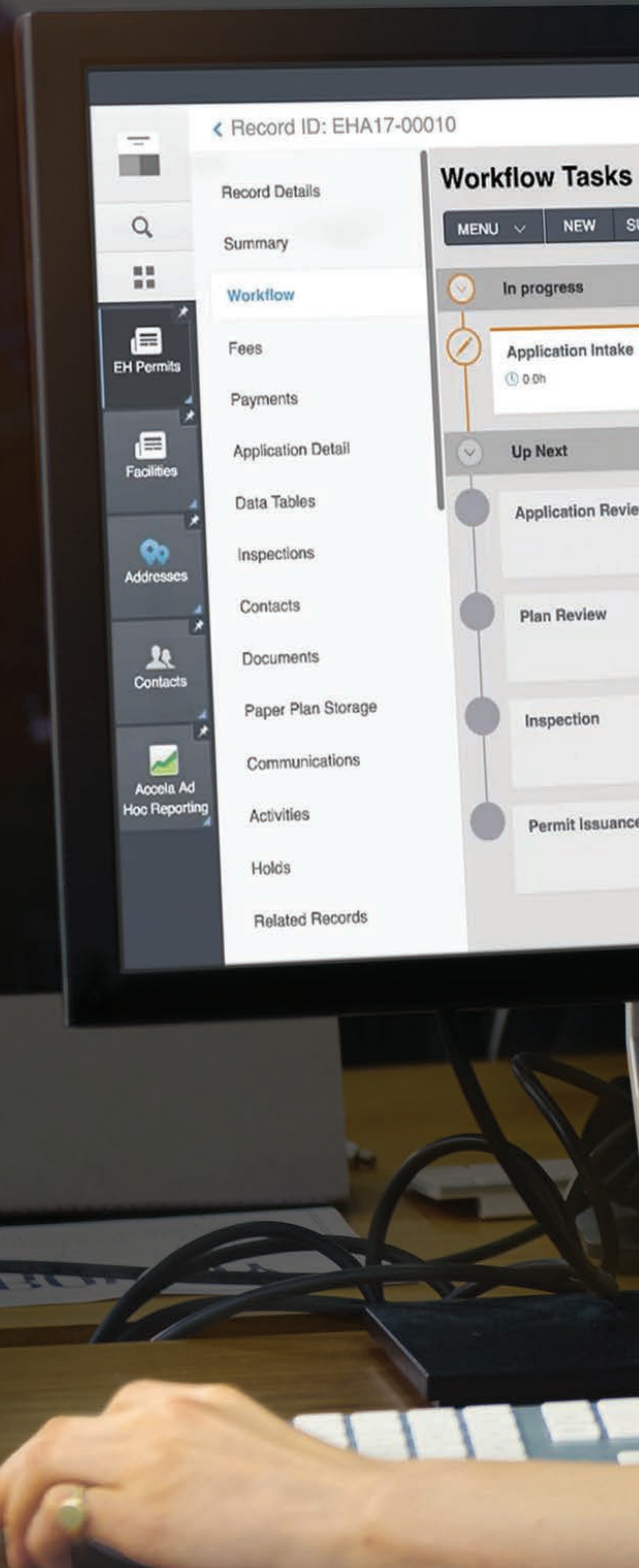
References

Cerro Gordo County Department of Public Health. (2015). *Arsenic in groundwater: A private well study in Cerro Gordo County, IA*. Retrieved from http://cghealth.com/wp-content/uploads/2015/09/Design-small.pdf

ChangeLab Solutions. (2017a). *About us*. Retrieved from http://www.changelabsolutions.org/about-us

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

Sabogal, R.I., & Hubbard, B. (2017). Improving state and local capacity to assess and manage risks associated with private wells and other drinking water systems not covered by the Safe Drinking Water Act. *Journal of Environmental Health*, *78*(5), 40–42.



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EH CALENDAR

UPCOMING NEHA CONFERENCES

June 25–28, 2018: NEHA 2018 Annual Educational Conference & Exhibition and HUD Healthy Homes Conference, Anaheim, CA. For more information, visit www.neha.org/aec.

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

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

NEHA AFFILIATE AND REGIONAL LISTINGS

Florida
July 24–27, 2018: Annual Education Meeting, hosted by the Florida Environmental Health Association, Cape Canaveral, FL. For more information, visit www.feha.org.

Idaho
March 5–7, 2018: Annual Educational Conference, hosted by the Idaho Environmental Health and Solid Waste Associations, Boise, ID. For more information, visit www.ieha.wildapricot.org.

Kentucky
February 14–16, 2018: Annual Conference, hosted by the Kentucky Environmental Health Association, Bowling Green, KY. For more information, visit www.kyeha.org.

Michigan
March 21–23, 2018: Annual Education Conference, hosted by the Michigan Environmental Health Association, Pontiac, MI. For more information, visit www.meha.net/AEC.

Minnesota
January 25, 2018: Winter Conference, hosted by the Minnesota Environmental Health Association, St. Paul, MN. For more information, visit www.mehaonline.org/meha-winter-conference.

Ohio
April 17–18, 2018: 72nd Annual Education Conference, hosted by the Ohio Environmental Health Association, Worthington, OH. For more information, visit www.ohioeha.org.

Utah
May 2–4, 2018: Spring Conference, hosted by the Utah Environmental Health Association, Vernal, UT. For more information, visit www.ueha.org/events.html.

Washington
May 7–9, 2018: 66th Annual Educational Conference—Environmental Public Health: Partnering, Protecting, & Planning, hosted by the Washington State Environmental Health Association, Olympia, WA. For more information, visit www.wseha.org.

TOPICAL LISTING

International
March 20–23, 2018: 15th IFEH World Congress on Environmental Health, hosted by the New Zealand Institute of Environmental Health, Auckland, New Zealand. For more information, visit www.2018wceh.org.

Public Health
April 10–11, 2018: Iowa Governor's Conference on Public Health, Des Moines, IA. For more information, visit www.ieha.net/IGCPH.

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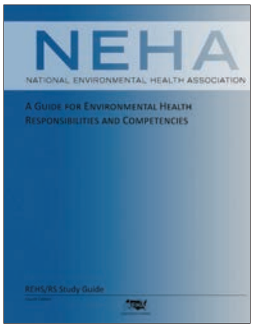
REHS/RS Study Guide, 4th Edition

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.

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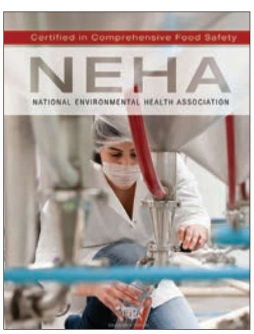
Certified in Comprehensive Food Safety Manual

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 announce 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 credential exam and deals with the information required to perform effectively as a CCFS.

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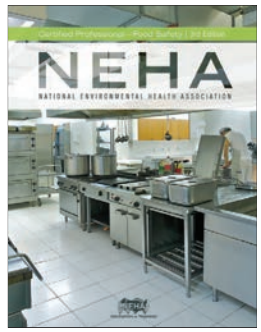
Certified Professional–Food Safety Manual, 3rd Edition

National Environmental Health Association (2014)



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

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

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JEH QUIZ

FEATURED ARTICLE QUIZ #4

The Sports Ball as a Fomite for Transmission of *Staphylococcus aureus*

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

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JEH Quiz #2 Answers

October 2017

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

➔ Quiz deadline: April 1, 2018

1. The community strain of methicillin-resistant *Staphylococcus aureus* (MRSA) accounts for between __ of hospital-reported MRSA infections.
   a. 2–10%
   b. 5–15%
   c. 8–20%
   d. 12–24%

2. Community-associated MRSA (CA-MRSA) infections are commonly distinguished from other staphylococci infections by
   a. recent attendance at a healthcare institution.
   b. the absence of predisposing patient risk factors.
   c. all the above.
   d. none of the above.

3. Over __ of the academic literature concerning sports infections describes outbreaks of MRSA.
   a. one quarter
   b. one third
   c. one half
   d. two thirds

4. The first outbreak of MRSA infection in the athletic community was reported in
   a. 1990.
   b. 1998.
   c. 2004.
   d. 2008.

5. The primary mechanism of CA-MRSA transmission between athletes that has tentatively emerged is
   a. skin-to-skin contact among players with traumatic lesions or abscesses.
   b. equipment sharing.
   c. poor hygiene.

6. In the study, simulation #1 explored *S. aureus* transfer from
   a. ball to floor and hand.
   b. hand to ball and floor.
   c. floor to ball and hand.

7. In simulation #1, the average change in CFUs following play was greatest in the
   a. floor.
   b. sports ball.
   c. hand.

8. In simulation #1, the average change in CFUs in the hand was significantly greater following play with __ compared with __ .
   a. basketballs; volleyballs
   b. volleyballs; basketballs

9. In simulation #2, there was __ change in CFUs sampled from the floor after play.
   a. significant
   b. no significant

10. In simulation #3, there was a significant increase in CFUs cultured from the __ following play.
    a. sports ball
    b. floor
    c. hand

11. In testing the survivability of *S. aureus* on sports balls, at the final time point the average number of CFUs __ between the volleyball and basketball.
    a. differed significantly
    b. did not differ significantly
    c. was the same

12. The study demonstrated the viability of *S. aureus* on sequestered sports balls for 72 hr.
    a. True.
    b. False.

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www.afcsushi.com

Air Chek, Inc.
www.radon.com

Allegheny County Health Department
www.achd.net

American Chemistry Council
www.americanchemistry.com

Arlington County Public Health Division
www.arlingtonva.us

Association of Environmental Health Academic Programs
www.aehap.org

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

Baltimore City Lead Hazard Reduction Program
www.baltimorehousing.org/ghsh_lead

Baltimore County Department of Planning
www.baltimorecountymd.gov/Agencies/planning

Black Hawk County Health Department
www.co.black-hawk.ia.us/258/Health-Department

Chemstar Corporation
www.chemstarcorp.com

Chester County Health Department
www.chesco.org/health

City of Milwaukee Health Department, CEH
http://city.milwaukee.gov/health/environmental-health

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

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

CKE Restaurants, Inc.
www.ckr.com

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

Custom Data Processing, Inc.
www.cdpehs.com

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

Diversey, Inc.
www.diversey.com

DuPage County Health Department
www.dupagehealth.org

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

Ecolab
www.ecolab.com

EcoSure
adolfo.rosales@ecolab.com

Eljen Corporation
www.eljen.com

Enviro-Decon Services
www.enviro-decon.com

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

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

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

GLO GERM/Food Safety First
www.glogerm.com

GoJo Industries
www.gojo.com

Health Department of Northwest Michigan
www.nwhealth.org

HealthSpace USA Inc
www.healthspace.com

Hedgerow Software Ltd.
www.hedgerowsoftware.com

Industrial Test Systems, Inc.
www.sensafe.com

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

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

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

Kenosha County Division of Health
www.co.kenosha.wi.us/297/Health-Services

LaMotte Company
www.lamotte.com

Lenawee County Health Department
www.lenaweehealthdepartment.org

Macomb County Health Department
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Marathon County Health Department
www.co.marathon.wi.us/Departments/HealthDepartment.aspx

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

Metro Public Health Department
www.nashville.gov/Health-Department.aspx

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

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

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

National Restaurant Association
www.restaurant.org

New Mexico Environment Department
www.env.nm.gov

NSF International
www.nsf.org

Opportunity Council/Building Performance Center
www.buildingperformancecenter.org

Orkin Commercial Services
www.orkincommercial.com

Ozark River Portable Sinks
www.ozarkriver.com

Paster Training, Inc.
www.pastertraining.com

Polk County Public Works
www.polkcountyiowa.gov/publicworks

Protec Instrument Corporation
www.protecinstrument.com

QuanTEM Food Safety Laboratories
www.quantemfood.com

SAI Global, Inc.
www.saiglobal.com

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

Seminole Tribe of Florida
www.semtribe.com

Skogen's Festival Foods
www.festfoods.com

Sonoma County Permit and Resource Management Department, Well and Septic Division
www.sonomacounty.ca.gov/Well-and-Septic

Southwest District Health Department
www.swdh.org

Starbucks Coffee Company
www.starbucks.com

StateFoodSafety.com
www.statefoodsafety.com

Steritech Group, Inc.
www.steritech.com

Sweeps Software, Inc.
www.sweepssoftware.com

Taylor Technologies, Inc.
www.taylortechnologies.com

Texas Roadhouse
www.texasroadhouse.com

Tri-County Health Department
www.tchd.org

Tyler Technologies
www.tylertech.com

UL
www.ul.com

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

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West Virginia Department of Health and Human Resources, Office of Environmental Health Services
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Michigan State University, Online Master of Science in Food Safety
www.online.foodsafety.msu.edu

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www.odu.edu/commhealth

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www.findlay.edu

University of Georgia, College of Public Health
www.publichealth.uga.edu

University of Washington, Department of Environmental & Occupational Health Sciences
www.deohs.washington.edu

University of Wisconsin–Madison, University Health Services
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NEHA NEWS

NEHA Supports Environmental Health at the 2017 InFORM Conference

By Elizabeth Landeen (elandeen@neha.org)

The 2017 John J. Guzewich Environmental Public Health Team Award was awarded to the *Salmonella* Oranienburg Investigation Team at the Integrated Foodborne Outbreak Response and Management (InFORM) 2017 Conference, November 6–9, 2017, in Garden Grove, California. The award-winning team was comprised of the California Department of Public Health (CDPH), City of Berkley Divisions of Public Health and Environmental Health, and California Emerging Infections Program.

The team worked together throughout 2015 and 2016 to prevent additional illnesses due to a strain of *Salmonella* at a local Mexican restaurant in Berkeley, California. After identifying a cluster of illnesses associated with the restaurant in August 2015, CDPH and the City of Berkeley worked together to plan an assessment at the restaurant using environmental swabbing techniques. Initial results indicated the presence of *Salmonella* in the facility, which resulted in the closure of the restaurant. Once the restaurant reopened, subsequent inspections and environmental assessments were completed by the team to determine if microbial contamination had been eliminated from the restaurant's environment. Additional *Salmonella* findings were confirmed by the laboratory in 2016 and resulted in significant corrections by the restaurant owner to eliminate the source of contamination. CDPH laboratories completed all testing in an efficient manner and were able to compare pulsed-field gel electrophoresis (PFGE) patterns from case patients and environmental samples to directly link the outbreak strain to the restaurant.

The John J. Guzewich Environmental Public Health Team Award recognizes the role of local, state, tribal, and territorial environmental and public health departments in protecting the national food safety system. Award winners are acknowledged for their efforts to promote and encourage innovative programs and best practices to prevent foodborne illnesses. The work and investigations done by the *Salmonella* Oranienburg Investigation Team highlights the exceptional teamwork between state and local public health agencies including epidemiology, environmental health, public health, and laboratory facilities.

NEHA is an active committee member for the InFORM Conference, which brings together laboratorians, epidemiologists, and environmental health specialists involved with foodborne and enteric disease outbreak response. NEHA's Elizabeth Landeen serves as the colead on the InFORM Environmental Health Planning Committee, along with Carrie Rigdon, who works at the Minnesota Department of Agriculture and represents the Association of Food and Drug Officials. Landeen also serves on the Environmental Health Award Committee, along with NEHA President-Elect Vince Radke, Centers for Disease Control and Prevention, National Center for Environmental Health/Environmental Health Services Branch; NEHA Region 9 Vice-President Larry Ramdin, Salem Board of Health; Michele DiMaggio, Contra Costa Environmental Health; and David Nicholas, New York State Department of Health.

The Salmonella *Oranienburg Investigation Team stands with some of NEHA's leadership (far left, Larry Ramdin; far right, Elizabeth Landeen and Vince Radke) after receiving the 2017 John J. Guzewich Environmental Public Health Team Award. Photo courtesy of Michéle Samarya-Timm.*

Through a formal submission and review process, the committee thoroughly reviewed and discussed all submissions for the 2017 John J. Guzewich Environmental Public Health Team Award. The committee made the award selection in October, which was then presented at the InFORM 2017 Conference in November. NEHA congratulates the *Salmonella* Oranienburg Investigation Team for receiving this notable award!

2018 HUD Secretary's Awards for Healthy Homes

By Vanessa DeArman (vdearman@neha.org)

The U.S. Department of Housing and Urban Development (HUD), in partnership with NEHA, announces the fourth annual Secretary's Awards for Healthy Homes. These awards will recognize excellence in healthy housing innovation and achievement in four categories: public housing/multifamily supported housing; policy and education innovation; cross program coordination; and research among health, environment, and housing. The activities or policies nominated must show measurable benefits in the health of residents and be available to low- and/or moderate-income families. Applications will open January 5 on NEHA's and HUD's websites. The deadline to submit an application is February 28. Previous award winners are ineligible to apply. The awards will be presented at the NEHA 2018 Annual Educational Conference (AEC) & Exhibition and HUD Healthy Homes Conference, June 25–28, in Anaheim, California (www.neha.org/aec).

DirecTalk

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ment for our services. Food, water, housing, climate, and select heavy metals receive attention in this very approachable and readable document, which can assist in answering the question about the value of our profession. While there is much more to do, the report represents a foundational step forward in efforts to answer the "so what" question. You can find the report in its entirety, a summary of almost 80 peer-reviewed articles, at www.apha.org/~/media/files/pdf/topics/environment/eh_values.ashx.

Each NEHPC member contributes what they can as almost none of us have funding to donate to the cause. We have joined together to deliver webinars, host panel sessions at conferences, and exchange ideas. We also have water and communications workgroups that are struggling with how best to tackle recalcitrant issues at the national level. We ask ourselves the question, "What can we do together that we can't do alone?" Like any community effort, groups and individuals migrate in and out over time, but ours is a stable collective of like-minded professionals who aim to make our nation healthy and productive. All two dozen organizations give a little so we can collectively achieve a lot.

Members of the National Environmental Health Partnership Council convene for a group photo outside the American Public Health Association (APHA) offices in Washington, DC. Photo courtesy of Olubukolami "Mimi" Musa, APHA.

In his annual message to Congress in 1862, President Abraham Lincoln noted, "The dogmas of the quiet past are inadequate to the stormy present. The occasion is piled high with difficulty, and we must rise with the occasion. As our case is new, so we must think anew and act anew." Our stormy present demands that we think and act anew. Our communities, like our life partners, demand our attention. As 2017 increasingly becomes a memory, we owe our constituents the promise of a better 2018 by working with organizations that share a common vision and purpose. NEHPC is the group where that happens, and NEHA is pleased to be a part of the larger environmental health family, which manifests itself across many places and faces.

You can learn more about NEHPC at www.apha.org/topics-and-issues/environmental-health/partners/national-environmental-health-partnership-council.

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DirecTalk MUSINGS FROM THE 10TH FLOOR

David Dyjack, DrPH, CIH

Reflections on Community

The dusty road that led to what seemed like the end of the world came to an abrupt stop in a remote community anchored in a dry and harsh environment. It was there that I learned a powerful life lesson about poverty, hope, and responsibility.

The water, sanitation, and hygiene project I was assigned to aimed to strike a different course. Like many development projects in the region, we were charged to reduce maternal and child mortality through improved nutrition, maternal empowerment, and enhanced environmental practices. Unlike other projects in the region, we were instructed to "not give any stuff away." We were not to distribute pyrethroid impregnated mosquito nets, energy efficient cookstoves, or anything else for that matter. The community, if they desired greater health, would need to pay. The approach sounded harsh to me as the beneficiaries seemed to be subsistence farmers.

The foundational wisdom of ensuring community buy in became evident soon enough. Dependency in any form often leads to abuse and can be rife with greed. We learned that many well-intentioned aid organizations created expectations among their recipients that proved too generous. In some cases, communities would withhold support to engage in projects until gifts of building supplies, vehicles, or cash were secured.

On the other hand, our project required community in-kind support, not of cash but of labor, simple meals, or bags of cement. Every family donated something in support of drinking water, ventilated improved pit latrines, and kitchen gardens. As time moved on, community members took turns to police their new well from vandals who evidently coveted the iron pump handle. A fence was constructed from thorny vegetation to keep grazing animals away. Our community owned their improvements and were proud of what they had accomplished.

> *Most sustainable solutions to society's ills are crafted and muscled into existence through local resources.*

As I reflect on my halcyon days jetting around the planet to do good works, Kenya is a potent reminder that most sustainable solutions to society's ills are crafted and muscled into existence through local resources, human or otherwise. I am pleased to report that a community effort in support of environmental health and our profession exists in the U.S.: the National Environmental Health Partnership Council (NEHPC). NEHPC strives to support healthy people by working for healthier environments. It brings together diverse stakeholders to help expand and sustain awareness, education, policies, and practices related to environmental health.

NEHPC is hosted by the American Public Health Association and has a constituency made up of approximately two dozen environmental and public health organizations. Yours truly is a cochair, along with the dynamic Laura Anderko, PhD, RN, Alliance of Nurses for Healthy Environments. NEHPC is a group where the environmental health community in all its various facets—environmental justice, children's issues, laboratories, health departments—and NEHA come together to build our own version of a community garden. The harvest has begun with two products that you should be aware of and should use in your advocacy work.

The first product is the *Environmental Health Playbook: Investing in a Robust Environmental Health System*, which was published in 2017. The *Playbook* identifies opportunities for federal, state, local, and tribal governments to adopt standard approaches that ensure environmental health equity, protections, and access for all, particularly vulnerable and at-risk populations. I believe you will find the *Playbook* to be a useful resource. It lays out a vision for healthier communities through effective environmental health practice, as illustrated by case studies. The development of a well-trained and highly skilled workforce is one of the priorities laid out in the *Playbook*. You can download the *Playbook* at www.apha.org/~/media/files/pdf/topics/environment/eh_playbook.ashx.

NEHPC has also recently produced a report, *The Value of Environmental Health Services: Exploring the Evidence*, that attempts to answer the age-old question about the return on invest-

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INTERNATIONAL PERSPECTIVES

Evaluation and Risk Assessment of Heavy Metals in the Groundwater Resources of Saqqez, Iran

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Abstract **Groundwater is the main water resource in rural areas throughout the world. The present study aimed to measure nine heavy metals (arsenic, chromium, cobalt, iron, manganese, mercury, molybdenum, nickel, and zinc) in rural areas of Saqqez, Iran. Water samples were collected from 150 sampling stations (wells, springs, and tanks). The heavy metal concentrations were measured using inductively coupled plasma and the spatial distribution of the heavy metal concentrations was mapped. Risk assessment was performed using average daily dose and hazard quotient. The mean concentration of heavy metals in drinking water from different sources were found in order of iron > zinc > chromium > molybdenum > nickel > cobalt > arsenic > mercury > manganese. The concentrations of arsenic, iron, and molybdenum were, however, higher than World Health Organization and U.S. Environmental Protection Agency standards in a few of the samples. Moreover, the statistical analysis revealed that there are no significant variations between well, spring, and tank sources (*p* < .05). In addition, no significant difference was observed between water quality with different geographical directions and slopes (*p* < .05). The mean human health risk values for mercury in well and tank water sources were above 1, indicating potential risk.**

Introduction

Water is the base of life on Earth: it is considered a vital substance in the environment, and its contamination with heavy metals (HMs) such as arsenic (As), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn) is a worldwide environmental issue (Muhammad, Tahir Shah, & Khan, 2010). HMs is a general collective term applying to metals and metalloids with an atomic density > 6 g/cm^3 (Awodele, Popoola, Amadi, Coker, & Akintonwa, 2013). Contamination with HMs mainly results from natural (i.e., weathering, erosion of bed rocks, and ore deposits) and anthropogenic (mining, smelting, industrial influx, agriculture and wastewater irrigation) processes (Demirak, Yilmaz, Tuna, & Ozdemir, 2006; Ettler, Křìbek, Majer, Knésl, & Mihaljevič, 2012; García-Lorenzo, Pérez-Sirvent, Martínez-Sánchez, & Molina-Ruiz, 2012; Khan, Cao, Zheng, Huang, & Zhu, 2008). Due to their toxicity, environmental persistence, and bioaccumulative nature in the environment, HMs are categorized as dangerous pollutants (Khalil, Radwan, & El-Moselhy, 2007; Pekey, Karakaş, & Bakoglu, 2004). Although some metals such as iron (Fe), Cu, Mn, and Zn are essential and have physiological roles at specific concentrations in living organisms, toxic effects are observed when a concentration exceeds the maximum permissible level (Kavcar, Sofuoglu, & Sofuoglu, 2009).

One of the most hazardous trace metals found in drinking waters is arsenic because it is both toxic and carcinogenic (Bloom, Surdu, Neamtiu, & Gurzau, 2014). Whereas Zn and Cu are essential elements for human health (Azizullah, Khattak, Richter, & Häder, 2011), their overexposure can lead to adverse health consequences (Singh, Kumar, Nada, & Prasad, 2006). A specific amount of Cr is essential for normal body functions, but in higher concentrations can cause toxicity, including liver and kidney disorders and genotoxic effects (Muhammad, Tahir Shah, & Khan, 2011). Cobalt (Co) is needed for the formation of vitamin B12 (Oves, Saghir Khan, Huda Qari, Nadeen Felemban, & Almeelbi, 2016). High intake of Co via consumption of contaminated food and water, however, can cause abnormal thyroid function, polycythemia, and coronary artery disease (Goyer et al., 2004).

Risk assessment methodologies are well developed and documented in the U.S. Numerous investigations have adopted human risk assessment techniques by taking into account the exposure of metal intake through contaminated soil and drinking

TABLE 1

Heavy Metal Concentrations (µg/L) in Water Samples Collected From Different Sources in the Study Area

Heavy Metal	Total	Statistics	Heavy Metal Concentration			Permissible Limits	
			Well (*n* = 36)	Spring (*n* = 15)	Tank (*n* = 99)	U.S. EPA	WHO
As	2.60	Mean	2.12	5.18	2.38	10.00	10.00
		SD	6.69	18.27	10.03		
Cr	17.94	Mean	17.96	17.76	17.96	50.00	50.00
		SD	0.85	0.86	1.19		
Co	7.53	Mean	7.79	7.72	7.50	–	50.00
		SD	0.77	0.90	0.81		
Fe	70.15	Mean	115.44	50.69	56.63	300.00	300.00
		SD	334.01	49.38	62.90		
Mn	1.20	Mean	2.46	0.20	0.89	500.00	400.00
		SD	11.72	0	4.19		
Mo	14.33	Mean	16.41	13.82	13.65	70.00	–
		SD	18.52	1.22	2.76		
Zn	27.24	Mean	22.30	11.25	31.22	5,000.00	3,000.00
		SD	28.11	11.27	78.64		
Ni	9.12	Mean	9.40	8.82	9.06	20.00	70.00
		SD	2.93	1.25	1.50		
Hg	1.34	Mean	1.40	0.99	1.36	50.00	10.00
		SD	0.75	0.56	0.78		

As = arsenic; Cr = chromium; Co = cobalt; Fe = iron; Mn = manganese; Mo = molybdenum; Zn = zinc; Ni = nickel; Hg = mercury; U.S. EPA = U.S. Environmental Protection Agency; WHO = World Health Organization.

water (Granero & Domingo, 2002; Kelepertzis, 2014; Wcisło, Ioven, Kucharski, & Szdzuj, 2002). Previously, health risk assessments of HMs, along with statistical analysis, have been reported in different parts of the world (Jang, 2010; Oyebog, Ako, Nkeng, & Suh, 2012). Some studies have reported high concentrations of trace elements such as Mn, Pb, Ni, Co, Sr, Fe, Zn, and Cu in groundwater, which constitute a threat to humans, plants, and animals that come in contact with them (Agusa et al., 2006; Buschmann, Berg, Stengel, & Sampson, 2007; Farías et al., 2003).

Hence, it was crucial to conduct a research project on the contamination of HMs in groundwater resources. Pirsaheb and coauthors (2013) collected 165 water samples from water supply resources (128 wells), 25 water reservoirs, and water distribution networks (tap water) of Kermanshah City, Iran. Their results indicated that concentrations of all measured metals (except the amount of aluminum [Al], Fe, and Mn in some samples of water resources, distribution network, and water reservoirs) were lower than the national standards and guidelines recommended by the World Health Organization (WHO) (Pirsaheb, Khosravi, Sharafi, Babajani, & Rezaei, 2013). Hoaghia and coauthors (2016) evaluated the concentrations of As, cadmium (Cd), Cr, Cu, Fe, Mn, Ni, Pb, and Zn in 21 drinking water sources. Results indicated that Mn and Cd concentrations exceeded the threshold limits of the drinking water quality guidelines, but only in the summer season. The quality assessment indices showed a low contamination degree, with all values being lower than the critical ones (Hoaghia, Roman, Kovacs, Tanaselia, & Ristoiu, 2016).

In the majority of rural areas, residents rely on springs and wells as the only drinking water supply. Moreover, disinfection as the only method for purifying water is useless in reducing HMs. Hence, the objective of this study was to evaluate the quality of drinking water of rural areas of Saqqez, Iran. Selected HMs in this study are Cr, Zn, Ni, Mn, As, Co, Fe, molybdenum (Mo), and mercury (Hg). We assessed the potential health risks on both adults and children. Indeed, it was attempted to determine the most significant contaminant and exposure pathway with respect to human health risk.

Methods

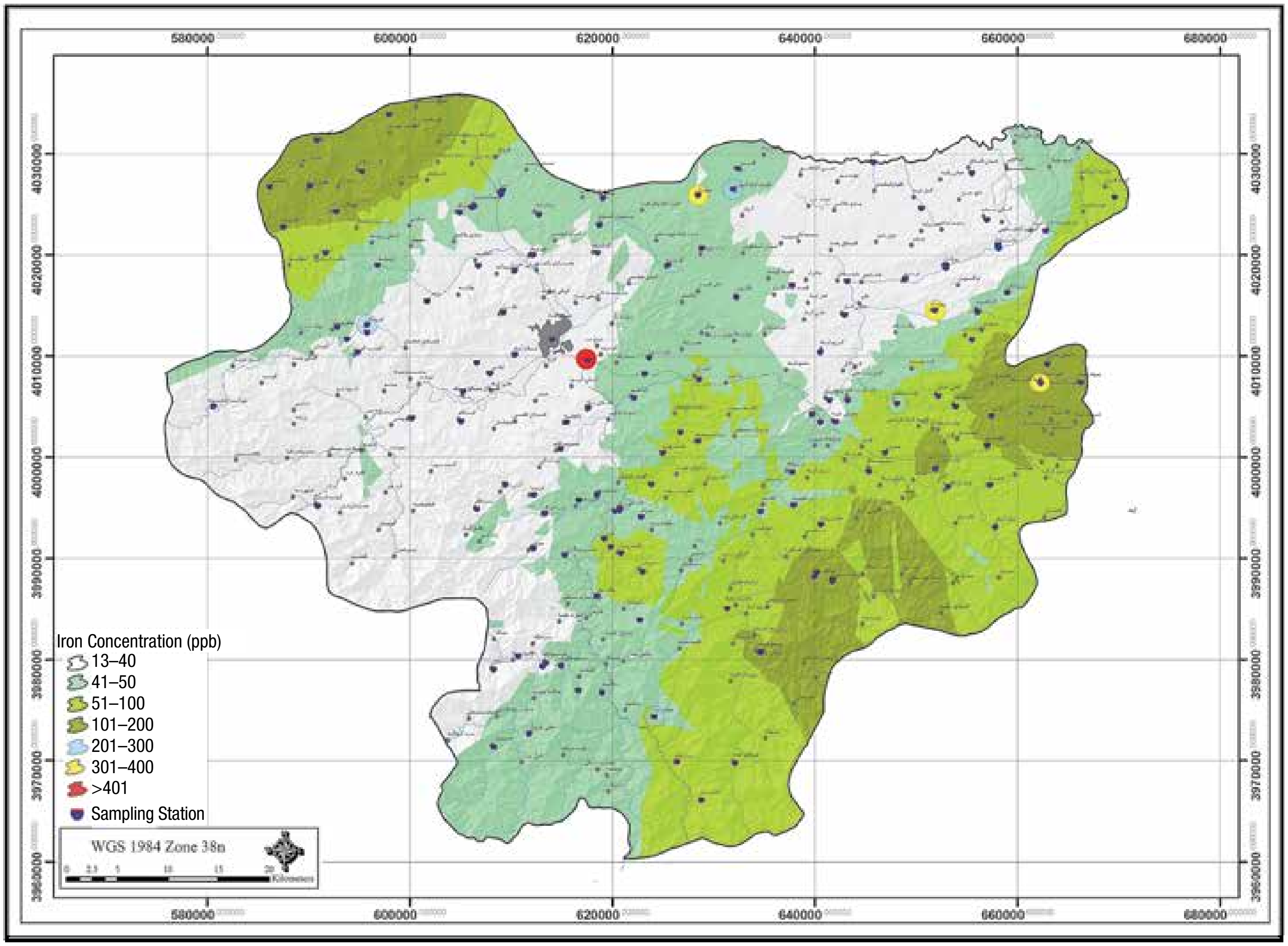
Saqqez is located at 36°14'N latitude and 46°16'E longitude, and is one of the main towns in Kurdistan, Iran. It includes more than 206 villages covered by various water resources (springs and wells).

Groundwater samples were collected from 150 drinking water sources (15 springs, 33 wells, and 102 tanks) from 150 villages in Saqqez, Iran. The location of sampling stations was recorded using GPS. Each water sample was collected in high-density polyethylene terephthalate bottles, at 8–10 a.m., and analyzed for HMs (Zn, Cr, Ni, Mn, As, Co, Fe, Mo, and Hg). Water samples were collected from each source using grab sampling methods in two phases (rainy and dry seasons) (Mkude, 2015). Before collecting the sample, each polyethylene container was cleaned by soaking it in 10% nitric acid overnight. The containers were then washed and rinsed with double distilled water on the day of sampling. At the sampling site, the bottles were rinsed twice with the water being sampled prior to filling. Then 1 ml/L of concentrated nitric acid was added to each sample until the pH was reduced to less than 2. Each sample was filtered immediately upon arrival at the laboratory using a 0.45 µm Millipore membrane filter and the water samples were stored in the laboratory at 4 °C in order to prevent a change in the volume due to evaporation (Okoro, Adeyinka, Jondiko, Ximba, & Kakalanga, 2012).

The water samples were digested to remove all that could interfere with the analysis by ensuring that the ions were in solution using a combination of nitric acid and hydrochloric acid, after which they were subjected to

FIGURE **1**

Spatial Distribution of Iron in Saqqez, Iran



inductively coupled plasma-optical emission spectrometry (ICP-OES) analysis. The instrument used was ICP-OES with flared end EOP torch 2.5 mm and a pump rate of 30 RPM (Espinoza-Quiñones, Módenes, de Pauli, & Palácio, 2015; Raju, Prasad, Varalakshmi, & Reddy, 2014; Sarojam, 2010). The spatial distribution of HMs was mapped using ArcGIS version 10.1 software.

Approaches for Assessing Health Risks: Average Daily Dose (ADD) and Hazard Quotient (HQ)

HMs enter into the human body through several pathways including food chain, dermal contact, and inhalation—but in comparison to oral intake all others are negligible (Agency for Toxic Substances and Disease Registry, 2015). Average daily dose (ADD) through water intake was calculated according to the modified U.S. EPA equation (U.S. Environmental Protection Agency, 2017):

$$ADD = C \times IR/BW$$

Where C, IR, and BW represent the metal concentrations in water (mg/L), water ingestion rate (2 L/day), and body weight (72 kg), respectively (Muhammad et al, 2010).

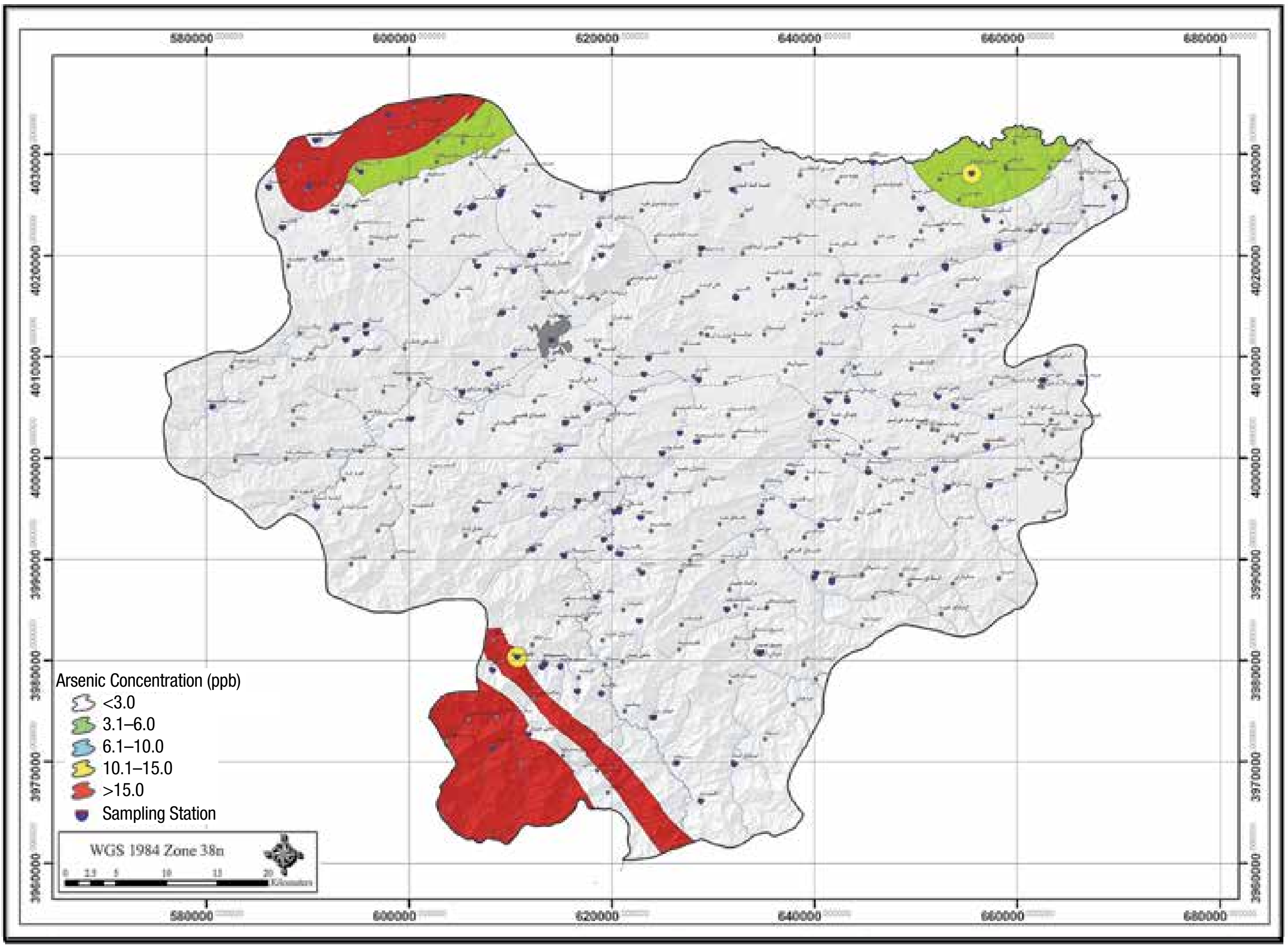
To estimate the noncarcinogenic/chronic risk, HQ can be calculated using the following equation (Khan et al., 2008):

$$HQ = ADD/RfD$$

Where, according to the U.S. EPA database, the oral toxicity reference dose values (RfD) are 0.30, 1.50, 0.02, 0.14, 3.00×10^{-4}, 1.40×10^{-3}, 5.00×10^{-3}, and 3.00×10^{-5} mg/kg/day for Zn, Cr, Ni, Mn, As, Co, Fe, Mo, and Hg, respectively (Goyer et al., 2004). The exposed population is assumed to be safe when HQ < 1 (Shah, Ara, Muhammad, Khan, & Tariq, 2012).

FIGURE **2**

Spatial Distribution of Arsenic in Saqqez, Iran



Descriptive statistics were calculated using Excel 2013 software. The univariate and multivariate statistical analysis such as one-way ANOVA procedure, intermetals correlation, cluster analysis, and principal component analysis were performed using SPSS software version 20.

Results and Discussion

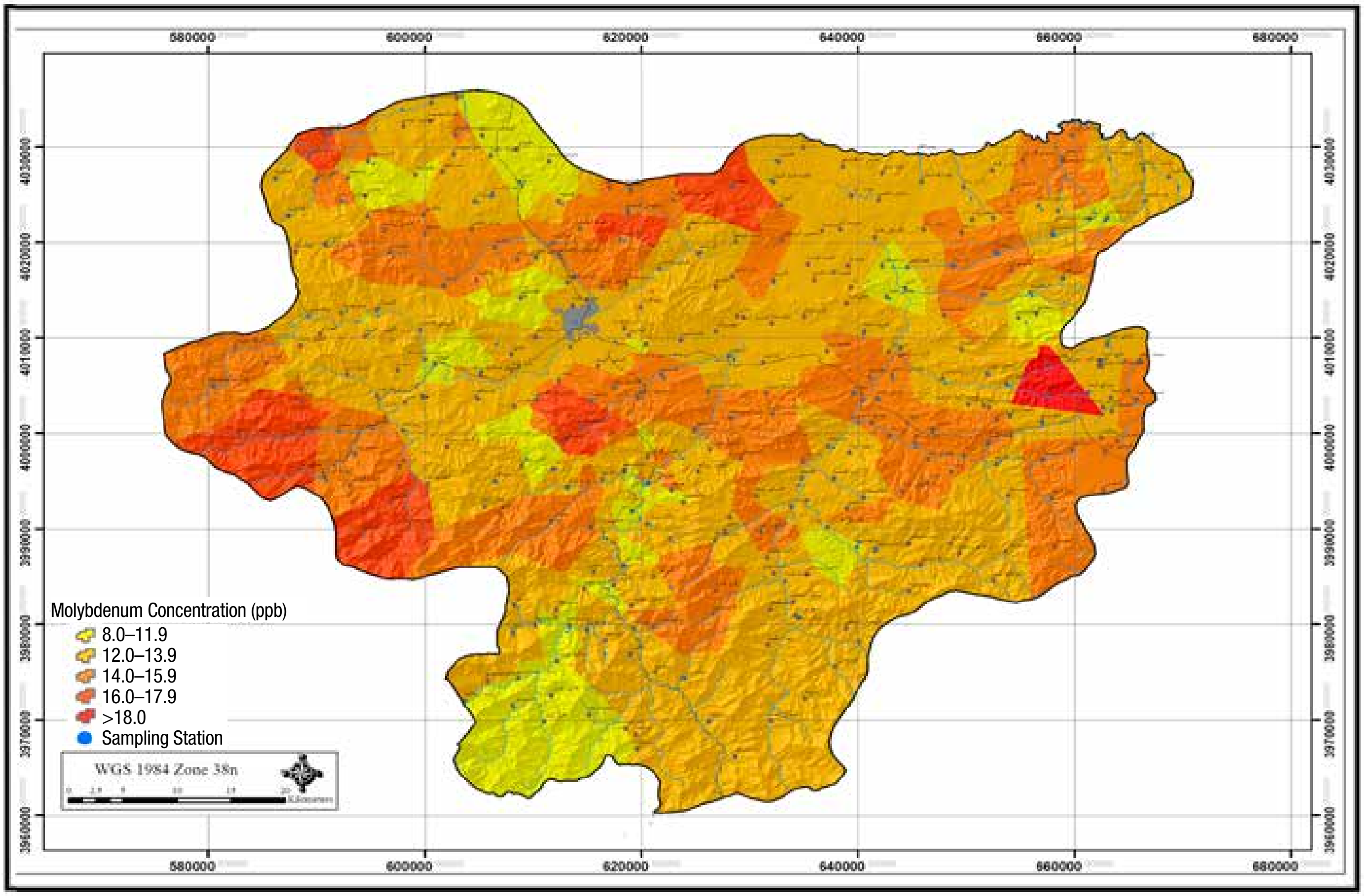
Drinking Water Contamination

Selected parameters in drinking water samples collected from different sources (spring, well, and tank) from 150 villages are summarized in Table 1. The mean concentration of HMs in drinking water from different sources were found in order of Fe > Zn > Cr > Mo > Ni > Co > As > Hg > Mn, respectively. The Fe, Zn, Cr, Mo, Ni, Co, As, Hg, and Mn mean concentrations of all water sources sampled in this study were within their expected permissible limit set by WHO and U.S. EPA (Table 1). Gul and coauthors (2015) analyzed water samples for As, Cd, Co, Cu, Cr, Hg, Ni, Pb, and Zn. Concentrations of HMs in drinking water showed the highest pollution index values: 17.80, 11.92, 7.50, and 5.70 for Pb, Cr, Cd, and Ni, respectively. The contaminations of Cd and Pb were significantly higher ($p < .05$) than their maximum allowable limits set by WHO (Gul, Shah, Khan, Khattak, & Muhammad, 2015).

Bortey-Sam and coauthors (2015) assessed the health risk associated with HMs and metalloids in borehole drinking water in Tarkwa, Ghana. Hazard index values indicating noncarcinogenic health risk for adults and children in Huniso, Ghana, were 0.781 (low risk) and 1.08 (medium risk), respectively. Based on the U.S. EPA assessment, the average cancer risk values of As for adults (3.65 x 10^{-5}) and children (5.08 x 10^{-5}) indicated three (adults) and five (children) cases of neoplasm in 100,000 inhabitants (Bortey-Sam et al., 2015).

FIGURE 3

Spatial Distribution of Molybdenum in Saqqez, Iran



Known as one of the most toxic pollutants in the world, Cr naturally occurs in rocks and soil. The highest Cr concentration (19.90 µg/L) was observed in tank water samples, which is within WHO and U.S. EPA permissible limits.

Quite common in basic and ultrabasic rocks, Co is a rare metal existing in porphyritic igneous rocks in small quantities (Dixon, 2012). The highest Co concentration (9.40 µg/L) was observed in samples collected from well sources, which is within the WHO permissible limit.

Fe is an essential mineral for normal physiology of the body and physical health. Fe deficiency causes anemia, which is common during malnutrition. In three villages, Fe concentrations were 2,041, 400, and 390 µg/L, which are higher than the WHO permissible limit. Spatial distribution of Fe at different stations is presented in Figure 1.

The contamination of water with As, derived from anthropogenic and geological sources, has disastrous and life-threatening consequences (Arain et al., 2008; Brahman et al., 2013). Consumption of contaminated drinking water adversely affects human health worldwide (Arain et al., 2009). In four villages, As concentrations were 12.7, 39.5, 69.0, and 71.2 µg/L, which is much higher than the WHO permissible limit. Spatial distribution of As at different stations is presented in Figure 2.

An essential trace element, Mn acts as a cofactor for many enzymes (Crowley, Traynor, & Weatherburn, 2000). Mn concentrations in all villages were within its permissible limit set by WHO.

In one village alone, the Mo concentration of water from one well was 124 µg/L, which is much higher than the U.S. EPA permissible limit. Spatial distribution of Mo at different stations is presented in Figure 3.

Zn is an essential trace element and plays an important role in various cell processes including normal growth, brain development, behavioral response, bone formation, and wound healing (Jabeen, Shah, Khan, & Hayat, 2010). The daily requirement of an adult of 70 kg for Zn is 15 mg (Khan, 2011). The highest Zn concentration was 393 µg/L, which is within permissible limits set by WHO and U.S. EPA.

The long-term or occupational exposure of Ni causes the following effects: decrease in body weight, cardiac and hepatic damages, and skin irritation (Pirsaheb, Khamutian, &

TABLE 2

Average Daily Dose (ADD) Indices for Heavy Metals via Drinking Water (µg/kg/day)

Heavy Metal	Total	Statistics	ADD Index		
			Well (n = 36)	Spring (n = 15)	Tank (n = 99)
As	0.07	Mean	0.05	0.14	0.06
		SD	0.18	0.50	0.27
Cr	0.49	Mean	0.49	0.49	0.49
		SD	0.02	0.02	0.03
Co	0.21	Mean	0.21	0.21	0.20
		SD	0.02	0.02	0.02
Fe	1.94	Mean	3.20	1.40	1.57
		SD	9.27	1.37	1.74
Mn	0.03	Mean	0.06	0	0.24
		SD	0.32	0	0.11
Mo	0.39	Mean	0.45	0.38	0.37
		SD	0.51	0.03	0.07
Zn	0.75	Mean	0.61	0.31	0.86
		SD	0.78	0.31	2.18
Ni	0.25	Mean	0.26	0.24	0.25
		SD	0.08	0.03	0.04
Hg	0.03	Mean	0.03	0.02	0.03
		SD	0.02	0.01	0.02

As = arsenic; Cr = chromium; Co = cobalt; Fe = iron; Mn = manganese; Mo = molybdenum; Zn = zinc; Ni = nickel; Hg = mercury.

Pourhaghighat, 2015). The highest Ni concentration (24.4 µg/L) was observed in a well water sample, which is above U.S. EPA permissible limit. Ni contamination could result from the erosion of mafic and ultramafic rocks (Khan et al., 2013).

Exposure to high levels of metallic, inorganic, or organic Hg can permanently damage the brain, kidneys, and developing fetus (Graeme & Pollack, 1998). Hg concentration in all samples were within the permissible limits set by WHO and U.S. EPA.

Statistical Analysis

A comparison of mean concentrations of HMs between well, spring, and tank water with WHO and U.S. EPA permissible limits is shown in Table 1. Mean values of some HMs such as Cr, Co, and Ni were similar in well, spring, and tank water sources. Hg mean values were similar in both well and tank water sources but higher than spring water. Mean concentrations of As were similar in both well and tank water sources, but lower than spring water. There were no significant variations of concentrations of HMs between well, spring, and tank sources (p > .05) (see online supplemental table 1).

One-way ANOVA comparison of selected HM pollution for different geographical directions in the target area was performed (see online supplemental table 2). No significant difference of HM concentrations between different geographical directions was observed (p > .05). The same finding was observed in the case of the ground slope.

Human Health Risk Assessment

In the study area, inhabitants were interviewed for age, sex, health status, dietary habits, and drinking water source information. The residents were generally using groundwater (well, spring, and tank) for drinking and other domestic purposes. Therefore, groundwaters that were used for drinking purposes were also selected for HM risk assessment such as ADD and HQ indices.

The ADD values of selected HMs are summarized in Table 2. Based on the drinking water quality in the study area, the ADD values of HMs were found in the order of Fe > Zn > Cr > Mo > Ni > Co > As > Hg > Mn from well, spring, and tank water consumption, respectively. Table 3 summarizes the health risk indices (HRI) of HMs through consumption of drinking water in the study area.

Mean HRI values for Hg in well and tank water sources were above 1; therefore, these resources might not be safe for the consumers (Muhammad et al., 2011). Nevertheless, the mean HRI calculated was less than unity (except Hg), because mean concentration was considered for its calculation, so there might be some villages where the HRI for some HMs are above unity. Thus, it is necessary to screen the water sources for HMs much better. The HRI of Cr, Mn, Ni, and Zn, however, were lower in this study compared with studies conducted previously (Fakhri & Mirzaei, 2015; Sakizadeh & Mirzaei, 2016; Shah et al., 2012).

The intermetal correlation analysis provides valuable information about the concentrations of HMs and their respective pathway (Manta, Angelone, Bellanca, Neri, & Sprovieri, 2002). The correlation analysis showed positive significant correlations in some pairs of HMs such as As–Mn (r = 0.237), As–Co (r = 0.199), Mn–Zn (r = 0.206), Mo–Ni (r = 0.651), and Zn–Ni (r = 0.268) (see online supplemental table 3).

In well water, some HMs showed positive correlation such as Mn–As (r = 0.955), Mo–Zn (r = 0.813), Mo–Ni (r = 0.885), and Zn–Ni (r = 0.762). In spring water samples, the correlation analysis revealed positive correlations in several metal pairs such us As–Co (r = 0.714), As–Ni (r = 0.541), and Zn–Fe (r = 0.807). In the case of tank water samples, the correlation analysis revealed positive correlations in several metal pairs such as Fe–Zn (r = 0.480), Fe–Ni (r = 0.236), Mn–Zn (r = 0.376), and Zn–Ni (r = 0.234) (see online supplemental tables 4–6).

The intermetal correlation analysis was performed in different geographical directions and positive correlations for some HMs were found. In the northern direction, the correlation analysis was significant at the 0.01 level for some HMs such as As–Mn (r = 0.815), Cr–Fe (r = 0.288), Zn–Mo (r = 0.295), Mo–Ni (r = 0.792), and Zn–Ni (r = 0.446) (see online supplemental tables 7–10).

The intermetal correlation analysis of selected HMs was done in water sources

TABLE 3

Health Risk Indices (HRI) for Heavy Metals via Drinking Water (µg/kg/day)

Heavy Metal	Total	Statistics	HRI		
			Well (n = 36)	Spring (n = 15)	Tank (n = 99)
As	0.240	Mean	0.195	0.479	0.220
	0.956	*SD*	0.619	1.692	0.928
Cr	0.00033	Mean	0.00033	0.00032	0.00033
	0.00002	*SD*	0.00001	0.00001	0.00002
Co	0.150	Mean	0.154	0.153	0.148
	0.016	*SD*	0.015	0.018	0.016
Fe	0.002	Mean	0.004	0.002	0.002
	0.007	*SD*	0.013	0.002	0.002
Mn	0.00023	Mean	0.00048	0.00003	0.00017
	0.00132	*SD*	0.00232	0	0.00083
Mo	0.079	Mean	0.091	0.076	0.075
	0.052	*SD*	0.102	0.007	0.015
Zn	0.002	Mean	0.002	0.001	0.002
	0.006	*SD*	0.003	0.001	0.007
Ni	0.012	Mean	0.013	0.012	0.012
	0.003	*SD*	0.004	0.002	0.002
Hg	1.24	Mean	1.30	0.918	1.26
	0.70	*SD*	0.69	0.516	0.72

As = arsenic; Cr = chromium; Co = cobalt; Fe = iron; Mn = manganese; Mo = molybdenum; Zn = zinc; Ni = nickel; Hg = mercury.

with different ground slopes, indicating positive correlations in some HM pairs. In zero-degree slope grounds, all pairs had significant correlation (positive and negative). In 0–8-degree slope ground, positive significant correlations in some HM pairs such as As–Mn (r = 0.818), Cr–Fe (r = 0.399), Mo–Ni (r = 0.841), Zn–Ni (r = 0.469), and Mo–Zn (r = 0.306), and negative significant correlations were noted for Cr–Hg (r = -0.446) and Co–Hg (r = -0.311) pairs (see online supplemental tables 11–15).

Conclusion

The research found that the HM concentration was the highest for Fe, followed by > Zn > Cr > Mo > Ni > Co > As > Hg > Mn in the drinking water collected from well, spring, and tank sources of Saqqez, Iran. Fe, Zn, Cr, Mo, Ni, Co, As, Hg, and Mn mean concentrations in all water sources were found within the limits set by WHO and U.S. EPA. In some stations, however, the concentration of Fe, As, and Mo was higher than national and international standards. The ANOVA analysis showed that that HM concentration at different sources, slopes, and geographical directions did not vary significantly. Intermetal correlation of HMs in different sources, geographical directions, and slopes showed a strong correlation between HM pairs.

According to health risk assessment, health risk was observed for Hg in well and tank water sources (HRI > 1) based on U.S. EPA standards, while multifold higher concentrations of Fe and As might pose potential health risks to the local inhabitants and some of the selected HMs exceeded their safe levels. Therefore, it is strongly recommended that water from contaminated locations should not be used for drinking purposes without proper treatment. The Iranian government should provide drinking water alternatives to these areas in recognition of the potential health risks associated with HMs.

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References

Agency for Toxic Substances and Disease Registry. (2015). *Toxic substances portal—Arsenic*. Retrieved from https://www.atsdr.cdc.gov/toxprofiles/TP.asp?id=22&tid=3

Agusa, T., Kunito, T., Fujihara, J., Kubota, R., Minh, T.B., Trang, P.T.K., & Iwata, H. (2006). Contamination by arsenic and other trace elements in tube-well water and its risk assessment to humans in Hanoi, Vietnam. *Environmental Pollution, 139*(1), 95–106.

Arain, M.B., Kazi, T.G., Baig, J.A., Jamali, M.K., Afridi, H.I., Jalbani, N., . . . Kandhro, G.A. (2009). Respiratory effects in people exposed to arsenic via the drinking water and tobacco smoking in southern part of Pakistan. *Science of the Total Environment, 407*(21), 5524–5530.

Arain, M.B., Kazi, T.G., Jamali, M.K., Jalbani, N., Afridi, H.I., & Shah, A. (2008). Total dissolved and bioavailable elements in water and sediment samples and their accumulation in Oreochromis mossambicus of polluted Manchar Lake. *Chemosphere, 70*(10), 1845–1856.

References

Awodele, O., Popoola, T.D., Amadi, K.C., Coker, H.A., & Akintonwa, A. (2013). Traditional medicinal plants in Nigeria—Remedies or risks. *Journal of Ethnopharmacology, 150*(2), 614–618.

Azizullah, A., Khattak, M.N.K., Richter, P., & Häder, D.-P. (2011). Water pollution in Pakistan and its impact on public health—A review. *Environment International, 37*(2), 479–497.

Bloom, M.S., Surdu, S., Neamtiu, I.A., & Gurzau, E.S. (2014). Maternal arsenic exposure and birth outcomes: A comprehensive review of the epidemiologic literature focused on drinking water. *International Journal of Hygiene and Environmental Health, 217*(7), 709–719.

Bortey-Sam, N., Nakayama, S.M., Ikenaka, Y., Akoto, O., Baidoo, E., Mizukawa, H., & Ishizuka, M. (2015). Health risk assessment of heavy metals and metalloid in drinking water from communities near gold mines in Tarkwa, Ghana. *Environmental Monitoring and Assessment, 187*(7), 397.

Brahman, K.D., Kazi, T.G., Afridi, H.I., Naseem, S., Arain, S.S., & Ullah, N. (2013). Evaluation of high levels of fluoride, arsenic species and other physicochemical parameters in underground water of two sub districts of Tharparkar, Pakistan: A multivariate study. *Water Research, 47*(3), 1005–1020.

Buschmann, J., Berg, M., Stengel, C., & Sampson, M.L. (2007). Arsenic and manganese contamination of drinking water resources in Cambodia: Coincidence of risk areas with low relief topography. *Environmental Science & Technology, 41*(7), 2146–2152.

Crowley, J.D., Traynor, D.A., & Weatherburn, D.C. (2000). Enzymes and proteins containing manganese: An overview. *Metal Ions in Biological Systems, 37*, 209–278.

Demirak, A., Yilmaz, F., Tuna, A.L., & Ozdemir, N. (2006). Heavy metals in water, sediment and tissues of *Leuciscus cephalus* from a stream in southwestern Turkey. *Chemosphere, 63*(9), 1451–1458.

Dixon, C.J. (Ed.). (2012). *Atlas of economic mineral deposits*. New York, NY: Springer Science & Business Media.

Espinoza-Quiñones, F.R., Módenes, A.N., de Pauli, A.R., & Palácio, S.M. (2015). Analysis of trace elements in groundwater using ICP-OES and TXRF techniques and its compliance with Brazilian protection standards. *Water, Air, & Soil Pollution, 226*, 32.

Ettler, V., Křı́bek, B., Majer, V., Knésl, I., & Mihaljevič, M. (2012). Differences in the bioaccessibility of metals/metalloids in soils from mining and smelting areas (Copperbelt, Zambia). *Fuel and Energy Abstracts, 113*, 68–75.

Fakhri, Y., & Mirzaei, M. (2015). Determination concentration of Radon 222 in tap drinking water, Jask City, Iran. *IOSR Journal of Environmental Science, Toxicology and Food Technology, 9*(8), 6–9.

Farías, S.S., Casa, V.A., Vázquez, C., Ferpozzi, L., Pucci, G.N., & Cohen, I.M. (2003). Natural contamination with arsenic and other trace elements in ground waters of Argentine Pampean Plain. *Science of the Total Environment, 309*(1–3), 187–199.

García-Lorenzo, M.L., Pérez-Sirvent, C., Martínez-Sánchez, M.J., & Molina-Ruiz, J. (2012). Trace elements contamination in an abandoned mining site in a semiarid zone. *Journal of Geochemical Exploration, 113*, 23–35.

Goyer, R., Golub, M., Choudhury, H., Hughes, M., Kenyon E., & Stifelman, M. (2004). *Issue paper on the human health effects of metals*. Washington, DC: U.S. Environmental Protection Agency Risk Assessment Forum. Retrieved from https://www.epa.gov/sites/production/files/2014-11/documents/human_health_effects.pdf

Graeme, K.A., & Pollack, C.V., Jr. (1998). Heavy metal toxicity, Part I: Arsenic and mercury. *The Journal of Emergency Medicine, 16*(1), 45–56.

Granero, S., & Domingo, J.L. (2002). Levels of metals in soils of Alcalá de Henares, Spain: Human health risks. *Environment International, 28*(3), 159–164.

Gul, N., Shah, M.T., Khan, S., Khattak, N.U., & Muhammad, S. (2015). Arsenic and heavy metals contamination, risk assessment and their source in drinking water of the Mardan District, Khyber Pakhtunkhwa, Pakistan. *Journal of Water and Health, 13*(4), 1073–1084.

Hoaghia, M.-A., Roman, C., Kovacs, E.D., Tanaselia, C., & Ristoiu, D. (2016). The evaluation of the metal contamination of drinking water sources from Medias town, Romania using the metal pollution indices. *Studia Universitatis Babes-Bolyai, Chemia, 61*, 461–471.

Jabeen, S., Shah, M.T., Khan, S., & Hayat, M.Q. (2010). Determination of major and trace elements in ten important folk therapeutic plants of Haripur basin, Pakistan. *Journal of Medicinal Plants Research, 4*(7), 559–566.

Jang, C.-S. (2010). Applying scores of multivariate statistical analyses to characterize relationships between hydrochemical properties and geological origins of springs in Taiwan. *Journal of Geochemical Exploration, 105*(1–2), 11–18.

Kavcar, P., Sofuoglu, A., & Sofuoglu, S.C. (2009). A health risk assessment for exposure to trace metals via drinking water ingestion pathway. *International Journal of Hygiene and Environmental Health, 212*(2), 216–227.

Kelepertzis, E. (2014). Investigating the sources and potential health risks of environmental contaminants in the soils and drinking waters from the rural clusters in Thiva area (Greece). *Ecotoxicology and Environmental Safety, 100*, 258–265.

Khalil, M.Kh., Radwan, A.M., & El-Moselhy, Kh.M. (2007). Distribution of phosphorus fractions and some of heavy metals in surface sediments of Burullus lagoon and adjacent Mediterranean Sea. *Egyptian Journal of Aquatic Research, 33*(1), 277–289.

Khan, K., Lu, Y., Khan, H., Zakir, S., Ihsanullah, Khan, S., . . . Wang, T. (2013). Health risks associated with heavy metals in the drinking water of Swat, northern Pakistan. *Journal of Environmental Sciences, 25*(10), 2003–2013.

Khan, S., Cao, Q., Zheng, Y.M., Huang, Y.Z., & Zhu, Y.G. (2008). Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environmental Pollution, 152*(3), 686–692.

References

Khan, T.A. (2011). Trace elements in the drinking water and their possible health effects in Aligarh City, India. *Journal of Water Resource and Protection, 3*(7), 522–530.

Manta, D.S., Angelone, M., Bellanca, A., Neri, R., & Sprovieri, M. (2002). Heavy metals in urban soils: A case study from the city of Palermo (Sicily), Italy. *Science of the Total Environment, 300*(1), 229–243.

Mkude, I.T. (2015). Comparative analysis of heavy metals from groundwater sources situated in Keko and Kigogo Residential Areas, Dar es Salaam. *Journal of Water Resources and Ocean Science, 4*(1), 1–5.

Muhammad, S., Tahir Shah, M., & Khan, S. (2010). Arsenic health risk assessment in drinking water and source apportionment using multivariate statistical techniques in Kohistan region, northern Pakistan. *Food and Chemical Toxicology, 48*(10), 2855–2864.

Muhammad, S., Tahir Shah, M., & Khan, S. (2011). Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, northern Pakistan. *Microchemical Journal, 98*(2), 334–343.

Okoro, H.K., Adeyinka, A., Jondiko, O.E., Ximba, B.J., & Kakalanga, S.J. (2012). Assessment of heavy metals contamination in groundwater: A case study of central industrial district in Ilorin, Kwara State, Nigeria. *International Journal of Physical Sciences, 7*(28), 5078–5088.

Oves, M., Saghir Khan, M., Huda Qari, A., Nadeen Felemban, M., & Almeelbi, T. (2016). Heavy metals: Biological importance and detoxification strategies. *Journal of Bioremediation and Biodegradation, 7*(2).

Oyebog, S.A., Ako, A.A., Nkeng, G.E., & Suh, E.C. (2012). Hydrogeochemical characteristics of some Cameroon bottled waters, investigated by multivariate statistical analyses. *Journal of Geochemical Exploration, 112*, 118–130.

Pekey, H., Karakaş, D., & Bakoglu, M. (2004). Source apportionment of trace metals in surface waters of a polluted stream using multivariate statistical analyses. *Marine Pollution Bulletin, 49*(9–10), 809–818.

Pirsaheb, M., Khamutian, R., & Pourhaghighat, S. (2015). Review of heavy metal concentrations in Iranian water resources. *International Journal of Health and Life Sciences, 1*(1), 35–45.

Pirsaheb, M., Khosravi, T., Sharafi, K., Babajani, L., & Rezaei, M. (2013). Measurement of heavy metals concentration in drinking water from source to consumption site in Kermanshah—Iran. *World Applied Sciences Journal, 21*(3), 416–423.

Raju, O.V.S., Prasad, P.M.N., Varalakshmi, V., & Reddy, Y.V.R. (2014). Determination of heavy metals in ground water by ICP-OES in selected coastal area of Spsr Nellore district, Andhra Pradesh, India. *International Journal of Innovative Research in Science, Engineering and Technology*, *3*(2), 9743–9749.

Sakizadeh, M., & Mirzaei, R. (2016). Health risk assessment of Fe, Mn, Cu, Cr in drinking water in some wells and springs of Shush and Andimeshk, Khuzestan Province, Southern Iran. *Iranian Journal of Toxicology, 10*(2), 29–35.

Sarojam, P. (2010). *Analysis of wastewater for metals using ICP-OES*. Shelton, CT: PerkinElmer, Inc.

Shah, M.T., Ara, J., Muhammad, S., Khan, S., & Tariq, S. (2012). Health risk assessment via surface water and sub-surface water consumption in the mafic and ultramafic terrain, Mohmand agency, northern Pakistan. *Journal of Geochemical Exploration, 118*, 60–67.

Singh, R.P., Kumar, S., Nada, R., & Prasad, R. (2006). Evaluation of copper toxicity in isolated human peripheral blood mononuclear cells and its attenuation by zinc: Ex vivo. *Molecular and Cellular Biochemistry, 282*(1–2), 13–21.

U.S. Environmental Protection Agency. (2017). *U.S. EPA Integrated risk information system*. Retrieved from https://www.epa.gov/iris

Wcisło, E., Ioven, D., Kucharski, R., & Szdzuj, J. (2002). Human health risk assessment case study: An abandoned metal smelter site in Poland. *Chemosphere, 47*(5), 507–515.