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

Special Invitation to NEHA Members

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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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.

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.

We should welcome opportunities to demonstrate the ongoing value of environmental health 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

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 SCCmec 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, & Saura, 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, Provence, & 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.

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.

Brandon A. Haghighidian, MD
Hospital of the University of Pennsylvania
Nimesh Patel
Touro University College of Osteopathic Medicine in California
Lisa Wang, RN, CCRN
Stanford University Medical Center
Joshua A. Cotter, PhD
California State University, Long Beach
The purpose of this study is twofold: 1) to demonstrate the prevalence of \textit{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 \textit{S. aureus} between the gym floor and athlete’s hands. We elected to study the transmission of \textit{S. aureus} as a model for CA-MRSA, as the greater environmental prevalence of \textit{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 \textit{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 \textit{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 \textit{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.
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.

**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.
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 Staphylococcus 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).

**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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**Corresponding Author:** Brandon A. Haghverdian, Department of Orthopaedic Surgery, Hospital of the University of Pennsylvania, 3737 Market Street, 6th Floor, Philadelphia, PA 19104. E-mail: brandon.haghverdian@uphs.upenn.edu.

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**References**


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

Patrick Chang, MPH
Haresh Rochani, DrPH
Department of Biostatistics
Jiann-Ping Hsu College of Public Health
Georgia Southern University
William A. Mase, DrPH
Jeffery A. Jones, PhD
Department of Health Policy and Management
Jiann-Ping Hsu College of Public Health
Georgia Southern University
Asli Aslan, PhD
Department of Environmental Health
Jiann-Ping Hsu College of Public Health
Georgia Southern University

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 (Beke meier, 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 to data and methodologies allow for a more detailed examination of the relationship between food safety code violations and risk classifications at the Cincinnati food service operations. The primary aim of this study was to explore the relationship between the Ohio uniform 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.

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.
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 3701-21-0.23 (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 finally, 3) random slope and intercept (Browne & Rasbash, 2004). The general forms of the models are as follows:

Model 1: Random Intercept

\[ Y_{ij} = \beta_0 + \beta_1 X_{ij} + \epsilon_{ij} \]

Model 2: Random Slope

\[ Y_{ij} = \beta_0 + \beta_1 X_{ij} + \epsilon_{ij} \]

Model 3: Random Slope and Intercept

\[ Y_{ij} = \beta_0 + \beta_1 X_{ij} + \beta_2 \text{Risk class} + \epsilon_{ij} \]

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 1**

Ohio Safety Code Violation Types

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

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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 VNFRFSPS 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 incidence 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
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.

**Acknowledgements:** The authors would like to thank CHD for providing the data and participating in the study. Special thanks to Dr. Mohammad Alam, Gail Long-Cook, Dale Grigsby, Dr. Camille Jones, Ken Sharkey, and all members of CHD’s Division of Food Safety who have worked in the food safety program and collected the data utilized in the analysis. This research was funded by FDA grant 4U18FD004688-04. Approval was granted by the Georgia Southern University IRB #H16255.

**Corresponding Author:** William A. Mase, Assistant Professor, Department of Health Policy and Management, Jiann-Ping Hsu College of Public Health, Georgia Southern University, 501 Forest Drive, Statesboro, GA 30458-8015. E-mail: wmase@georgiasouthern.edu.

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**References**


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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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2004 - Peter D. Thornton
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Predictors of Radon Testing Among Utah Residents Using a Theory-Based Approach

Siena F. Davis, MPH
James D. Johnston, PhD, CIH
Brianna M. Magnusson, PhD
M. Lelinneth B. Novilla, MPH, MD
Breanna K. Torgersen
Abigail J. Schnell
AliceAnn Crandall, PhD
Department of Health Science
Brigham Young University

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 (222Rn) 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/m³ (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 (238U) 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-Mayron, & 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).
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 tested for radon 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/m³ (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 sur-
vey 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.

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).
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...
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.

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**

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

*aScale score, items averaged.

*bScale response ranges: 1 (strongly disagree) to 5 (strongly agree).
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 Commu-
nity 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.

Acknowledgement: We would like to thank UCHD staff and administration for their support.

Corresponding Author: James D. Johnston, Associate Professor, Department of Health Science, Brigham Young University, 2045 Life Sciences Building, Provo, UT 84602. E-mail: james_johnston@byu.edu.

References


**References**
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;
• 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 Solutions’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.

Corresponding Author: Gregory Miao, Staff Attorney, ChangeLab Solutions, 2201 Broadway, Suite 502, Oakland, CA 94612. E-mail: gmiao@changelabsolutions.org.

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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

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.

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3. a 6. d 9. c 12. b
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**Nevada**—Erin Cavin, REHS, Environmental Health Specialist II, Southern Nevada Health District, Las Vegas, NV. nevadaeha@gmail.com

**New Jersey**—Paschal Nwako, MPH, PhD, REHS, CHES, DAAS, Health Officer, Camden County Health Dept., Blackwood, NJ. pn2@njlincs.net

**New Mexico**—Cecilia Garcia, MS, CP-FS, Environmental Health Specialist, City of Albuquerque Environmental Health Dept., Albuquerque, NM. cgarcia@cabq.gov

**New York**—Contact Region 9 Vice-President Larry Ramdin. lramdin@lchd.org

**North Carolina**—Victoria Hudson, Rochkimgton, NC. vhudson@orangeountync.gov

**North Dakota**—Grant Larson, Fargo Cass Public Health, Fargo, ND. glarson@cityoffargo.com
## NEHA ORGANIZATIONAL MEMBERS

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| Waco-McLennan County Public Health District | www.waco-texas.com/cms-healthdepartment |
| Waukesha County Environmental Health Division | www.waukeshacounty.gov/ehcontact |
| West Virginia Department of Health and Human Resources, Office of Environmental Health Services | www.dhhr.wv.gov |
| Yakima Health District | www.yakimacounty.us/275/Health-District |

## Educational Members

| Baylor University | www.baylor.edu |
| Eastern Kentucky University | http://chs.eku.edu |
| Michigan State University Extension | www.msuextension.msu.edu |
| Michigan State University, Online Master of Science in Food Safety | www.online.foodsafety.msu.edu |
| Old Dominion University | www.odu.edu/commhealth |
| The University of Findlay | 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 | www.uhs.wisc.edu |
| University of Wisconsin–Oshkosh, Lifelong Learning & Community Engagement | www.uwo.edu/llec |
| University of Wisconsin–Stout, College of Science, Technology, Engineering, and Mathematics | www.uwsstout.edu |
2018 Walter S. Mangold Award

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

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

Nomination deadline is March 15, 2018.

To access the online application, visit www.neha.org/about-neha/awards/walter-s-mangold-award.

2018 Joe Beck Educational Contribution Award

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

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

Nomination deadline is March 15, 2018.

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

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).
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.

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.

DirecTalk
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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.

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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.

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.

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/pdfs/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 investment.
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Evaluation and Risk Assessment of Heavy Metals in the Groundwater Resources of Saqqez, Iran

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, Kříbek, Majer, Kněsl, & Mihaljević, 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, Karakas, & 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

<table>
<thead>
<tr>
<th>Heavy Metal</th>
<th>Total</th>
<th>Statistics</th>
<th>Heavy Metal Concentration</th>
<th>Permissible Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Well (n = 36)</td>
<td>Spring (n = 15)</td>
</tr>
<tr>
<td>As</td>
<td>2.60</td>
<td>Mean</td>
<td>2.12</td>
<td>5.18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>6.69</td>
<td>18.27</td>
</tr>
<tr>
<td>Cr</td>
<td>17.94</td>
<td>Mean</td>
<td>17.96</td>
<td>17.76</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.85</td>
<td>0.86</td>
</tr>
<tr>
<td>Co</td>
<td>7.53</td>
<td>Mean</td>
<td>7.79</td>
<td>7.72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.77</td>
<td>0.90</td>
</tr>
<tr>
<td>Fe</td>
<td>70.15</td>
<td>Mean</td>
<td>115.44</td>
<td>50.69</td>
</tr>
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<td></td>
<td></td>
<td>SD</td>
<td>334.01</td>
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</tr>
<tr>
<td>Mn</td>
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<td>Mean</td>
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<td>0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>11.72</td>
<td>1.22</td>
</tr>
<tr>
<td>Mo</td>
<td>14.33</td>
<td>Mean</td>
<td>16.41</td>
<td>13.82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>18.52</td>
<td>1.22</td>
</tr>
<tr>
<td>Zn</td>
<td>27.24</td>
<td>Mean</td>
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<td>11.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>28.11</td>
<td>11.27</td>
</tr>
<tr>
<td>Ni</td>
<td>9.12</td>
<td>Mean</td>
<td>9.40</td>
<td>8.82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>2.93</td>
<td>1.25</td>
</tr>
<tr>
<td>Hg</td>
<td>1.34</td>
<td>Mean</td>
<td>1.40</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>0.75</td>
<td>0.56</td>
</tr>
</tbody>
</table>

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.

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
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-Quíñones, Módenes, de Pauli, & Palacio, 2015; Raju, Prasad, Varalakshmi, & Reddy, 2014; Sanojam, 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):

\[
HQ = \frac{ADD}{RfD}
\]

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 x 10^{-4}, 1.40 x 10^{-3}, 5.00 x 10^{-3}, and 3.00 x 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).
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 non-carcinogenic 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).
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, &
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 as 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 such as arsenic; Cr = chromium; Co = cobalt; Fe = iron; Mn = manganese; Mo = molybdenum; Zn = zinc; Ni = nickel; Hg = mercury.

<table>
<thead>
<tr>
<th>Heavy Metal</th>
<th>Total</th>
<th>Statistics</th>
<th>Well (n = 36)</th>
<th>Spring (n = 15)</th>
<th>Tank (n = 99)</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>0.07</td>
<td>Mean</td>
<td>0.05</td>
<td>0.14</td>
<td>0.06</td>
</tr>
<tr>
<td>Cr</td>
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<td>Mean</td>
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<td>0.49</td>
<td>0.49</td>
</tr>
<tr>
<td>Co</td>
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<td>Mean</td>
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<td>0.21</td>
<td>0.20</td>
</tr>
<tr>
<td>Fe</td>
<td>1.94</td>
<td>Mean</td>
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<td>1.57</td>
</tr>
<tr>
<td>Mn</td>
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<td>Mean</td>
<td>0.06</td>
<td>0.06</td>
<td>0.24</td>
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<tr>
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<td>Mean</td>
<td>0.45</td>
<td>0.38</td>
<td>0.37</td>
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<tr>
<td>Zn</td>
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<tr>
<td>Ni</td>
<td>0.25</td>
<td>Mean</td>
<td>0.26</td>
<td>0.24</td>
<td>0.25</td>
</tr>
<tr>
<td>Hg</td>
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<td>Mean</td>
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<td>0.02</td>
<td>0.03</td>
</tr>
</tbody>
</table>

As = arsenic; Cr = chromium; Co = cobalt; Fe = iron; Mn = manganese; Mo = molybdenum; Zn = zinc; Ni = nickel; Hg = mercury.
TABLE 3

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

<table>
<thead>
<tr>
<th>Heavy Metal</th>
<th>Total</th>
<th>Statistics</th>
<th>Well (n = 36)</th>
<th>Spring (n = 15)</th>
<th>Tank (n = 99)</th>
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</thead>
<tbody>
<tr>
<td>As</td>
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<td>Mean</td>
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<td></td>
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<td>0.928</td>
</tr>
<tr>
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<td>Mean</td>
<td>0.00033</td>
<td>0.00032</td>
<td>0.00033</td>
</tr>
<tr>
<td></td>
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<td>0.00001</td>
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<tr>
<td>Co</td>
<td>0.150</td>
<td>Mean</td>
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<td>0.153</td>
<td>0.148</td>
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<tr>
<td></td>
<td>0.016</td>
<td>SD</td>
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</tr>
<tr>
<td>Fe</td>
<td>0.002</td>
<td>Mean</td>
<td>0.004</td>
<td>0.002</td>
<td>0.002</td>
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<tr>
<td></td>
<td>0.007</td>
<td>SD</td>
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<td>0.002</td>
<td>0.002</td>
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<td>Mn</td>
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<td>SD</td>
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<td>0.001</td>
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<td>SD</td>
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<td>0.002</td>
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<tr>
<td>Hg</td>
<td>1.24</td>
<td>Mean</td>
<td>1.30</td>
<td>0.918</td>
<td>1.26</td>
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<td></td>
<td>0.70</td>
<td>SD</td>
<td>0.69</td>
<td>0.516</td>
<td>0.72</td>
</tr>
</tbody>
</table>

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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Corresponding Author: Behzad Shahmoradi, Environmental Health Research Center, Kurdistan University of Medical Sciences, Sanandaj, Iran. E-mail: bshahmorady@gmail.com.

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