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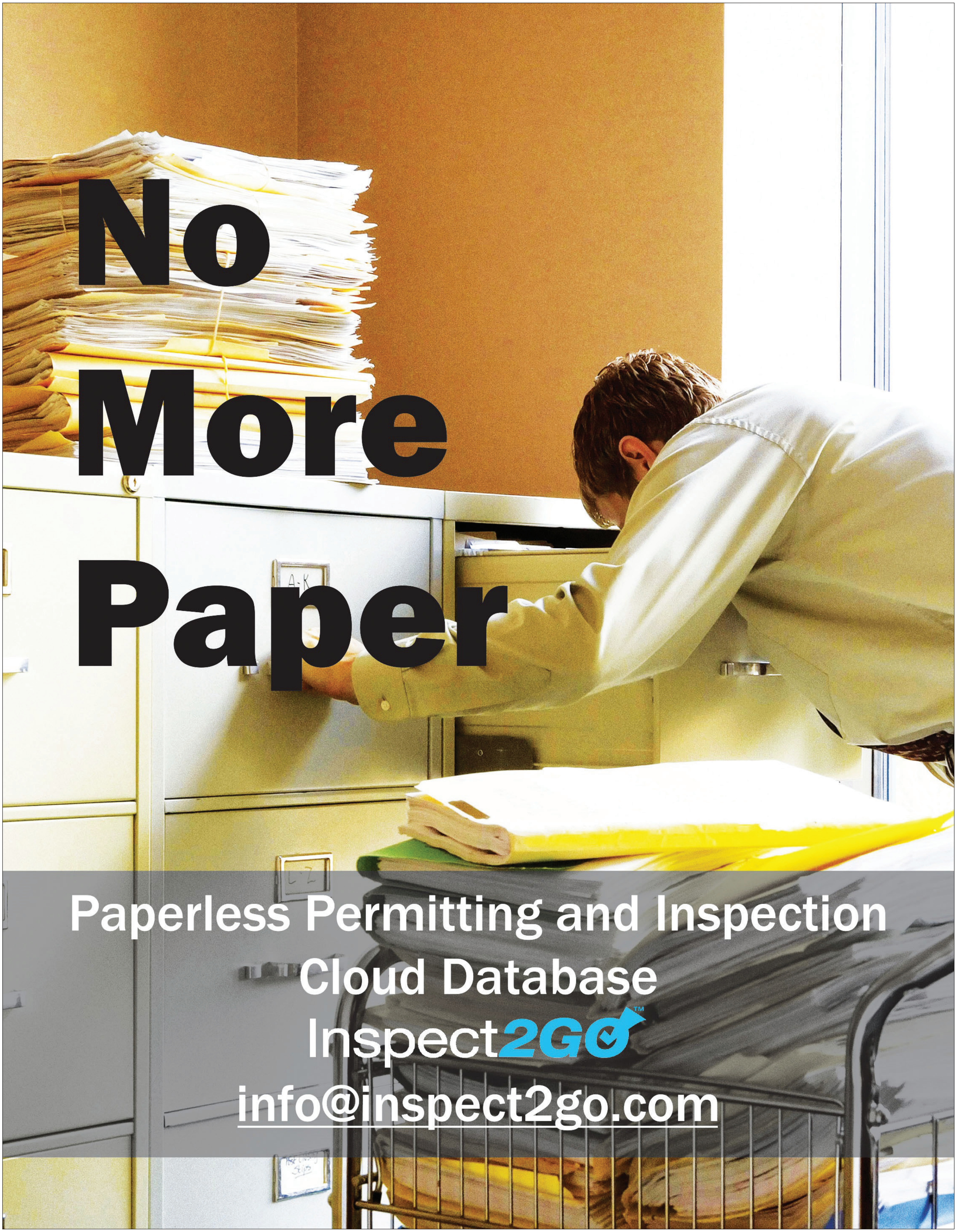
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Volume 84, No. 6 January/February 2022

ABOUT THE COVER

The Moscow Mule cocktail is traditionally served in a copper mug. Given the acidic nature of the drink there is increasing concern that copper can leach into the cocktail. This month's cover article, "Quantifying the Rate Copper Leaches From a Copper Drinking Vessel Into Simulated Beverages Under Conditions of Consumer Use," explored the rate, total amount, and mechanism of copper leaching from a copper mug into a Moscow Mule cocktail. The rate of copper leaching into the Moscow Mule cocktail was found to be significant and the accumulated copper concentration exceeded the U.S. Environmental Protection Agency standards for drinking water. Risks posed by the accumulation of copper can be mitigated by serving this cocktail in copper mugs lined with stainless steel to avoid contact of the acidic liquid with the copper surface.

See page 8.

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PRESIDENT'S MESSAGE

Roy Kroeger, REHS

The Challenges Just Keep Coming

I want to start by saying Happy New Year to all my National Environmental Health Association family and friends. I hope all of you had festive good times with your loved ones. I know that I did. After all the holiday parties, dinners, drinks, and gatherings, the only social distancing occurring around me are the buttons on my shirt. I believe we all hope for a better year in 2022.

This month I am going a little off topic to talk about something we are all experiencing in our communities. The lack of a workforce and supply chain issues are not just environmental health or public health problems—the concerns are all around us. Some of our food service industry friends might be the hardest hit, but it is undoubtedly not limited to just them.

The last labor information I heard is that there are over 10 million advertised jobs in the country and only 8.5 million unemployed individuals. To me, 8.5 million seems like many people to fill jobs, but in reality, they are being very particular about what they are looking for in a position. Since workers are in high demand, they can be more selective on where they want to work and the type of that work.

According to *Forbes Magazine*, there are many different reasons people choose not to go back to work or be selective about what they want to do. The most noted reason for employees not to take a job is that the pay is too low. Wage growth is climbing at its fastest pace since the late 1970s and early 1980s, primarily because employers are trying to draw workers back in from the sidelines. The pandemic could also be keeping those who are worried about becoming sick from returning to work. Whatever the reason, job seekers appear to have leverage to determine when they will return and what they will do when they return. Many employees are insisting on higher pay and better benefits, while others want to work remotely. The Great Reassessment, as some call it, is changing the world in which we live.

> *Even though everyone is encountering these hardships right now, times will get better.*

I know you are saying to yourself, "Yeah, we hear you, but how is this related to environmental health?" I can't think of a single day that the economy has not affected my environmental health program in the last several weeks. Let me start by saying that the world has not been kind to many of us in public health over the past 22 months. Everyone is already stressed, yet when we reach a turning point in the pandemic, we all know we will be asked to catch up on everything that fell behind.

Environmental health professionals are trying to get back into the field to inspect restaurants, swimming pools, and massage and body art facilities, yet we hear it all the time—why are you here? Many establishments are uncomfortable with nonemployees entering their facilities, some for real and some as an excuse. At other times, inspectors are returning to the office, saying the facility was not open. They have to determine if the facility has shuttered the doors for good or closed because they have no staff to work. I have even heard rumors where an establishment demanded proof of vaccine before allowing an inspector on site.

I decided to talk about the economy this month because it is affecting my ability to hire new staff. Like the rest of the economy, I lost two staff that were able to find better paying positions. I always encourage people to improve their situation and I am happy for both, but I never dreamed that I would see so few people apply to replace them. In the past I would get dozens of qualified (at least on paper) candidates. Now I hear crickets from job seekers. I understand that public health has never offered the best paid positions. We do, however, have great careers and many of us love the work we do. I also believe that our work–life balance is second to none.

So why is it so difficult to find great new help? The pay in our office has climbed 10% this year alone, yet it does not seem to matter. Are there not enough people in the workforce with a science background? Are people not willing to enter environmental public health because of the political strife surrounding COVID-19? Is it because people do not want to go out in the public to work as we cannot inspect restaurants, swimming pools, day cares, and schools from home? At least, not yet. I need people who are willing to come to an office at least some of the time and spend time out in public.

I also mentioned supply chain issues at the beginning of my column. The lack of goods is changing our world as much as the lack of employees. I am sure all of you have witnessed bare shelves in the local grocery or discount stores. The same thing is occurring in restaurants, day cares, and schools. I recently had planned on visiting a German restaurant in downtown Denver with my daughter. I was advised not to bother because they had very few items on their menu.

Our small wastewater program is also having significant problems due to the shortage of supplies. Locally, septic tanks are in short supply due to the difficulty in obtaining raw materials for the concrete, as well as the staffing to build them. I asked a local product representative if we allowed plastic tanks could the company supply them, and he told me not to bother right now because tanks were taking months to get into stock. Perforated pipe is another issue; actually, all pipe is in a supply crisis. A contractor has asked me if he could drill his own holes in the pipe and another just did so without asking. Having expensive homes set all over the prairie waiting on septic systems is no better than all the vehicles sitting around with no computer chips.

I am sorry to start the new year off sounding like such a pessimist. Even though everyone is encountering these hardships right now, times will get better. They always do. Like in the past, we will each find our new star employees and the shelves will once again be whole. Until then, hang in there. Deep down, all of us in environmental public health know that what we are doing is worth it.

Ray Kuogge

President@neha.org

Did You Know?

The NEHA Denver office has moved! While still located in the same building, we have moved from the 10th floor to the 1st floor. Our new address is 720 South Colorado Boulevard, Suite 105A, Denver, CO, 80246. More information about our new office will be shared in the NEHA News section of the March issue.

SUPPORT THE NEHA ENDOWMENT FOUNDATION

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

Individuals who have contributed to the foundation are listed below by club category. These listings are based on what people have actually donated to the foundation—not what they have pledged. Names will be published under the appropriate category for 1 year; additional contributions will move individuals to a different category in the following year(s). For each of the categories, there are a number of ways NEHA recognizes and thanks contributors to the foundation. If you are interested in contributing to the Endowment Foundation, please call NEHA at (303) 756-9090. You can also donate online at www.neha.org/donate.

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Quantifying the Rate Copper Leaches From a Copper Drinking Vessel Into Simulated Beverages Under Conditions of Consumer Use

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Abstract

The Moscow Mule cocktail, which contains ginger beer, lime juice, and vodka, is commonly served in a copper mug. There has been increasing concern that copper can leach into the cocktail, given the acidic nature of the drink. Under the experimental conditions studied, copper does leach from the copper mug into the beverage. We observed copper leaching into the cocktail solution at a rate of 0.048 ± 7 x 10^{-4} ppm copper/min at room temperature. The leaching rate was found to be dependent on the acidity of the solution (increasing at lower pH) and molecular oxygen content. We quantified the copper concentration using inductively coupled plasma-atomic emission spectroscopy (ICP-AES). The rate of copper leaching into the Moscow Mule cocktail was found to be significant and accumulated copper concentration exceeds the U.S. Environmental Protection Agency standards for drinking water within 27 minutes (World Health Organization, 2004). Any risk posed by the accumulation of copper, however, can be mitigated by serving the Moscow Mule cocktail in a copper mug lined with stainless steel to avoid direct contact of the acidic liquid with the copper surface directly, as stipulated by the Food and Drug Administration model *Food Code*.

Introduction

Identifying the conditions under which potentially hazardous chemical agents, such as metal ions, are released from surfaces in contact with foodstuffs and beverages is an important first step in assisting environmental health professionals as they promote consumer safety. Copper leaching from a food contact zone into foodstuffs remains an undercharacterized process despite the presence of copper and copper alloy surfaces in both a) industrial food and beverage production and b) municipal water supplies. There are several food products—notably cheese (Rodriguez et al., 2011), beer (Zufall & Tyrell, 2008), distilled spirits (Neves et al., 2007), and tea (Karak & Bhagat, 2010; Lv et al., 2013)—that are brought into contact with a copper surface during production. Copper leaching is especially problematic for foodstuffs with low pH. Ishiwata et al. (1986) found that after 24 hr at room temperature, a 4% acetic acid aqueous solution in a copper mug contained 103 ± 10 ppm copper compared with a pure water solution in a copper mug, which contained 1.7 ± 0.1 ppm copper. The rate and mechanism of the copper leaching, however, was not reported.

Copper leached into foodstuffs has various potential impacts on consumer health. The recommended dietary allowance of copper for adults is 900 µg/day (Institute of Medicine, 2001). Copper has known health benefits and is essential for the functioning of some enzymes (Festa & Thiele, 2011). Copper also has a low incidence of eliciting allergic reactions (Fage et al., 2014). Little is known, however, about the toxicity of extended copper intake, and more research is needed to determine if copper intake over a prolonged period of time poses a significant public health risk (Brewer, 2010; Patel & Aschner, 2021).

In this article we use a popular cocktail traditionally served in a copper vessel as a model system to study copper leaching under conditions of simulated consumer use. This cocktail, known as the Moscow Mule, contains vodka, lime juice, and ginger beer. Much lore surrounds the reason why the drink is served in a copper mug, but many argue that the taste is enhanced by the copper vessel. A study by Hong et al. (2009) indicates that interactions between copper and salivary proteins could play an important role in the perception of flavor. Despite the potential flavor enhancement, there has been increasing public health concern regarding the safety of using a copper mug for a beverage as acidic as the Moscow Mule cocktail (State of Iowa Alcoholic Beverages Division, 2017). To our knowledge, the amount of copper leaching into the Moscow Mule cocktail has never been quantified. In this article we report the rate, total amount, and mechanism of copper leaching from a copper mug into a Moscow Mule cocktail.

TABLE 1

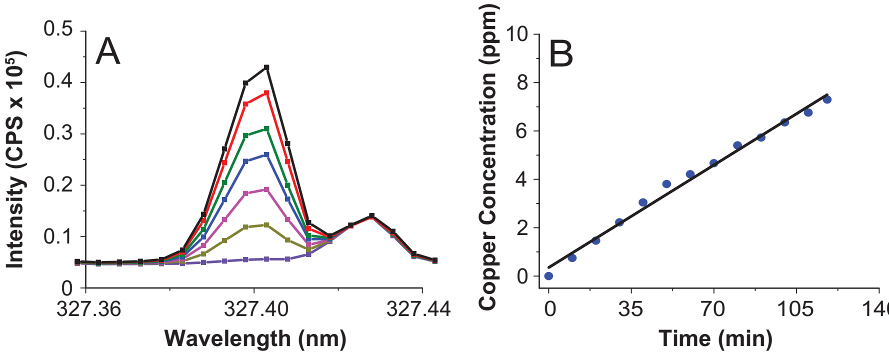
Ingredient Volumes and pH Values of the Moscow Mule Solution

Ingredient	Volume of Pure Ingredient Used (ml)[a]	pH of Pure Ingredient	pH of Ingredient After Dilution[b]
Lime juice	22	2.6	2.5
Ginger beer	133	3.0	3.2
200 proof ethanol	35.6	–	–
Deionized water	53.4	–	–

[a] The total volume of the Moscow Mule solution was 244 ml, which represents approximately one half of the volume of the copper mug.
[b] The pH of the ingredient after dilution to the final volume of 244 ml with deionized water; the pH of the Moscow Mule solution was 2.7.

FIGURE 1

Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AEC) and Copper Concentration From a Moscow Mule Solution Within a Copper Mug



Note. A) ICP-AES of copper from a Moscow Mule solution held within a copper mug at 0 min (purple), 20 min (dark yellow), 40 min (magenta), 60 min (blue), 80 min (green), 100 min (red), and 120 min (black). B) Copper concentration as a function of time for a Moscow Mule solution held within a copper mug. The copper concentration (blue circles) as a function of time was fit with a linear trendline (black). CPS = counts per second.

Methods

Moscow Mule Solution Preparation

All materials were used as received directly from the supplier. Cocktail ingredients were chosen to be representative of consumer use. Moscow Mule components included: lime juice, ginger beer, aqueous ethanol solution, and a 16-oz solid copper mug.

We prepared a Moscow Mule cocktail solution in a copper mug. Table 1 details the ingredients and their pH values. Ice was not used as an ingredient for any of the experiments conducted in this study. When analyzing the contribution each ingredient had on copper leaching, the individual ingredients were diluted with deionized (DI) water to the concentration typically found in a Moscow Mule cocktail. For the purposes of this study, vodka was replaced with 200 proof ethanol diluted to the appropriate concentration with DI water. For pH studies, an aqueous solution was brought to the desired pH using hydrochloric acid.

Measurements via Inductively Coupled Plasma-Atomic Emission Spectroscopy

All metal ion concentration measurements were performed using inductively coupled plasma-atomic emission spectroscopy (ICP-AES; PerkinElmer Instruments model Optima 2000 DV). Copper and gold ICP standards (GFS Chemicals, Inc.) were prepared in aqueous 1% nitric acid solution.

Internal Standards

We selected an internal standard of gold to quantify copper concentrations because the emission intensity is similar to copper, the emission maxima between copper and gold do not overlap, and any gold that might be present in the copper mug would not be expected to undergo a redox leaching process and contaminate the solution. For a given concentration, the copper emission at 327.393 nm was approximately 10 times more intense than the gold emission at 267.595 nm. We calculated the copper–gold response factor (*f*) for the ICP-AES instruments using the following equation:

$$\frac{\text{Peak Area Copper}}{[\text{Copper}]} = f\,\frac{\text{Peak Area Gold}}{[\text{Gold}]}$$

We calculated the copper–gold response factor over a range of concentrations to ensure minimal variance. The average response factor was 12.7 with a standard deviation of 0.1 over the concentration range investigated. Samples to be analyzed were taken from the copper mug at time intervals, transferred to volumetric flasks that had been cleaned with aqua regia (1:3 molar ratio of nitric and hydrochloric acid) to remove trace metals, spiked with 10 ppm gold, and then diluted to volume in preparation for ICP-AES analysis. The previous equation was used to calculate the copper concentration in the solution.

UV-Vis Measurements

All UV-Vis measurements were performed with an HP 8453 diode array UV-Visible spectrophotometer.

Scanning Electron Microscopy

All scanning electron microscopy (SEM) images were gathered using a Zeiss Supra 55VP field emission scanning electron microscope.

Results and Discussion

ICP-AES measurements demonstrated that copper does leach into a Moscow Mule solution in a copper mug. Figure 1A shows ICP-AES measurements of copper from a Moscow Mule solution in a copper mug at time intervals of: 0 min (purple), 20 min (dark yellow), 40 min (magenta), 60 min (blue), 80 min (green), 100 min (red), and 120 min (black). Figure 1B shows copper concentration as a function of time for a Moscow Mule solution in a copper mug; the copper concentration (blue circles) as a function of time was fit with a linear trend line (black).

We observed copper leaching into the solution at a rate of 0.048 ± 7 x 10^{-4} ppm copper/min at room temperature (Figure 1B). At this rate, the concentration of leached copper in a copper mug reaches 1.3 ppm in slightly over 27 min. The U.S. Environmental Protection Agency mandates that copper levels in drinking water that exceed 1.3 ppm must be reported (World Health Organization, 2004). The Food and Drug Administration (FDA) model *Food Code* prohibits foodstuffs with a pH < 6.0 from coming in contact with copper due to concerns of copper leaching (U.S. Department of Health and Human Services, 2017). The Moscow Mule solutions in our experiments had a measured pH of 2.7 and the pH did not change throughout the course of the experiment. Despite FDA regulations, Moscow Mule cocktails routinely are served in copper mugs in establishments all over the country.

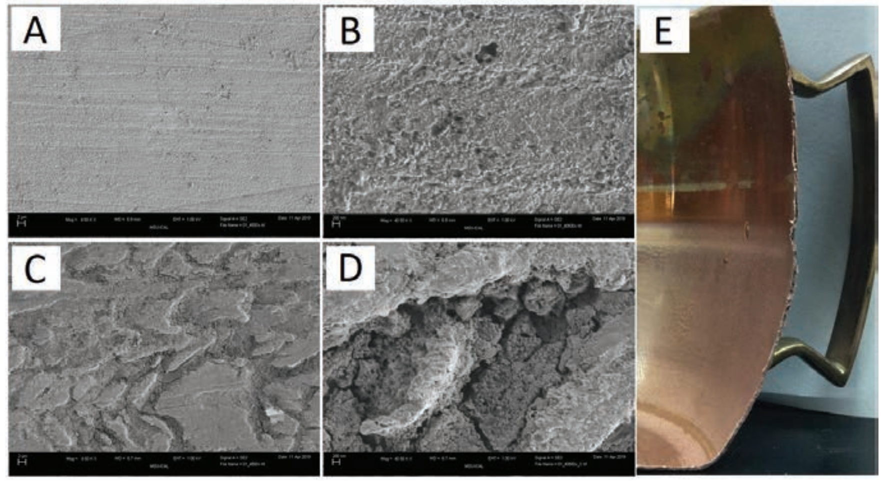
It is informative to consider the maximum daily allowance of copper that can safely be consumed. According to the World Health Organization (2004), a safe maximum consumption of copper is 10 mg/day. Thus, an individual would need to consume over 30 Moscow Mule cocktails (each containing 1.3 ppm of copper and a volume of 244 ml) to exceed the limit of 10 mg of copper per day. Given this information, acute copper toxicity from consumption of Moscow Mule cocktails in one sitting is unlikely. As mentioned previously, however, the long-term effects of elevated copper consumption are largely unknown (Brewer, 2010; Patel & Aschner, 2021).

We observed slight differences between the copper leaching rates for the mugs used in this study, but copper leaching was observed under all conditions studied. While it might not be possible to directly apply the specific leaching rate values presented here to a Moscow Mule cocktail prepared under other conditions, the overall trend of copper accumulation appears to hold true.

The difference in the copper leaching rate between the mugs did not appear to be correlated with any properties of the mug that could be assessed with the unaided eye. The geometric surface area and microscopic electrochemically active surface area could both be important factors that contribute to the difference in copper leaching rates among the mugs used in this study. The microscopic surface area of the mugs used in this study was characterized using SEM. Figure 2 shows SEM images of the copper mug surface with limited contact with the Moscow Mule cocktail at 2 μm (Figure 2A) and 200 nm (Figure 2B) scale. SEM images of the copper mug surface after exposure to

FIGURE **2**

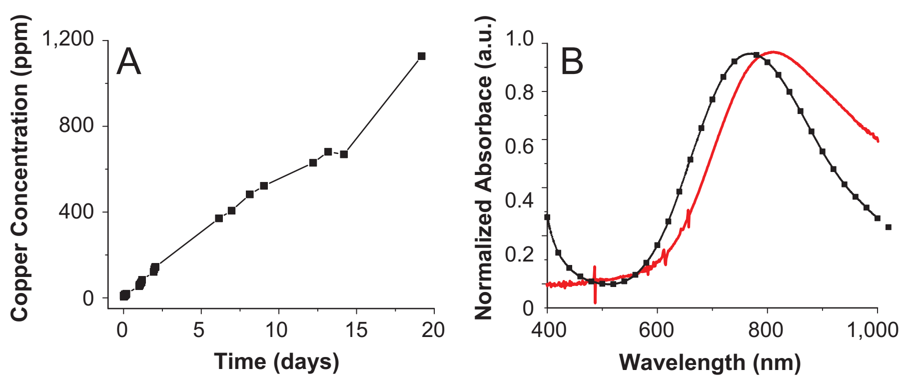
Scanning Electron Microscope (SEM) Images of Copper Mug Surface



Note. SEM images of copper mug surface with limited contact with the Moscow Mule cocktail at A) 2 μm scale and B) 200 nm scale. SEM images of copper mug surface after exposure to 26 Moscow Mule cocktails for a cumulative exposure time of 75 hr at C) 2 μm scale and D) 200 nm scale. E) Cross-sectional digital photograph of the copper mug; upper half of the mug had limited exposure and the lower half of the mug had exposure to 26 Moscow Mule cocktails for a cumulative exposure time of 75 hr.

FIGURE **3**

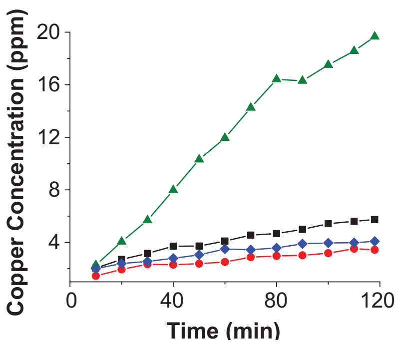
Copper Concentration as a Function of Time and Normalized UV-Vis Absorption Spectra



Note. A) Copper concentration as a function of time for a Moscow Mule solution held within a copper mug over the course of 20 days. B) Normalized UV-Vis absorption spectra of an aqueous copper(II) nitrate solution (red) and a Moscow Mule solution held within a copper mug for over 20 days (black squares).

FIGURE **4**

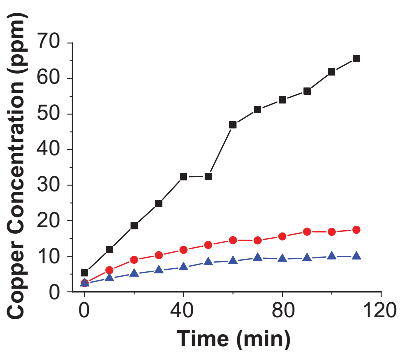
Copper Concentration as a Function of Time for Moscow Mule Ingredient Solutions Held Within a Copper Mug



Note. The Moscow Mule ingredient solutions include ginger beer (green triangles), lime juice (black squares), deionized water (blue diamonds), and ethanol (red circles).

FIGURE **5**

Copper Concentration as a Function of Time for Hydrochloric Acid Solutions of Varying pH

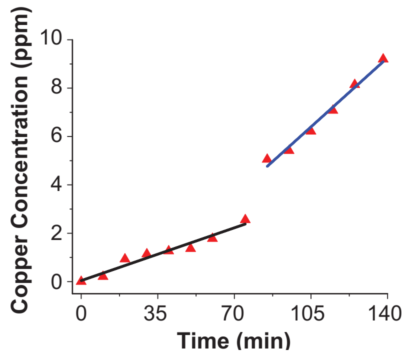


Note. The solutions had pH values of 1 (black squares), 2.9 (red circles), and 4.5 (blue triangles).

26 Moscow Mule cocktails for a cumulative exposure time of 75 hr are shown at 2 µm (Figure 2C) and 200 nm (Figure 2D) scale. Figure 2E shows a cross-sectional digital photograph of the copper mug. The upper half of the mug had limited exposure to the Moscow Mule solution and the lower half of the mug had a cumulative exposure time of 75 hr.

FIGURE **6**

Copper Concentration as a Function of Time for Moscow Mule Solutions Held Within a Copper Mug



Note. Each Moscow Mule solution initially was sparged with nitrogen gas to remove atmospheric oxygen and then placed in the copper mug under a nitrogen atmosphere. At 75 min, the solution was sparged with atmospheric gas for 15 min to replenish dissolved oxygen. Linear fits of the oxygen-free (black) and oxygen reintroduced (blue) regions are shown.

The oxidation of elemental copper to aqueous copper(II) ions results in both the leaching of copper(II) ions into the solution and the formation of microstructures as well as nanostructures on the copper surface. Outside of a controlled laboratory environment, the washing, polishing, and repeated use of copper surfaces likely has an effect on the electrochemically active microscopic surface area. Additionally, mechanical polishing is likely to obscure the visual evidence of the chemical etching, thus making it more difficult for consumers to realize that contaminates are being introduced into their beverage.

In our experiments, after being left undisturbed for several days in the mug, the cocktail solution turns a distinct turquoise color and we measured the copper concentration to be as high as 1,000 ppm. Figure 3A shows copper concentration as a function of time for a Moscow Mule solution in a copper mug over the course of 20 days. Normalized UV-Vis absorption spectra of an aqueous copper(II) nitrate solution (red) and a Moscow Mule solution in a copper mug for over 20 days (black squares) are shown in Figure 3B. The concentration of copper as a function of time is linear over the course of 20 days, consistent with a zero-order reaction mechanism (Figure 3A). Zero-order reactions have been encountered in other heterogeneous reactions where access to the surface limits the rate at which the reaction proceeds.

Due to the zero-order reaction kinetics, the copper is continuously accumulating in the Moscow Mule solution and does not equilibrate at a fixed value. Thus, while not directly applicable to the typical consumer experience with a Moscow Mule cocktail, the continuous leaching over the 20-day study highlights the importance of applying the FDA model *Food Code* prohibiting acidic foodstuffs coming in contact with any copper surface. More broadly, the accumulation of metal ions into acidic foodstuffs and drinking water with prolonged exposures to metal surfaces should not be overlooked by environmental health professionals. For example, water with a low pH in metal pipes was an important and preventable factor that contributed to the high levels of lead leached into the Flint, Michigan, water system in 2014 (Torrice, 2016).

The constant leaching rate of copper into the Moscow Mule solution contrasts with the time-dependent leaching rates observed from most other metal surfaces into foodstuffs or simulated foodstuffs. For the leaching of chromium, iron, and nickel from a stainless steel surface, the initial leaching rate was fastest and the leaching rate decreased with time (Herting et al., 2008; Kamerud et al., 2013). Additionally, the decrease in the leaching rate of tin from metal cans into foodstuffs was attributed to the eventual consumption of all the oxygen dissolved in the foodstuffs or trapped in the headspace (Parkar & Rakesh, 2014). Finally, chromium is unique among the other metals studied and was found to leach from a stainless steel surface at a constant rate on a 20-day time scale (Chiavari et al., 2014).

Solutions of the individual ingredients were diluted with DI water to the concentration found in a Moscow Mule cocktail (Table 1) to study the effect of each ingredient on the copper leaching rate. Figure 4 shows copper concentration as a function of time for solutions of ginger beer (green triangles), lime juice (black squares), DI water (blue diamonds), and 14% ethanol (red circles) in a copper mug. We observed copper leaching with all four ingredients investigated. The highest leaching rates were observed for ginger beer. Lime juice and ginger beer had the lowest pH values and fastest copper leaching rates.

We systematically investigated the effect of pH on the copper leaching rate by preparing hydrochloric acid of varying pH. Figure 5 shows copper concentration as a function of time for solutions of varying pH. The aqueous solutions had pH values of 1 (black squares), 2.9 (red circles), and 4.5 (blue triangles). As the pH of the aqueous hydrochloric acid solution decreased, the rate of copper leaching increased. The data in Figures 4 and 5 are consistent with pH being an important predictor of copper leaching rate, but it is not the sole contributor.

Interestingly, the lowest pH component (lime juice) of the cocktail solution does not result in the fastest leaching rate, suggesting that there are other species in solution that contribute to copper leaching. This result is consistent with studies (Agarwal et al., 1997) that showed that chromium and nickel leached from stainless steel vessels at a higher rate for foodstuffs than for pH-equivalent aqueous solutions of the predominate pure organic acids found in the foodstuffs. The ginger beer solution (133 ml diluted to 244 ml) is much more concentrated than the lime juice solution (22 ml diluted to 244 ml) once diluted to the total volume of the drink—thus any effect due to other species in solution could be more pronounced.

We investigated the mechanism by which metallic copper is transformed to copper(II) and found molecular oxygen to have a pronounced effect on the rate of copper leaching into the solution. Figure 6 shows copper concentration as a function of time for Moscow Mule solutions held within a copper mug (red triangles). The Moscow Mule solution initially was sparged with nitrogen gas for 15 min to remove atmospheric oxygen and then placed in the copper mug under a nitrogen atmosphere. At 75 min, the solution was sparged with atmospheric gas for 15 min to replenish dissolved oxygen. Linear fits of the oxygen-free (black) and oxygen-reintroduced (blue) regions are shown.

For the mug used in this experiment, copper leaches into the nitrogen-sparged Moscow Mule solution at a rate of 0.03 ± 0.003 ppm copper/min. Once oxygen was reintroduced, the copper leaches into the Moscow Mule solution at a rate of 0.08 ± 0.005 ppm copper/min. The 2.6-fold increase in the copper leaching rate is consistent with molecular oxygen acting as an oxidant in the copper leaching mechanism. Interestingly, the copper leaching rate is not zero under oxygen-free conditions, suggesting that the other ingredients in the Moscow Mule solution could contain compounds that act as oxidants under these conditions.

There are several important factors that must be taken into consideration before directly applying the findings here to a consumer setting. First, the copper leaching rate varied among different mugs. The electrochemically active surface area of a mug, and therefore the rate of copper leaching, is strongly dependent on the mechanical and chemical processes that mug has experienced. Second, the studies we conducted were at room temperature, whereas a Moscow Mule cocktail typically is served over ice. The slightly elevated temperature of the Moscow Mule solution in this study likely results in a lower dissolved gas concentration and a slower copper oxidation reaction rate constant.

Therefore, the rate of copper leaching in a Moscow Mule cocktail served to a consumer may be different than that reported here. Regardless, our results clearly demonstrate that copper leaching does occur at an appreciable rate under multiple solution conditions, and thus supports the discontinuance of serving an acidic cocktail such as the Moscow Mule in a copper mug.

Conclusion

In summary, under the conditions studied, copper leaches into the Moscow Mule solution at a constant rate. The zero-order copper leaching kinetics are consistent with a reaction mechanism that is rate limited by the microscopic surface area of the copper mug. We also found the leaching rate to be dependent on pH and dissolved oxygen concentration. Other ingredients in solution, however, might also act as oxidants or chelating ligands that could accelerate the copper leaching rate.

In this article, we provide an intriguing and relevant example to environmental health professionals and the public of a potentially hazardous substance that is common and at the same time extremely easy to avoid. Our study presents a clear alternative for environmental health professionals and the public, as fortunately copper mugs lined with stainless steel or other chemically inert materials are widely available for a similar cost. As such, the potential hazard posed by the direct contact between an acidic beverage—such as the Moscow Mule—and the copper surface could easily be mitigated.

While our study focused on one particular cocktail, the identified mechanism and rate of copper leaching can inform environmental health professionals of the "why" behind this regulation and enable them to effectively evaluate plan reviews and carry out inspections in related situations. In particular, review of large catered events where specialty drinks or other specialty foods might be served should prompt an environmental health professional to ask more questions and determine if vessels lined with stainless steel might be more appropriate. In addition to the acidity of the foodstuffs, the temperature and the amount of time the product is contained in the copper vessel could all impact safety implications. In agreement with the FDA model *Food Code*, individuals should avoid consuming foodstuffs with a pH lower than 6.0 that have come in contact with copper.

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References

Agarwal, P., Srivastava, S., Srivastava, M.M., Prakash, S., Ramanamurthy, M., Shrivastav, R., & Dass, S. (1997). Studies on leaching of Cr and Ni from stainless steel utensils in certain acids and in some Indian drinks. *Science of the Total Environment*, *199*(3), 271–275. https://doi.org/10.1016/s0048-9697(97)05455-7

Brewer, G.J. (2010). Risks of copper and iron toxicity during aging in humans. *Chemical Research in Toxicology*, *23*(2), 319–326. https://doi.org/10.1021/tx900338d

Chiavari, C., Bernardi, E., Balijepalli, S.K., Kaciulis, S., Ceschini, L., & Martini, C. (2014). Influence of low-temperature carburising on metal release from AISI316L austenitic stainless steel in acetic acid. *Journal of Food Engineering*, *137*, 7–15. https://doi.org/10.1016/j.jfoodeng.2014.03.030

Fage, S.W., Faurschou, A., & Thyssen, J.P. (2014). Copper hypersensitivity. *Contact Dermatitis*, *71*(4), 191–201. https://doi.org/10.1111/cod.12273

Festa, R.A., & Thiele, D.J. (2011). Copper: An essential metal in biology. *Current Biology*, *21*(21), R877–R883. https://doi.org/10.1016/j.cub.2011.09.040

Herting, G., Odnevall Wallinder, I., & Leygraf, C. (2008). Corrosion-induced release of chromium and iron from ferritic stainless steel grade AISI 430 in simulated food contact. *Journal of Food Engineering*, *87*(2), 291–300. https://doi.org/10.1016/j.jfoodeng.2007.12.006

Hong, J.H., Duncan, S.E., Dietrich, A.M., O'Keefe, S.F., Eigel, W.N., & Mallikarjunan, K. (2009). Interaction of copper and human salivary proteins. *Journal of Agricultural and Food Chemistry*, *57*(15), 6967–6975. https://doi.org/10.1021/jf804047h

Institute of Medicine (U.S.) Panel on Micronutrients. (2001). *Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc*. The National Academies Press. http://www.ncbi.nlm.nih.gov/books/NBK222310/

Ishiwata, H., Inoue, T., & Yoshihira, K. (1986). Migration of copper and some other metals from copper tableware. *Bulletin of Environmental Contamination and Toxicology*, *37*(5), 638–642. https://doi.org/10.1007/BF01607816

Kamerud, K.L., Hobbie, K.A., & Anderson, K.A. (2013). Stainless steel leaches nickel and chromium into foods during cooking. *Journal of Agricultural and Food Chemistry*, *61*(39), 9495–9501. https://doi.org/10.1021/jf402400v

Karak, T., & Bhagat, R.M. (2010). Trace elements in tea leaves, made tea and tea infusion: A review. *Food Research International*, *43*(9), 2234–2252. https://doi.org/10.1016/j.foodres.2010.08.010

Lv, H.P., Lin, Z., Tan, J-.F., & Guo, L. (2013). Contents of fluoride, lead, copper, chromium, arsenic and cadmium in Chinese Puerh tea. *Food Research International*, *53*(2), 938–944. https://doi.org/10.1016/j.foodres.2012.06.014

Neves, E.A., Oliveira, A., Fernandes, A.P., & Nóbrega, J.A. (2007). Simple and efficient elimination of copper(II) in sugar-cane spirits. *Food Chemistry*, *101*(1), 33–36. https://doi.org/10.1016/j.foodchem.2005.12.050

Parkar, J., & Rakesh, M. (2014). Leaching of elements from packaging material into canned foods marketed in India. *Food Control*, *40*, 177–184. https://doi.org/10.1016/j.foodcont.2013.11.042

Rodriguez, L.M., Ritvanen, T., Joutsjoki, V., Rekonen, J., & Alatossava, T. (2011). The role of copper in the manufacture of Finnish Emmental cheese. *Journal of Dairy Science*, *94*(10), P4831–P4842. https://doi.org/10.3168/jds.2011-4536

State of Iowa Alcoholic Beverages Division. (2017, July 28). *Use of copper mugs in the serving of alcoholic beverages* (AB-2017-01). https://abd.iowa.gov/sites/default/files/advisory_bulletin_-_use_of_copper_mugs_in_the_serving_of_alcoholic_beverages_-_july_28_2017.pdf

U.S. Department of Health and Human Services, Public Health Service, Food and Drug Administration. (2017). *Food Code: 2017 recommendations of the United States Public Health Service, Food and Drug Administration*. https://www.fda.gov/media/110822/download

World Health Organization. (2004). *Guidelines for drinking-water quality, volume 1: Recommendations* (3rd ed.). http://apps.who.int/iris/bitstream/handle/10665/42852/9241546387.pdf

Zufall, C., & Tyrell, T. (2008). The influence of heavy metal ions on beer flavour stability. *Journal of the Institute of Brewing*, *114*(2), 134–142. https://doi.org/10.1002/j.2050-0416.2008.tb00318.x

Health Effects and Factors Affecting Formaldehyde Exposure Among Students in a Cadaver Laboratory

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Abstract **Formaldehyde is associated with a wide range of adverse health effects and occupational exposure to formaldehyde is very common. The objective of this study was to determine formaldehyde-related health effects and factors that affect student exposure and compliance with safety measures and training during cadaver class. Study participants were university students and the survey predominantly gathered information about formaldehyde-related symptoms, the relevant health status of students, willingness to embrace safety practices, and willingness to get training on formaldehyde exposure in a cadaver laboratory setting. Our results showed that there is a significant relationship between preexisting respiratory conditions and willingness to use respiratory personal protective equipment (PPE) in the laboratory (25.5%, $p = .01$). Compared with male students, female students were more willing to get training on the use of formaldehyde in the laboratory ($p = .008$) and were more likely to be willing to use respiratory PPE ($p = .018$). Our study indicates that students experience symptoms in the laboratory that could be formaldehyde-related, supporting the need to educate students on the adverse health effects of formaldehyde exposure in the laboratory. Finally, gender, preexisting respiratory conditions, and ease of compliance with respiratory protection should be considered when designing preventive programs for formaldehyde exposure.**

Introduction

Formaldehyde (CH_2O) is a colorless, flammable gas found in various household and industry products. Due to its pungent odor, it is usually diluted with water or alcohol for use in disinfectants, preservatives, fabrics, cleaning product, beauty products, and glues. Its cost effectiveness makes it an abundant, widely used chemical and thus a common source of exposure among many populations. Measuring the concentration of formaldehyde in the air is expressed in terms of ppm (Raja & Sultana, 2012). The Occupational Safety and Health Administration (OSHA, 2013) mandates a permissible exposure limit (PEL) of 0.75 ppm as an 8-hr time-weighted average (TWA), an action level (AL) of 0.5 ppm, and a short-term exposure limit (STEL) of 2.0 ppm over a 15-min period. An excellent preservative, formaldehyde was discovered by German chemist August Wilhelm von Hofmann in 1869 and has been a major component of embalming solutions, with changes in its proportion of formaldehyde and composition over the years (Brenner, 2014).

Adverse Health Effects of Formaldehyde Exposure

Limits to formaldehyde exposure exist because the chemical is associated with a range of adverse health effects in both human and nonhuman mammals (Raja & Sultana, 2012). These effects range from acute, intermediate discomforts such as burning eyes and itchy skin to more chronic, severe conditions (Onyeka et al., 2018). Acute effects of formaldehyde exposure include nausea, headaches, eye irritation, and burning eyes and throat (Onyeka et al., 2018; Raja & Sultana, 2012). Studies have found that a high probability and high intensity of exposure to formaldehyde is associated with an increased rate of amyotrophic lateral sclerosis (ALS) in workers (Roberts et al., 2016; Seals et al., 2017). Additionally, formaldehyde exposure has been shown to be associated with cognitive dysfunction (Tulpule & Dringen, 2013; Zendehdel et al., 2016) and neurotoxicity as a result of impaired metabolic signals (Zendehdel et al., 2016).

Formaldehyde is classified as a human carcinogen (Agency for Toxic Substances and Disease Registry [ATSDR], 2021; Chen et al., 2017; International Agency for Research on Cancer [IARC], 2012; National Academy of Sciences, 2014; Thetkathuek et al., 2016). Additionally, formaldehyde exposure has been linked to decreased sperm fertility, male infertility, and miscarriage in spouses of men who had been exposed to formaldehyde as a result of their work (Wang et al., 2012). Similarly, formaldehyde exposure in humans is of concern during pregnancy: cases of spontaneous abortion, congenital malformation, and premature births have been reported (Amiri et al., 2015; Amiri & Turner-Henson, 2017; Duong et al., 2011; Xu et al., 2017).

In animal populations, formaldehyde exposure has been demonstrated to be associated with the induction of autophagy in testicular tissues of adult male rats (Han et al., 2015). Among pregnant mice and rats, formaldehyde has been shown to be teratogenic (Raja & Sultana, 2012). Another study showed that formaldehyde could worsen pulmonary fibrosis induced by bleomycin in a mouse model (Leal et al., 2018).

Populations With High Occupational Exposure to Formaldehyde

Air is the primary source of formaldehyde exposure and workers mostly are exposed through inhalation, but some individuals experience dermal exposure through intact skin (ATSDR, 2021). Despite the adverse health effects associated with formaldehyde, occupational exposure to this organic compound is very common. Formaldehyde-based resin industries are a major source of occupational exposure. Other employees, such as dentists, physicians, embalmers, nurses, pathologists, veterinarians, and workers in the clothing industry or in furniture factories are equally at risk of formaldehyde exposure (ATSDR, 2021). Furthermore, populations working in the construction, cosmetic, agricultural, and manufacturing industries tend to be regularly exposed to formaldehyde (Raja & Sultana, 2012). Individuals working in laboratories, most notably anatomists and medical students, are exposed to varying amounts of formaldehyde during cadaver dissections (Brenner, 2014; Raja & Sultana, 2012).

Reported conditions among populations are often differential based on the scope of their exposure to the compound. Traditionally, laboratory workers report acute conditions such as burning eyes and nasal pathways, nasal congestion, and itchy, irritated skin (Onyeka et al., 2018). In Thailand, employees working in a furniture factory among high levels of formaldehyde and medium-density fiberboard (MDF) reported consistent coughing, even when not in the factory environment; employees who had a history of atopic allergies were at a higher risk for symptoms related to respiratory irritation while being exposed to formaldehyde (Thetkathuek et al., 2016). Interestingly, there is also a seasonal variation of formaldehyde exposure, with more exposure in the spring compared with in the winter (Amiri et al., 2015).

Objective

Actively protecting against formaldehyde is one of the most pragmatic ways of preventing its adverse health effects among exposed populations (Raja & Sultana, 2012). Means of protection against extensive formaldehyde exposure can include wearing protective devices (Raja & Sultana, 2012); receiving training on how to safely handle formaldehyde (National Institute for Occupational Safety and Health [NIOSH], 2019; OSHA, 2013); and monitoring time spent in the laboratory during dissections (OSHA, 2013). There is little existing research about disparities in the usage of the above preventive methods among medical and laboratory students. When comparing students who take precautions on excess formaldehyde exposure with those who do not, there can be differences in age, gender, race, or existence of allergies and other preexisting conditions. Identifying disparities in the usage of safety measures is integral to better reach populations at a heightened risk of excess exposure and reduce the number of students negatively affected by formaldehyde exposure. Thus, the objective of this article is to examine the adverse health effects of formaldehyde on graduate students working in laboratories and to identify any existing disparities in taking preventive measures by demographics and medical history.

Methods

Study Population

Out of 252 students recruited, 194 (77.0%; 56 male and 136 female students) participated in this study. The students were recruited through their class representatives and professors in the programs and also received direct emails from our research group. The students were from two graduate programs at Slippery Rock University: the Doctor of Physical Therapy program and the Physician Assistant program. Students from both these programs dissect and work with cadavers as part of required coursework. Students have laboratory classes at least once a week and are exposed to formaldehyde; the physical therapy students spend a considerably longer time in the cadaver laboratory compared with the physician assistant students. In accordance with the Declaration of Helsinki, the students were informed of the study objectives, and their informed consent was obtained before the study started. In addition, university institutional review board approval was obtained before the study began. We collected data between October 2017 and January 2018. Relative to the academic calendar, the students had been in the laboratory for at least 6 weeks before taking the survey.

Questionnaire

We designed the questionnaire based on our experience working with students in the cadaver laboratory, along with some questions adopted from OSHA's Nonmandatory Medical Disease Questionnaire and studies that looked at work-related formaldehyde exposure (OSHA., 2019; Thetkathuek et al., 2016; Ya'Acob et al., 2013). Students were first asked for their demographic information, including age, sex, and ethnicity. Then they were asked if they had any previous experience working with cadavers and formaldehyde, as well as if they had ever received training before coming in contact with either cadavers or formaldehyde. Subsequent questions gauged current student behaviors, including willingness to use respiratory personal protective equipment (PPE) in the laboratory, reasons for not wanting to use respiratory PPE, duration spent in the laboratory, utilization of breaks in between laboratory sessions, and willingness to get training on safety precautions regarding contact with formaldehyde. The questionnaire asked about any preexisting respiratory conditions and existing allergies caused by any chemical or agent. Lastly, the questionnaire asked if students had any of the following symptoms either during the laboratory session or shortly after: eye irritation, nose irritation, headache, runny nose, itchy skin, fatigue, shortness of breath, dry throat, sore throat, chest tightness, and wheezing.

Data Collection and Analysis

We collected data using SurveyMonkey; data were then exported and further analyzed using SPSS version 25. We used a chi-squared test to determine if sex had any effect on the student willingness to use respiratory PPE in the laboratory, as well as on willingness to be trained on formaldehyde safety precautions. A second chi-squared test measured the effect of having a preexisting respiratory condition (e.g., asthma) on willingness to use respiratory PPE in the laboratory.

Results

Demographic Information

In this study, approximately 90% of respondents were between 20 and 30 years. Of the respondents, approximately 70.8% of the participants self-identified as female students, while 29.8% self-identified as male students. Furthermore, 92.7% of the participants self-identified as White, 2.7% as Black, 3.1% as Asian, 0.5% as Hispanic, and 1.1% as other. All participants were graduate students in two different programs at Slippery Rock University.

Experience History and Time Spent in the Laboratory

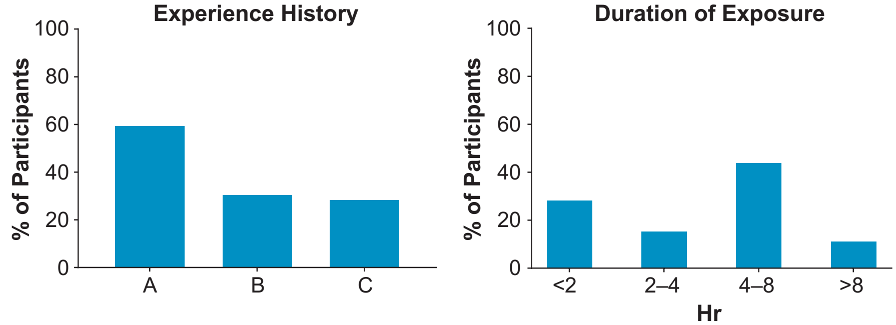
Approximately 60.0% of the participants had previous experience coming in contact with fixatives such as formaldehyde. Furthermore, 30.7% had prior training working with chemicals such as formaldehyde, and 28.7% had previous experience working with human cadavers (Figure 1). Regarding the duration of time spent in the laboratory per week, 28.7% of participants normally spend <2 hr, 15.6% spend 2–4 hr, 44.3% spend 4–8 hr, and 11.5% spend >8 hr in the laboratory (Figure 1).

Safety and Attitude Toward Safety

Only 25.5% of participants wanted to use respiratory PPE in the laboratory (Figure 2). Notable reasons for not wanting to use respiratory PPE included interference with one's ability to work, uncomfortable to wear, needing training before using, and personal preference (Figure 2). However, 80.2% of participants were willing to receive training on proper handling techniques and OSHA regulations while working with formaldehyde (Figure 2). Compared with male students, female students were more willing to get training on the use of formaldehyde in the laboratory and use respiratory PPE (p = .008 and p = .018, respectively; Table 1).

FIGURE **1**

Experience History and Duration of Exposure to Formaldehyde



Note. The graph on the left shows the percentage of participants with previous experience A) coming in contact with fixatives such as formaldehyde, B) training in working with chemicals such as formaldehyde, and C) working with human cadavers. The graph on the right shows the percentage of participants who spent various durations of time in the laboratory per week.

Health Conditions

There were 16.7% of participants with preexisting respiratory conditions such as asthma and reactive airways (Figure 3). In addition, 34.4% of participants had either seasonal allergies or allergic reactions to at least one of the following: dust, grass, trees, animal fur, tobacco, penicillin, bee stings, manufactured fragrances, specific foods, oxacillin, sugar, sulfa, NSAIDS, azithromycin, and latex (Figure 3).

There was a significant relationship between the presence of a preexisting respiratory condition and willingness to use respiratory PPE in the laboratory (p = 0.01). Moreover, 43.8% of participants with preexisting respiratory conditions had the willingness to use respiratory PPE in the laboratory, while only 21.9% did in the group without preexisting respiratory conditions (Table 1).

Allergy Symptoms

Participants experienced allergy symptoms during laboratory sessions or shortly after, with 73.7% reporting eye irritation, 69.6% sinus irritation, 77.6% a runny nose, and 21.9% itchy skin (Figure 3).

Respiratory Symptoms

Participants also experienced respiratory symptoms during laboratory sessions or shortly after, with 8.9% reporting chest tightness, 6.3% wheezing, 27.1% dry throat, and 12.1% shortness of breath (Figure 4).

Cardiovascular Symptoms

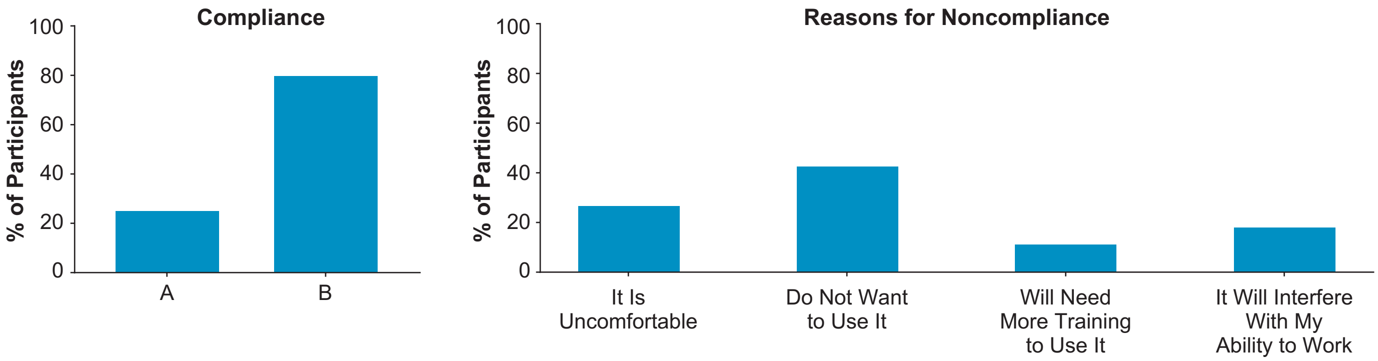
Participants also experienced cardiovascular symptoms during laboratory sessions or shortly after, with 51.6% reporting headaches, 33.3% fatigue, and 25.5% dizziness (Figure 4).

Current Practices

The students get general information from the professor in charge of the cadaver laboratory course on the need to protect themselves from the harmful effects of embalming fluid, which contains formaldehyde. The students do not undergo formal training on working with formaldehyde. Students wear respiratory PPE (e.g., eye coverings, surgical mask, or a respirator) in instances where they have severe reactions. Students take frequent breaks in between dissection sessions to minimize exposure time and wear appropriate clothing (e.g., laboratory coats) and gloves to protect the skin. The laboratory relies on an HVAC ventilation system to maintain sufficient indoor air quality in the cadaver laboratory. The HVAC system undergoes regular maintenance, but there is no periodic measurement of formaldehyde levels in the laboratory.

FIGURE **2**

Compliance and Reason for Noncompliance



Note. The graph on the left shows the percentage of participants who are willing to A) use respiratory personal protective equipment (PPE) while working with formaldehyde and B) receive training on the proper handling techniques and Occupational Safety and Health Administration regulations while working with formaldehyde. The graph on the right shows the percentage of participants who are not willing to use respiratory PPE for various listed reasons.

TABLE **1**

Respiratory PPE and Training Compliance by Sex and Preexisting Respiratory Conditions

	Sex			Preexisting Respiratory Conditions		
	Male # (%)	Female # (%)	*p*-Value*	Yes # (%)	No # (%)	*p*-Value*
Willingness to use respiratory PPE in the laboratory	7 (12.5)	42 (30.9)	.008	14 (43.8)	35 (21.9)	.01
Willingness to receive training on the proper handling techniques	39 (69.6)	115 (84.6)	.018	–	–	–

Note. PPE = personal protective equipment.
* From chi-squared test.

Discussion

Exposure to formaldehyde is common in many professions and there are health risks associated with it. All the participants in this study were graduate students, with the majority self-identifying as between 20 and 30 years and female. The duration of formaldehyde exposure varied among the students depending on their program of study, but all participants performed dissections on cadavers as part of their coursework. A majority of the students in this study spent between 4 and 8 hr/week in the laboratory dissecting cadavers and thus being exposed to formaldehyde (Figure 1).

A study of faculty members and workers involved with cadaver dissections with prolonged exposure to formaldehyde experienced more respiratory symptoms and migraines (Bhat et al., 2019). Furthermore, instructors had higher formaldehyde exposure than students (Vohra, 2011), with pulmonary function decreased more in instructors than in students (Saowakon et al., 2015). The duration of exposure and the levels of formaldehyde determine the health risk to individuals; however, we did not measure the level of formaldehyde in the laboratory. According to OSHA (2011), all workers exposed to a formaldehyde level of 0.1 ppm should undergo training on ways to protect against exposure.

Only 25.5% of participants were willing to use respiratory PPE in the laboratory, for a myriad of reasons (Figure 2). Compared with male participants, female participants were more willing to use respiratory PPE ($p = .018$; Table 1). Common factors that influence PPE compliance include worker comfort while wearing PPE, workplace culture, effective training on the use of PPE, and worker state of mind (SafeStart, 2014). Although not usually associated with PPE compliance, one of the most important issues often faced by female workers is ill-fitting PPE (Onyebeke et al., 2016). In the absence of adequate engineering, administrative control, or workplace control to provide protection, workers are expected to wear appropriate PPE for levels at or above the PEL, AL, or STEL (NIOSH, 2019; OSHA, 2006). Therefore, the use of

PPE while dissecting cadavers is very important to protect students from exposure to formaldehyde and its harmful effects.

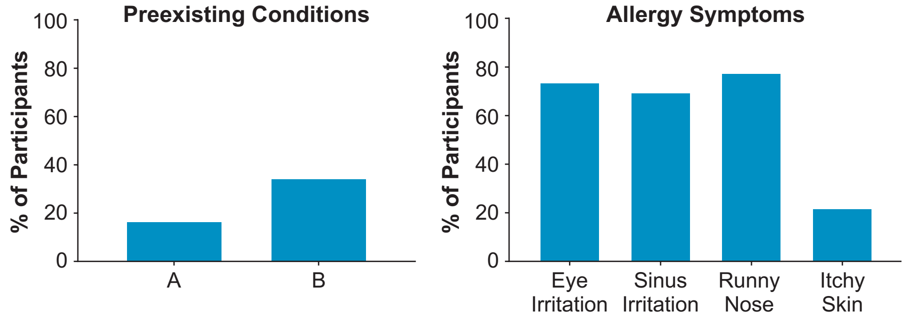
Of the participants, 80.2% were willing to receive training on proper handling techniques and OSHA regulations for working with formaldehyde (Figure 2). One study showed that "training employees on safety measures is vital in increasing their knowledge, competence, and use of safety measures at the workplace" (Wright et al., 2019). A lack of experience working with human cadavers, and little prior training working with chemicals such as formaldehyde, might be reason for the high interest in getting training. Compared with male students, female students were more willing to get training on the use of formaldehyde in the laboratory (p = .008; Table 1), which suggests that in addition to other factors, gender should be considered when designing training programs to protect workers against exposure to formaldehyde.

We reported that 16.7% of this study's participants had preexisting respiratory conditions such as asthma and reactive airways. Additionally, 34.4% of participants reported being allergic to numerous materials and chemicals (Figure 3). Occupational-induced asthma is caused by exposure to hazardous chemicals in the workplace; formaldehyde has been linked to occupational-induced asthma as well as to the exacerbation of asthmatic attacks in people living with asthma (Niemelä & Vainio, 1981; Nordman et al., 1985).

In a mouse experiment, formaldehyde exposure and increase in relative humidity exacerbated allergic asthma (Duan et al., 2020). Studies have shown that repeated exposure to high levels of formaldehyde-containing hair straightener is common (Pexe et al., 2019) and is associated with new-onset asthma in salon workers (Dahlgren & Talbott, 2018). Furthermore, high exposure to formaldehyde increases the likelihood of the development of asthma in children (McGwin et al., 2011; Rumchev et al., 2002; Yao et al., 2015; Yu et al., 2020) and in adults (Yu et al., 2020). Occupational exposure to formaldehyde also increases the risk of nasopharyngeal carcinoma (Vaughan et al., 2000). Furthermore, a positive correlation has been reported between formaldehyde exposure and formic acid in urine as well as DNA damage in the exposed individuals (Peteffi et al., 2016).

FIGURE **3**

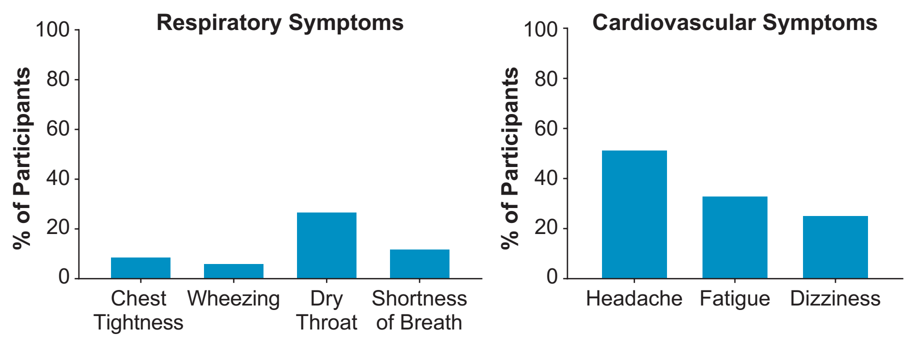
Preexisting Conditions and Allergy Symptoms



Note. The graph on the left shows the percentage of participants with A) preexisting respiratory conditions and B) allergies. The graph on the right shows the percentage of participants with various allergy symptoms during laboratory sessions or shortly after.

FIGURE **4**

Respiratory and Cardiovascular Symptoms



Note. The graph on the left shows the percentage of participants with various respiratory symptoms. The graph on the right shows the percentage of participants with various cardiovascular symptoms during laboratory sessions or shortly after.

There was a significant relationship between preexisting respiratory conditions and the willingness to use respiratory PPE in the laboratory (p = .01; Table 1). Furthermore, susceptibility to disease and perceived severity of contracting occupational diseases, which are components of the Health Belief Model, are positive predictive factors in determining compliance regarding the use of respiratory PPE (Wright et al., 2019). This finding suggests that knowledge of preexisting respiratory conditions such as occupational-induced asthma and exacerbation of asthma is an important predictive factor regarding compliance with the use of respiratory PPE.

Some of the participants experienced allergy symptoms during laboratory sessions or shortly after, including eye irritation, sinus irritation, runny nose, and itchy skin (Figure 3). These symptoms are consistent with findings from other studies on allergy symptoms experienced by individuals exposed to formaldehyde (Onyije & Avwioro, 2012, Saowakon et al., 2015). Prolonged exposure to formaldehyde is also associated with a decrease in the sense of smell and increased nasal and throat irritation (Koirala et al., 2015). Furthermore, some participants experienced cardiovascular symptoms such as headache, fatigue, and dizziness during laboratory sessions or shortly after (Figure 4). Headache is a common symptom experienced by students as a result of exposure to formaldehyde in gross anatomy dissection laboratories (Alnagar et al., 2018). A different study showed that formaldehyde exposure significantly increased blood concentration of formaldehyde in the exposed group compared with the control group in workers in a wood industry (Jafari et al., 2015).

Finally, some participants also experienced respiratory symptoms such as chest tightness, wheezing, dry throat, and shortness of breath during laboratory sessions or shortly after (Figure 4). Similarly, Alnagar et al. (2018) showed that students experienced respiratory distress as a result of exposure to formaldehyde. In our study, most of the respiratory symptoms are consistent with results described by Jafari et al. (2015).

Limitations

One of the limitations of our study is that formaldehyde levels were not measured in the laboratory during the dissection sessions. We also did not get measurements from students from previous class cohorts. Further, participant symptoms were self-reported, not directly assessed. The participants in this study were all graduate students, mostly between the ages of 20 and 30, and 70% of them self-identified as female, which could be a source of bias.

Conclusion

In light of the classification of formaldehyde as a carcinogen, more efforts should be made to prevent occupational exposure. Students experience various formaldehyde-related symptoms and should spend no more time than required in the dissection room. Proper engineering controls should be in place to maintain lower levels of formaldehyde in the rooms. Efforts should also be made to consistently monitor formaldehyde levels in dissection rooms to maintain acceptable levels. Factors such as gender, preexisting respiratory conditions, training for use of PPE, and pregnancy status should be considered when designing a program to minimize exposure to formaldehyde during dissection sessions.

Therefore, the recommendation is for periodic measurement of formaldehyde in the laboratory to be in compliance with OSHA standards. Knowledge from this study can be applied to other industries where workers are exposed to formaldehyde, taking into account factors such as gender, worker attitude, and preexisting conditions to prevent any associated adverse health effects. Finally, we recommend future research to measure ambient formaldehyde levels in the laboratory and record the corresponding student respiratory (e.g., respiratory rate and oxygen saturation) and cardiovascular (e.g., blood pressure and pulse rate) parameters as well as symptoms associated with formaldehyde exposure in the cadaver laboratory.

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References

Agency for Toxic Substances and Disease Registry. (2021). *Toxic substances portal: Formaldehyde—Public health statement for formaldehyde.* https://wwwn.cdc.gov/TSP/PHS/PHS.aspx?phsid=218&toxid=39

Alnagar, F.A., Shmela, M.E., Alrtib, A.M., Benashour, F.M., Buker, A.O., & Abdalmula, A.M. (2018). Health adverse effects of formaldehyde exposure to students and staff in gross anatomy. *International Journal of Scientific Research and Management*, *6*(2), MP-2018-27-36. https://doi.org/10.18535/IJSRM/V6I2.MP02

Amiri, A., Pryor, E., Rice, M., Downs, C.A., Turner-Henson, A., & Fanucchi, M.V. (2015). Formaldehyde exposure during pregnancy. *MCN, The American Journal of Maternal/Child Nursing*, *40*(3), 180–185. https://doi.org/10.1097/NMC.0000000000000125

Amiri, A., & Turner-Henson, A. (2017). The roles of formaldehyde exposure and oxidative stress in fetal growth in the second trimester. *Journal of Obstetric, Gynecologic, & Neonatal Nursing*, *46*(1), 51–62. https://doi.org/10.1016/j.jogn.2016.08.007

Bhat, D., Chittoor, H., Murugesh, P., Basavanna, P.N., & Doddaiah, S. (2019). Estimation of occupational formaldehyde exposure in cadaver dissection laboratory and its implications. *Anatomy & Cell Biology*, *52*(4), 419–425. https://doi.org/10.5115/acb.19.105

Brenner, E. (2014). Human body preservation—Old and new techniques. *Journal of Anatomy*, *224*(3), 316–344. https://doi.org/10.1111/joa.12160

Chen, D., Fang, L., Mei, S., Li, H., Xu, X., Des Marais, T.L., Lu, K., Liu, X.S., & Jin, C. (2017). Regulation of chromatin assembly and cell transformation by formaldehyde exposure in human cells. *Environmental Health Perspectives*, *125*(9), Article 097019. https://doi.org/10.1289/EHP1275

Dahlgren, J.G., & Talbott, P.J. (2018). Asthma from hair straightening treatment containing formaldehyde: Two cases and a review of the literature. *Toxicology and Industrial Health*, *34*(4), 262–269. https://doi.org/10.1177/0748233717750982

Duan, J., Xie, J., Deng, T., Xie, X., Liu, H., Li, B., & Chen, M. (2020). Exposure to both formaldehyde and high relative humidity exacerbates allergic asthma by activating the TRPV4-p38 MAPK pathway in Balb/c mice. *Environmental Pollution*, *256*, Article 113375. https://doi.org/10.1016/j.envpol.2019.113375

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References *continued from page 19*

Duong, A., Steinmaus, C., McHale, C.M., Vaughan, C.P., & Zhang, L. (2011). Reproductive and developmental toxicity of formaldehyde: A systematic review. *Mutation Research/Reviews in Mutation Research*, *728*(3), 118–138. https://doi.org/10.1016/j.mrrev.2011.07.003

Han, S.-P., Zhou, D.-X., Lin, P., Qin, Z., An, L., Zheng, L.-R., & Lei, L. (2015). Formaldehyde exposure induces autophagy in testicular tissues of adult male rats. *Environmental Toxicology*, *30*(3), 323–331. https://doi.org/10.1002/tox.21910

International Agency for Research on Cancer. (2012). *Chemical agents and related occupations: IARC monographs on the evaluation of carcinogenic risks to humans* (IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, No. 100F). https://www.ncbi.nlm.nih.gov/books/NBK304416/

Jafari, M.J., Rahimi, A., Omidi, L., Behzadi, M.H., & Rajabi, M.H. (2015). Occupational exposure and health impairments of formaldehyde on employees of a wood industry. *Health Promotion Perspectives*, *5*(4), 296–303. https://doi.org/10.15171/hpp.2015.035

Koirala, S., Shah, S., Khanal, L., Pokhrel, C., & Poudel, D. (2015). Effect of formalin among the medical and dental students attending regular laboratory session in dissecting hall, in Department of Human Anatomy, in B.P. Koirala Institute of Health Sciences. *European Journal of Forensic Sciences*, 2(3), 1–4. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.669.5493&rep=rep1&type=pdf

Leal, M.P., Brochetti, R.A., Ignácio, A., Câmara, N.O.S., da Palma, R.K., de Oliveira, L.V.F., Teixeira da Silva, D., & Lino-dos-Santos-Franco, A. (2018). Effects of formaldehyde exposure on the development of pulmonary fibrosis induced by bleomycin in mice. *Toxicology Reports*, *5*, 512–520. https://doi.org/10.1016/j.toxrep.2018.03.016

McGwin, G., Jr., Lienert, J., & Kennedy, J.I., Jr. (2011). Formaldehyde exposure and asthma in children: A systematic review. *Ciência & Saúde Coletiva*, *16*(9), 3845–3852. https://doi.org/10.1590/s1413-81232011001000020

National Academy of Sciences. (2014). *Review of the formaldehyde assessment in the National Toxicology Program 12th report on carcinogens*. The National Academies Press. https://www.nap.edu/resource/18948/formaldehyde-report-highlights-Final2.pdf

National Institute for Occupational Safety and Health. (2019). *Formaldehyde*. https://www.cdc.gov/niosh/topics/formaldehyde

Niemelä, R., & Vainio, H. (1981). Formaldehyde exposure in work and the general environment. Occurrence and possibilities for prevention. *Scandinavian Journal of Work, Environment & Health*, *7*(2), 95–100. https://doi.org/10.5271/sjweh.2554

Nordman, H., Keskinen, H., & Tuppurainen, M. (1985). Formaldehyde asthma—Rare or overlooked? *Journal of Allergy and Clinical Immunology*, *75*(1, Pt. 1), 91–99. https://doi.org/10.1016/0091-6749(85)90018-1

Onyeka, C.O., Chiemerie, M.S., Ozoemena, M.S., & Nwabunwanne, O.V. (2018). Effects of formaldehyde inhalation on cardiopulmonary functions on medical students of College of Health Sciences, Nnamdi Azikiwe University during dissection classes. *American Journal of Physiology, Biochemistry and Pharmacology*, *7*(2), 86–94. https://www.ajpbp.com/ajpbp-articles/effects-of-formaldehyde-inhalation-on-cardiopulmonary-functions-on-medical-students-of-college-of-health-sciences-nnamdi.pdf

Occupational Safety and Health Administration. (2006). *OSHA FactSheet: Personal protective equipment*. https://www.osha.gov/OshDoc/data_General_Facts/ppe-factsheet.pdf

Occupational Safety and Health Administration. (2011). *OSHA FactSheet: Formaldehyde*. https://www.osha.gov/sites/default/files/publications/formaldehyde-factsheet.pdf

Occupational Safety and Health Administration. (2013). *Formaldehyde* (Standard # 1910.1048). https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1048

Occupational Safety and Health Administration. (2019). *Nonmandatory medical disease questionnaire* (Standard # 1910.1048 App D). https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=10079&p_table=STANDARDS

Onyebeke, L.C., Papazaharias, D.M., Freund, A., Dropkin, J., McCann, M., Sanchez, S.H., Hashim, D., Meyer, J.D., Lucchini, R.G., & Zuckerman, N.C. (2016). Access to properly fitting personal protective equipment for female construction workers. *American Journal of Industrial Medicine*, *59*(11), 1032–1040. https://doi.org/10.1002/ajim.22624

Onyije, F.M., & Avwioro, O.G. (2012). Excruciating effect of formaldehyde exposure to students in gross anatomy dissection laboratory. *International Journal of Occupational and Environmental Medicine*, *3*(2), 92–95.

Peteffi, G.P., Antunes, M.V., Carrer, C., Valandro, E.T., Santos, S., Glaeser, J., Mattos, L., da Silva, L.B., & Linden, R. (2016). Environmental and biological monitoring of occupational formaldehyde exposure resulting from the use of products for hair straightening. *Environmental Science and Pollution Research*, *23*, 908–917. https://doi.org/10.1007/s11356-015-5343-4

Pexe, M.E., Marcante, A., Luz, M.S., Fernandes, P.H.M., Neto, F.C., Sato, A.P.S., & Olympio, K.P.K. (2019). Hairdressers are exposed to high concentrations of formaldehyde during the hair straightening procedure. *Environmental Science and Pollution Research*, *26*, 27319–27329. https://doi.org/10.1007/s11356-019-05402-9

Raja, D.S., & Sultana, B. (2012). Potential health hazards for students exposed to formaldehyde in the gross anatomy laboratory. *Journal of Environmental Health*, *74*(6), 36–41. https://www.jstor.org/stable/26329342

Roberts, A.L., Johnson, N.J., Cudkowicz, M.E., Eum, K.-D., & Weisskopf, M.G. (2016). Job-related formaldehyde exposure and ALS mortality in the USA. *Journal of Neurology, Neurosurgery, & Psychiatry*, *87*(7), 786–788. https://doi.org/10.1136/jnnp-2015-310750

Rumchev, K.B., Spickett, J.T., Bulsara, M.K., Phillips, M.R., & Stick, S.M. (2002). Domestic exposure to formaldehyde significantly increases the risk of asthma in young children. *European Respi-*

References

ratory Journal, *20*(2), 403–408. https://doi.org/10.1183/09031936.02.00245002

SafeStart. (2014, June 18). 4 factors that influence PPE compliance. https://safestart.com/news/4-factors-influence-ppe-compliance/

Saowakon, N., Ngernsoungnern, P., Watcharavitoon, P., Ngernsoungnern, A., & Kosanlavit, R. (2015). Formaldehyde exposure in gross anatomy laboratory of Suranaree University of Technology: A comparison of area and personal sampling. *Environmental Science and Pollution Research*, *22*(23), 19002–19012. https://doi.org/10.1007/s11356-015-5078-2

Seals, R.M., Kioumourtzoglou, M.-A., Gredal, O., Hansen, J., & Weisskopf, M.G. (2017). Occupational formaldehyde and amyotrophic lateral sclerosis. *European Journal of Epidemiology*, *32*(10), 893–899. https://doi.org/10.1007/s10654-017-0249-8

Thetkathuek, A., Yingratanasuk, T., & Ekburanawat, W. (2016). Respiratory symptoms due to occupational exposure to formaldehyde and MDF dust in a MDF furniture factory in Eastern Thailand. *Advances in Preventive Medicine*, *2016*, Article 3705824. https://doi.org/10.1155/2016/3705824

Tulpule, K., & Dringen, R. (2013). Formaldehyde in brain: An overlooked player in neurodegeneration? *Journal of Neurochemistry*, *127*(1), 7–21. https://doi.org/10.1111/jnc.12356

Vaughan, T.L., Stewart, P.A., Teschke, K., Lynch, C.F., Swanson, G.M., Lyon, J.L., & Berwick, M. (2000). Occupational exposure to formaldehyde and wood dust and nasopharyngeal carcinoma. *Occupational & Environmental Medicine*, *57*(6), 376–384. https://doi.org/10.1136/oem.57.6.376

Vohra, M.S. (2011). Personal formaldehyde exposure level in the gross anatomy dissecting room at College of Medicine King Saud University Riyadh. *International Journal of Occupational Medicine and Environmental Health*, *24*(1), 108–113. https://doi.org/10.2478/s13382-011-0004-4

Wang, H.-X., Zhou, D.-X., Zheng, L.-R., Zhang, J., Huo, Y.-W., Tian, H., Han, S.-P., Zhang, J., & Zhao, W.-B. (2012). Effects of paternal occupation exposure to formaldehyde on reproductive outcomes. *Journal of Occupational and Environmental Medicine*, *54*(5), 518–524. https://doi.org/10.1097/JOM.0b013e31824e6937

Wright, T., Adhikari, A., Yin, J., Vogel, R., Smallwood, S., & Shah, G. (2019). Issue of compliance with use of personal protective equipment among wastewater workers across the southeast region of the United States. *International Journal of Environmental Research and Public Health*, *16*(11), Article 2009. https://doi.org/10.3390/ijerph16112009

Xu, W., Zhang, W., Zhang, X., Dong, T., Zeng, H., & Fan, Q. (2017). Association between formaldehyde exposure and miscarriage in Chinese women. *Medicine*, *96*(26), e7146. https://doi.org/10.1097/MD.0000000000007146

Ya'Acob, S.H., Suis, A.J., Awang, N., & Sahani, M. (2013). Exposure assessment of formaldehyde and its symptoms among anatomy laboratory workers and medical students. *Asian Journal of Applied Sciences*, *6*(1), 50–55. https://doi.org/10.3923/ajaps.2013.50.55

Yao, Y., Liang, W., Zhu, L., Duan, Y., Jin, Y., & He, L. (2015). Relationship between the concentration of formaldehyde in the air and asthma in children: A meta-analysis. *International Journal of Clinical and Experimental Medicine*, *8*(6), 8358–8362. http://europepmc.org/article/PMC/4538175

Yu, L., Wang, B., Cheng, M., Yang, M., Gan, S., Fan, L., Wang, D., & Chen, W. (2020). Association between indoor formaldehyde exposure and asthma: A systematic review and meta-analysis of observational studies. *Indoor Air*, *30*(4), 682–690. https://doi.org/10.1111/ina.12657

Zendehdel, R., Fazli, Z., & Mazinani, M. (2016). Neurotoxicity effect of formaldehyde on occupational exposure and influence of individual susceptibility to some metabolism parameters. *Environmental Monitoring and Assessment*, *188*(11), Article 648. https://doi.org/10.1007/s10661-016-5662-z

Understanding Public Health Worker Beliefs About Radon Gas Exposure

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Abstract **Radon is a tasteless, colorless, and odorless gas that can cause lung cancer. Radon gas is estimated to be the second leading cause of lung cancer in the U.S. and is the leading cause of lung cancer mortality among nonsmokers. The goal of this study was to better understand radon gas exposure beliefs among public health workers. Public health workers engage in actions that enhance and improve health in the communities they serve. They act as change agents and can influence public perceptions and attitudes toward health risk factors. This study surveyed four classifications of public health workers in New Jersey (*N* = 386): health educators, health officers, registered nurses, and registered environmental health specialists. A questionnaire survey was used to explore their beliefs about radon gas exposure. This study found significant differences (p <.05) in public health worker beliefs regarding radon gas exposure, which suggests that the role of public health workers in disseminating information about environmental hazards to communities should be well defined and uniform. Furthermore, training for public health workers on the hazards posed by radon gas is needed.**

Introduction

Radon gas is a carcinogen (International Agency for Research on Cancer, 1988). Radon results from the breakdown of uranium in soil, rock, and water—producing an invisible, tasteless, and odorless radioactive gas (U.S. Environmental Protection Agency [U.S. EPA], 2016). When inhaled, radon particles become trapped in the lungs and can cause lung cancer.

Radon gas seeps through cracks, crevices, walls, and foundations and can build up to levels that are harmful to the lungs (Al Zabadi et al., 2012; U.S. EPA, 2014, 2016). The primary routes of exposure of radon to humans are through 1) inhalation and 2) ingestion of water that has dissolved radon in it. Radon gas sources include well water used for showering that releases radon into the air, which humans then inhale. There are no separate radon limits for well water. The most significant health risk to humans is inhalation of radon rather than ingestion (Al Zabadi et al., 2012; U.S. EPA, 2016). Testing for radon gas exposure is highly recommended to determine if a home has an elevated radon level (≥4 pCi/L). Previous studies show that radon exposure combined with smoking increases the smoker's risk of lung cancer at least 10-fold (National Research Council, 1988; Reif & Heeren, 1999). Both U.S. Department of Health and Human Services (2005) and U.S. EPA (2016) recommend that all homes below the third floor be tested for radon.

Radon gas is responsible for more than 21,000 deaths each year and causes approximately 22% of lung cancer cases in the U.S. (U.S. EPA, 2016). The first Healthy People report highlighted that environmental factors directly or indirectly contribute to chronic diseases (U.S. Department of Health, Education, and Welfare, 1979). Many researchers have identified associations between specific adverse health outcomes and environmental exposures (Abramson et al., 2014; Baldwin et al., 1998; Duckworth et al., 2002; Hazar et al., 2014). Many studies show positive correlations between radon gas exposure and accurate understanding of health risks from environmental exposure and have identified radon gas as a public health hazard with correlates of risk perception in the race, age, income, gender, educational level, and years on a property (Abramson et al., 2014; Baldwin et al., 1998; Duckworth et al., 2002; Hazar et al., 2014; Kennedy et al., 1991; Rinker et al., 2014; Shendell & Carr, 2013; Wang et al., 2000; Weinstein et al., 1991, 2008).

Public health workers are part of the public health system whose job is to enhance and improve health in their communities (World Health Organization [WHO], 2006). Public health workers act as change agents and can influence the public perception and attitude toward health risk factors because they are in daily contact with members of the public (Cohrssen & Covello, 1989; O'Fallon, 2006; WHO, 2006). A 1988 Institute of Medicine report stated that public health workers and their agencies serve as stewards of the primary healthcare needs of the entire U.S. population. They provide guidance and healthcare to individuals who do not have access to regular healthcare systems and programs. Public health workers can act as agents of change by communicating risk to the public using their knowledge about radon gas exposure (WHO, 2009).

There have been previous studies of radon knowledge among public health workers (Nwako & Cahill, 2020) and their personal practices about radon gas exposure (Nwako, 2021). It is imperative to study radon gas exposure beliefs of public health workers to understand if their beliefs vary by public health worker category. Studying their beliefs about radon gas exposure will determine the effectiveness of using public health workers as agents of change in their communities to increase radon gas exposure awareness and testing for radon gas.

Communicating effectively is part of the risk analysis process and therefore is essential for managing information and beliefs related to real and perceived hazards (Food and Agriculture Organization of the United Nations & World Health Organization, 1998). Public health workers engage in actions with the primary intention of enhancing and improving the health of their communities (WHO, 2006). Public health department workers have a particular significance as they are on the front line for providing essential public health services (National Association of County and City Health Officials [NACCHO], 2014). There are many professions in public health, depending on the areas of expertise.

The primary purpose of this study was to explore potential differences in various public health worker beliefs about radon gas exposure. Specifically, the proposed research question was: Is there a difference in beliefs about radon gas exposure among public health workers?

Methods

This study employed a descriptive, cross-sectional design. The principal investigator sought to understand radon gas exposure beliefs of public health workers. Seton Hall University Institutional Review Board approved this study. Study participants were public health workers employed by public health departments in New Jersey. Public health workers who participated in this study were health educators, health officers, registered nurses, and registered environmental health specialists (REHS).

The New Jersey Literacy Information and Communication System (NJLINCS) portal—a communication channel to public health workers in New Jersey—was used to send out survey information to public health workers. The survey went out to 1,330 users who were asked to forward the survey to other public health workers who were not part of the NJLINCS system. The survey email included a letter that explained the purpose of the study, study procedure, voluntary nature of the survey, anonymity of the survey, confidentiality of the data, and how to request further information. Two messages went out through NJLINCS 2 weeks apart reminding public health workers to participate in the study. Individuals who agreed to participate in the study accessed the survey via a link in the email to SurveyMonkey.

Variables

The public health workforce comprises individuals from various academic backgrounds, professional experiences, and credentials. The independent variables of this study are public health workers working at local public health departments in New Jersey. The public health workers include health educators, health officers, registered nurses, and REHS.

We developed a survey instrument by using thematic topics in the literature about radon gas and by engaging with authors who had expertise in environmental hazards and radon (Rinker et al., 2014; Rosenthal, 2011; Weinstein et al., 1991, 1998; 2008). A modified Delphi panel established face validity and content validity (Hasson et al., 2000; Powell, 2003). The Delphi panel was made up of six experts. They assessed questions for agreement with constructs in the scoring schematic and provided feedback to explain their choices. The survey instrument consisted of a 5-point Likert scale from strongly agree to strongly disagree. In addition, there were 12 questions related to public health worker beliefs. Thus, the dependent variables are the belief question scores. The beliefs scale had a Cronbach's α of 0.81, which indicates good internal consistency.

Data Analysis

This study used SPSS version 24.0 for data analysis. The 12 questions related to beliefs about perceptions of radon were treated as ordinal data. The test of differences was conducted using the Kruskal–Wallis test to measure the differences in beliefs. The types of public health workers are independent categorical nominal variables, while the scores from the beliefs questions are dependent categorical ordinal variables.

Results

A total of 386 participants completed surveys in this study. There were 107 (28%) health educators, 50 (13%) health officers, 100 (26%) registered nurses, and 129 (33%) REHS (Table 1). More than one half of participants were ages 31–40 years (195, 51%). The second-largest group of participants was 41–50 years, (88, 23%). Furthermore, the group 51–60 years had 48 participants (12%), the group 61–70 years had 16 participants (4%), and the group 20–30 years had 38 respondents (10%). There was one participant >70 years (Table 1).

The study predicted a significant difference in beliefs about radon gas exposure among public health workers. A Kruskal–Wallis H test was used to test the differences in beliefs among public health workers. A significant outcome ($H(3) = 19.19$, $p < .01$) indicated that the beliefs about radon gas exposure differed among public health workers. A follow-up pairwise comparison showed that REHS performed better in their responses than the other public health workers regarding their beliefs about radon gas exposure. Age did not factor in to the way respondents answered the beliefs questions. Respondents answered differently regardless of their age group.

Table 2 shows all responses from survey participants and Table 3 shows the differences in answers by public health worker category to the 12 beliefs questions:

1. **Living with radon exposure greater than 4 pCi/L could result in serious health problems for me.** For all survey participants, 92% strongly agreed/agreed, 7% were neutral, and 1% strongly disagreed/disagreed. For specific public health workers categories, 93% of health educators, 86% of health officers, 98% of registered nurses, and 88% of REHS strongly

agreed/agreed. Additionally, 6% of health educators, 14% of health officers, 2% of registered nurses, and 9% of REHS were neutral. Finally, 1% of health educators, 0% of health officers, 0% of registered nurses, and 2% of REHS strongly disagreed/disagreed.

2. **I am worried about radon causing illness in me.** For all survey participants, 79% strongly agreed/agreed, 9% were neutral, and 12% strongly disagreed/disagreed. For specific public health workers categories, 59% of health educators, 44% of health officers, 92% of registered nurses, and 73% of REHS strongly agreed/agreed. Additionally, 7% of health educators, 18% of health officers, 3% of registered nurses, and 12% of REHS were neutral. And lastly, 5% of health educators, 38% of health officers, 5% of registered nurses, and 15% of REHS strongly disagreed/disagreed.
3. **There is a real chance that I could have a radon problem in my house.** For all survey participants, 79% strongly agreed/agreed, 6% were neutral, and 16% strongly disagreed/disagreed. For specific public health workers categories, 49% of health educators, 48% of health officers, 93% of registered nurses, and 71% of REHS strongly agreed/agreed. Additionally, 6% of health educators, 12% of health officers, 3% of registered nurses, and 6% of REHS were neutral. Lastly, 7% of health educators, 40% of health officers, 4% of registered nurses, and 23% of REHS strongly disagreed/disagreed.
4. **Mitigation in my house can save lives.** For all survey participants, 91% strongly agreed/agreed, 7% were neutral, and 3% strongly disagreed/disagreed. For specific public health workers categories, 95% of health educators, 74% of health officers, 96% of registered nurses, and 89% of REHS strongly agreed/agreed. Moreover, 4% of health educators, 22% of health officers, 3% of registered nurses, and 6% of REHS were neutral. Finally, 1% of health educators, 4% of health officers, 1% of registered nurses, and 4% of REHS strongly disagreed/disagreed.
5. **I believe that radon is likely to be present in my neighborhood.** For all survey participants, 82% strongly agreed/agreed, 9% were neutral, and 9% strongly disagreed/disagreed. For specific public health workers categories, 90% of health educators, 64% of health officers, 93% of registered nurses, and 75% of REHS strongly agreed/agreed. Moreover, 6% of health educators, 16% of health officers, 2% of registered nurses, and 14% of REHS were neutral. Lastly, 5% of health educators, 16% of health officers, 5% of registered nurses, and 10% of REHS strongly disagreed/disagreed.
6. **I am worried about radon causing illness to the public that I serve.** For all survey participants, 88% strongly agreed/agreed, 8% were neutral, and 4% strongly disagreed/disagreed. For specific public health workers categories, 93% of health educators, 72% of health officers, 94% of registered nurses, and 84% of REHS strongly agreed/agreed. Additionally, 4% of health educators, 20% of health officers, 3% of registered nurses, and 10% of REHS were neutral. Lastly, 3% of health educators, 8% of health officers, 3% of registered nurses, and 5% of REHS strongly disagreed/disagreed.
7. **The health risk from the combination of smoking and radon is much greater than from either of those alone.** For all survey participants, 98% strongly agreed/agreed, 1% were neutral, and <1% strongly disagreed/disagreed. For specific public health workers categories, 98% of health educators, 98% of health officers, 100% of registered nurses, and 97% of REHS strongly agreed/agreed. And 2% of health educators, 0% of health officers, 0% of registered nurses, and 2% of REHS were neutral. Lastly, 0% of health educators, 4% of health officers, 0% of registered nurses, and 0% of REHS strongly disagreed/disagreed.
8. **If there is radon in my home, then it is a health risk to me.** For all survey participants, 98% strongly agreed/agreed, 1% were neutral, and 1% strongly disagreed/disagreed. For specific public health workers categories, 100% of health educators, 98% of health officers, 100% of registered nurses, and 97% of REHS strongly agreed/agreed. Also, 0% of health educators, 4% of health officers, 0% of registered nurses, and 1% of REHS were neutral. Lastly, 0% of health educators, 2% of health officers, 0% of registered nurses, and 1% of REHS strongly disagreed/disagreed.
9. **If there is radon in my home, then it is a health risk to others living with me.** For all survey participants, 99% strongly agreed/agreed, <1% were neutral, and 1% strongly disagreed/disagreed. For specific public health workers categories, 91% of

TABLE **1**

Survey Participant Characteristics (*N* = 386)

Characteristic	#	%
Job title		
Health educator	107	27.7
Health officer	50	13.0
Registered nurse	100	25.9
REHS	129	33.4
Age (years)		
20–30	38	9.8
31–40	195	50.5
41–50	88	22.8
51–60	48	12.4
61–70	16	4.1
>70	1	0.3

Note. REHS = registered environmental health specialist.

TABLE **2**

Survey Participant Responses to Beliefs Questions (*N* = 386)

Question	Strongly Agree # (%)	Agree # (%)	Neutral # (%)	Disagree # (%)	Strongly Disagree # (%)
1: Living with radon exposure greater than 4 pCi/L could result in serious health problems for me.	130 (33.7)	225 (58.3)	27 (7.0)	3 (0.8)	1 (0.3)
2: I am worried about radon causing illness in me.	102 (26.4)	201 (52.1)	35 (9.1)	44 (11.4)	4 (1.0)
3: There is a real problem that I could have a radon problem in my house.	149 (38.6)	154 (39.9)	23 (6.0)	43 (11.1)	17 (4.4)
4: Mitigation in my house can save lives.	195 (50.5)	155 (40.2)	26 (6.7)	6 (1.6)	4 (1.0)
5: I believe that radon is likely to be present in my neighborhood.	169 (43.8)	149 (38.6)	34 (8.8)	26 (6.7)	8 (2.1)
6: I am worried about radon causing illness to the public that I serve.	175 (45.3)	164 (42.5)	30 (7.8)	11 (2.8)	6 (1.6)
7: The health risk from the combination of smoking and radon is much greater than from either of these alone.	217 (56.2)	163 (42.2)	5 (1.3)	0	1 (0.3)
8: If there is radon in my home, then it is a health risk to me.	198 (51.3)	181 (46.9)	4 (1.0)	2 (0.5)	1 (0.3)
9: If there is radon in my home, then it is a health risk to others living with me.	207 (53.6)	176 (45.6)	1 (0.3)	1 (0.3)	1 (0.3)
10: I believe that the health risk from the combination of secondhand smoke and radon is much greater than from either of these alone.	192 (49.7)	185 (47.9)	7 (1.8)	1 (0.3)	1 (0.3)
11: Reducing radon levels in homes helps prevent disease.	92 (23.8)	220 (57.0)	70 (18.1)	3 (0.8)	1 (0.3)
12: I believe I have sufficient knowledge about radon to be a change agent in my community.	28 (7.3)	63 (16.3)	74 (19.2)	186 (48.2)	35 (9.1)

health educators, 96% of health officers, 100% of registered nurses, and 99% of REHS strongly agreed/agreed. And 0% of health educators, 2% of health officers, 0% of registered nurses, and 0% of REHS were neutral. Lastly, 0% of health educators, 2% of health officers, 0% of registered nurses, and <1% of REHS strongly disagreed/disagreed.

10. **I believe that the health risk from the combination of secondhand radon is much greater than from either of these alone.** For all survey participants, 98% strongly agreed/agreed, 2% were neutral, and 1% strongly disagreed/disagreed. For specific public health workers categories, 96% of health educators, 96% of health officers, 99% of registered nurses, and 98% of REHS strongly agreed/agreed. Moreover, 4% of health educators, 0% of health officers, 1% of registered nurses, and 1% of REHS were neutral. And finally, 0% of health educators, 4% of health officers, 0% of registered nurses, and 0% of REHS strongly disagreed/disagreed.
11. **Reducing radon levels in homes helps prevent disease.** For all survey participants, 86% strongly agreed/agreed, 18% were neutral, and 1% strongly disagreed/disagreed. For specific public health workers categories, 63% of health educators, 98% of health officers, 71% of registered nurses, and 97% of REHS strongly agreed/agreed. Also, 36% of health educators, 0% of health officers, 29% of registered nurses, and 1% of REHS were neutral. And finally, 1% of health educators, 2% of health officers, 0% of registered nurses, and 1% of REHS strongly disagreed/disagreed.
12. **I believe I have sufficient knowledge about radon to be a change agent in my community.** For all survey participants, 24% strongly agreed/agreed, 19% were neutral, and 57% strongly disagreed/disagreed. For specific public health workers categories, 12% of health educators, 62% of health officers, 6% of registered nurses, and 32% of REHS strongly agreed/agreed. Additionally, 13% of health educators, 26% of health officers, 1% of registered nurses, and 36% of REHS were neutral. Lastly, 74% of health educators, 12% of health officers, 93% of registered nurses, and 68% of REHS strongly disagreed/disagreed.

Discussion

These study findings present similar results from previous studies regarding radon knowledge of public health workers, which found significant differences among health educators, health officers, registered nurses, and REHS (Nwako & Cahill, 2020). Significant differences were also found among personal practices of public health workers regarding radon gas exposure (Nwako, 2021). These results are consistent with previous studies that found public health workers differ in their knowledge and attitudes acquired from their training (NACCHO, 2011a, 2011b; WHO, 2006). Beliefs are formed through experiences in various aspects of life, including professional skills acquired from knowledge. As a result, public health workers perform their daily roles with acquired beliefs and pertinent knowledge of environmental and ecological hazards. These beliefs translate into how they disseminate information to the public regarding environmental hazards, including radon gas exposure. As local health departments across the U.S. perform public health prevention services, these services—directly and indirectly—affect the lives of individuals and communities that public health workers serve.

The response to question 12 (belief about having sufficient knowledge about radon to be a change agent) showed that all public health workers (57%) strongly disagreed/disagreed with the question (specifically, 74% of health educators, 12% of health officers, 93% of registered nurses, and 68% of REHS). Public health workers agreed that they need more knowledge about radon to become change agents in their communities. Health educators and registered nurses indicated they needed more radon knowledge training than did health officers and REHS, because these latter public health workers have to prepare for their board exams using environmental health knowledge, including radon.

The findings from this study align with the previous study conducted by Terpstra et al. (2009). Their study found that people had differences in how they perceive or view a hazard depending on their level of knowledge acquired through various sources. They reported that hazard adjustments increase adoption intentions with personal experience and provide more vibrant detailed information and lower levels of uncertainty. Secondhand experience with or without knowledge of a hazard, experience of a hazard, or hazard modifications can affect hazard modification adoption in the same ways as people's direct experience and protection motivation (Lindell & Prater, 2002; Terpstra et al., 2009).

The beliefs of public health workers differ because these workers come from various backgrounds and complete multiple trainings where they develop knowledge about radon gas exposure depending on prior experience, level of education, and daily work activity. Therefore, public health workers form their beliefs based on professional training, beliefs about the hazards, and how those hazards are presented during training.

The fact that radon is a tasteless, odorless, and invisible naturally occurring gas makes belief adoption difficult. Typically, humans believe that what cannot be seen and felt may not necessarily be harmful. Therefore, compared with many tangible environmental health hazards, people react less to radon gas because of its properties.

The role of public health workers as agents of change in the communities they serve has been well established and documented. Exploring public health worker beliefs about radon gas exposure enables public health agencies across the country to understand the beliefs of their staff, which provides a baseline to identify the different levels of environmental hazards training that public health workers need. A deeper understanding of these beliefs can foster increased public awareness. Results from this study can foster institutions of higher learning to include knowledge of environmental risks in the curriculum of environmental health professionals. Furthermore, foundational beliefs about radon gas exposure could be used to create trainings for public health workers.

TABLE **3**

Survey Participant Responses to Beliefs Questions by Public Health Worker Category

Question	Strongly Agree # (%)	Agree # (%)	Neutral # (%)	Disagree # (%)	Strongly Disagree # (%)
1: Living with radon exposure greater than 4 pCi/L could result in serious health problems for me.					
Health educator	43 (40)	57 (53)	6 (6)	0	1 (1)
Health officer	14 (28)	29 (58)	7 (14)	0	0
Registered nurse	21 (21)	77 (77)	2 (2)	0	0
REHS	52 (40)	62 (48)	12 (9)	3 (2)	0
2: I am worried about radon causing illness in me.					
Health educator	38 (35)	56 (52)	8 (7)	4 (4)	1 (1)
Health officer	7 (14)	15 (30)	9 (18)	17 (34)	2 (4)
Registered nurse	18 (18)	74 (74)	3 (3)	4 (4)	1 (1)
REHS	39 (30)	56 (43)	15 (12)	19 (15)	0
3: There is a real problem that I could have a radon problem in my house.					
Health educator	48 (45)	46 (43)	6 (6)	4 (4)	3 (3)
Health officer	8 (16)	16 (32)	6 (12)	12 (24)	8 (16)
Registered nurse	43 (43)	50 (50)	3 (3)	3 (3)	1 (1)
REHS	50 (39)	42 (32)	8 (6)	24 (19)	5 (4)
4: Mitigation in my house can save lives.					
Health educator	52 (48)	50 (47)	4 (4)	0	1 (1)
Health officer	19 (38)	18 (36)	11 (22)	1 (2)	1 (2)
Registered nurse	52 (52)	44 (44)	3 (3)	0	1 (1)
REHS	72 (56)	43 (33)	8 (6)	5 (4)	1 (<1)
5: I believe that radon is likely to be present in my neighborhood.					
Health educator	47 (44)	49 (46)	6 (6)	3 (3)	2 (2)
Health officer	12 (24)	20 (40)	8 (16)	6 (12)	4 (8)
Registered nurse	50 (50)	43 (43)	2 (2)	4 (4)	1 (1)
REHS	60 (46)	37 (29)	18 (14)	13 (10)	1 (<1)
6: I am worried about radon causing illness to the public that I serve.					
Health educator	55 (51)	45 (42)	4 (4)	1 (1)	2 (2)
Health officer	9 (18)	27 (54)	10 (20)	1 (2)	3 (6)
Registered nurse	50 (50)	43 (43)	2 (2)	4 (4)	1 (1)
REHS	53 (41)	56 (43)	13 (10)	7 (5)	0

continued ▸

TABLE **3** continued

Survey Participant Responses to Beliefs Questions by Public Health Worker Category

Question	Strongly Agree # (%)	Agree # (%)	Neutral # (%)	Disagree # (%)	Strongly Disagree # (%)
7: The health risk from the combination of smoking and radon is much greater than from either of these alone.					
Health educator	59 (55)	46 (43)	2 (2)	0	0
Health officer	28 (56)	21 (42)	0	1 (2)	1 (2)
Registered nurse	56 (56)	44 (44)	0	0	0
REHS	74 (57)	52 (40)	3 (2)	0	0
8: If there is radon in my home, then it is a health risk to me.					
Health educator	59 (55)	48 (45)	0	0	0
Health officer	18 (36)	29 (58)	2 (4)	0	1 (2)
Registered nurse	56 (56)	44 (44)	0	0	0
REHS	68 (53)	57 (44)	2 (1)	2 (1)	0
9: If there is radon in my home, then it is a health risk to others living with me.					
Health educator	55 (51)	52 (48)	0	0	0
Health officer	19 (38)	29 (58)	1 (2)	0	1 (2)
Registered nurse	52 (52)	48 (48)	0	0	0
REHS	81 (63)	47 (36)	0	1 (<1)	0
10: I believe that the health risk from the combination of secondhand smoke and radon is much greater than from either of these alone.					
Health educator	50 (47)	53 (49)	4 (4)	0	0
Health officer	26 (52)	22 (44)	0	1 (2)	1 (2)
Registered nurse	45 (45)	54 (54)	1 (1)	0	0
REHS	71 (55)	56 (43)	2 (1)	0	0
11: Reducing radon levels in homes helps prevent disease.					
Health educator	19 (18)	48 (45)	39 (36)	1 (1)	0
Health officer	22 (44)	27 (54)	0	0	1 (2)
Registered nurse	5 (5)	66 (66)	29 (29)	0	0
REHS	46 (36)	79 (61)	2 (1)	2 (1)	0
12: I believe I have sufficient knowledge about radon to be a change agent in my community.					
Health educator	4 (4)	9 (8)	14 (13)	52 (48)	28 (26)
Health officer	7 (14)	24 (48)	13 (26)	4 (8)	2 (4)
Registered nurse	0	6 (6)	1 (1)	89 (89)	4 (4)
REHS	17 (13)	24 (19)	46 (36)	41 (32)	1 (<1)

Note. Percentages are calculated within each public health worker category and not by the total number of survey responses (N = 386). For health educators, n = 107. For health officers, n = 50. For registered nurses, n = 100. For registered environmental health specialists (REHS), n = 129.

Implications for Policy and Practice

Competency-based training is essential for public health workers to follow the professional lines they represent in public health. According to NACCHO (2014), public health workers are credentialed in many areas of specialization. Competency-based training of all public health workers should include education on environmental health hazards—including radon gas hazards. Public health workers should also be part of the periodic internal assessments conducted in public health departments. Furthermore, regular internal evaluation should be part of a radon awareness program in public health departments to understand the beliefs public health workers hold about radon gas exposure.

Study Limitations

There were some limitations to this study. First, this study was cross-sectional and the sample was surveyed at a single time. Therefore, the generalizability of the findings is limited to the sample surveyed. Further, this study surveyed public health workers who work in New Jersey. Outreach to the community, however, is not always part of professional practice for all public health workers.

This study used SurveyMonkey to gather data from public health workers. Some respondents might have wanted clarification on some questions, but no additional information was available because the survey was online. Furthermore, respondents self-reported the data. Also, the geographic location of respondents in New Jersey could not be verified. Lastly, the study might have excluded public health workers who did not have access to email during the study period and this study did not correlate years of experience with beliefs.

Conclusion

The primary purpose of this study was to explore potential differences in the beliefs of different categories of various public health workers regarding radon gas exposure. We found that there are differences in their radon gas exposure beliefs. These differences are because public health workers have different educational backgrounds and training experiences before they enter the public health field. Competency-based training is essential for public health workers to follow the professional lines they represent in public health. Public health workers should go through yearly environmental health training, including radon gas awareness. This regular training can assist them in creating community awareness about radon gas exposure. Directions for future research should include longitudinal studies of public health worker beliefs about radon exposure to ascertain their responses over a period of time.

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References

Abramson, Z., Barkanova, S., & Redden, A.M. (2014). Concerning knowledge: Assessing radon knowledge and concern in rural Nova Scotia. *The Journal of Rural and Community Development*, *9*(2), 103–111. https://journals.brandonu.ca/jrcd/article/view/686/153

Al Zabadi, H., Musmar, S., Issa, S., Dwaikat, N., & Saffarini, G. (2012). Exposure assessment of radon in the drinking water supplies: A descriptive study in Palestine. *BMC Research Notes*, *5*, Article 29. https://doi.org/10.1186/1756-0500-5-29

Baldwin, G., Frank, E., & Fielding, B. (1998). U.S. women physicians' residential radon testing practices. *American Journal of Preventive Medicine*, *15*(1), 49–53. https://doi.org/10.1016/S0749-3797(98)00030-0

Cohrssen, J.J., & Covello, V.T. (1989). *Risk analysis: A guide to principles and methods for analyzing health and environmental risks*. Council on Environmental Quality. https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB89137772.xhtml

Duckworth, L.T., Frank-Stromborg, M., & Oleckno, W.A. (2002). Relationship of perception of radon as a health risk and willingness to engage in radon testing and mitigation. *Oncology Nursing Forum*, *29*(7), 1099–1107. https://doi.org/10.1188/02.ONF.1099-1107

Food and Agriculture Organization of the United Nations, & World Health Organization. (1998). *The application of risk communication to food standards and safety matters: 3. Elements and guiding principles of risk communication*. https://www.fao.org/3/x1271e/X1271E00.htm

Hasson, F., Keeney, S., & McKenna, H. (2000). Research guidelines for the Delphi survey technique. *Journal of Advanced Nursing*, *32*(4), 1008–1015. https://doi.org/10.1046/j.1365-2648.2000.t01-1-01567.x

Hazar, N., Karbakhsh, M., Yunesian, M., Nedjat, S., & Naddafi, K. (2014). Perceived risk of exposure to indoor residential radon and its relationship to willingness to test among health care providers in Tehran. *Journal of Environmental Health Science and Engineering*, *12*(1), Article 118. https://doi.org/10.1186/s40201-014-0118-2

Institute of Medicine. (1988). *The future of public health*. The National Academies Press. https://dx.doi.org/ 10.17226/1091

International Agency for Research on Cancer, & World Health Organization. (1988). *IARC monographs on the evaluation of the carcinogenic risks to humans: Man-made mineral fibres and radon, volume 43*. https://publications.iarc.fr/61

Kennedy, C.J., Probart, C.K., & Dorman, S.M. (1991). The relationship between radon knowledge, concern and behavior, and health values, health locus of control and preventive health behaviors. *Health Education Quarterly*, *18*(3), 319–329. https://doi.org/10.1177/109019819101800305

Lindell, M.K., & Prater, C.S. (2002). Risk area residents' perceptions and adoption of seismic hazard adjustments. *Journal of Applied Social Psychology*, *32*(11), 2377–2392. https://doi.org/10.1111/j.1559-1816.2002.tb01868.x

National Association of County and City Health Officials. (2011a). *Describing the local public health workforce: Workers who prevent, promote, and protect the nation's health*. http://www.naccho.org/uploads/downloadable-resources/Describing-the-Local-Public-Health-Workforce-Workers-who-Prevent-Promote-and-Protect-the-Nation-s-Health.pdf

National Association of County and City Health Officials. (2011b). *Local public health workforce benchmarks*. http://naccho.org/uploads/downloadable-resources/local-public-health-workforce-staffing-benchmarks.pdf

National Association of County and City Health Officials. (2014). *2013 national profile of local health departments*. https://naccho.org/uploads/downloadable-resources/2013_National_Profile021014.pdf

National Research Council. (1988). *Health risks of radon and other internally deposited alpha-emitters: BEIR IV*. The National Academies Press. https://doi.org/10.17226/1026

Nwako, P. (2021). Understand public health workers personal practices about radon gas exposure. *Journal of Community Medicine and Public Health Reports*, *2*(2). https://doi.org/10.38207/jcmphr20210021

Nwako, P., & Cahill, T. (2020). Radon gas exposure knowledge among public health educators, health officers, nurses, and registered environmental health specialists: A cross-sectional study. *Journal of Environmental Health*, *82*(6), 22–28.

O'Fallon, L.R. (2006). Fostering the relationship between environmental health and nursing. *Public Health Nursing*, *23*(5), 377–380. https://doi.org/10.1111/j.1525-1446.2006.00576.x

Powell, C. (2003). The Delphi technique: Myths and realities. *Journal of Advanced Nursing*, *41*(4), 376–382. https://doi.org/10.1046/j.1365-2648.2003.02537.x

Reif, A.E., & Heeren, T. (1999). Consensus on synergism between cigarette smoke and other environmental carcinogens in the causation of lung cancer. *Advances in Cancer Research*, *76*, 161–186. https://doi.org/10.1016/S0065-230X(08)60776-9

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

Rosenthal, S. (2011). Measuring knowledge of indoor environmental hazards. *Journal of Environmental Psychology*, *31*(2), 137–146. https://doi.org/10.1016/j.jenvp.2010.08.003

References

Shendell, D.G., & Carr, M. (2013). Physical conditions of a house and their effects on measured radon levels: Data from Hillsborough Township, New Jersey, 2010–2011. *Journal of Environmental Health, 76*(3), 18–24.

Terpstra, T., Lindell, M.K., & Gutteling, J.M. (2009.) Does communicating (flood) risk affect (flood) risk perceptions? Results of a quasi-experimental study. *Risk Analysis*, *29*(8), 1141–1155. https://doi.org/10.1111/j.1539-6924.2009.01252.x

U.S. Department of Health and Human Services. (2005). *Surgeon General releases national health advisory on radon* [Press release]. http://www.adph.org/radon/assets/surgeon_general_radon.pdf

U.S. Department of Health, Education, and Welfare. (1979). *Healthy people: The Surgeon General's report on health promotion and disease prevention*. https://profiles.nlm.nih.gov/101584932X92

U.S. Environmental Protection Agency. (2014). *Air quality index: A guide to air quality and your health* (EPA-456/F-14-002). https://www.airnow.gov/sites/default/files/2018-04/aqi_brochure_02_14_0.pdf

U.S. Environmental Protection Agency. (2016). *A citizen's guide to radon* (EPA 402/K-12/002). https://www.epa.gov/sites/default/files/2016-12/documents/2016_a_citizens_guide_to_radon.pdf

Wang, Y., Ju, C., Stark, A.D., & Teresi, N. (2000). Radon awareness, testing, and remediation survey among New York State residents. *Health Physics*, *78*(6), 641–647. https://doi.org/10.1097/00004032-200006000-00006

Weinstein, N.D., Lyon, J.E., Sandman, P.M., & Cuite, C.L. (1998). Experimental evidence for stages of health behavior change: The precaution adoption process model applied to home radon testing. *Health Psychology*, *17*(5), 445–453. https://doi.org/10.1037//0278-6133.17.5.445

Weinstein, N.D., Sandman, P.M., & Blalock, S.J. (2008). The precaution adoption process model. In K. Glanz, B.K. Rimer, & K. Viswanath (Eds.), *Health behavior and health education: Theory, research, and practice* (pp. 123–147). Jossey-Bass. https://psycnet.apa.org/record/2008-17146-006

Weinstein, N.D., Sandman, P.M., & Roberts, N.E. (1991). Perceived susceptibility and self-protective behavior: A field experiment to encourage home radon testing. *Health Psychology*, *10*(1), 25–33. https://doi.org/10.1037/0278-6133.10.1.25

World Health Organization. (2006). *Working together for health: The world health report 2006*. https://www.who.int/whr/2006/whr06_en.pdf

World Health Organization. (2009). *WHO handbook on indoor radon: A public health perspective*. https://apps.who.int/iris/bitstream/handle/10665/44149/9789241547673_eng.pdf

DIRECT FROM CDC ENVIRONMENTAL HEALTH SERVICES

Water Management Programs Are Key to Managing *Legionella* Growth and Spread

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National Center for Environmental Health
Centers for Disease Control and Prevention

Editor's Note: The National Environmental Health Association (NEHA) strives to provide up-to-date and relevant information on environmental health and to build partnerships in the profession. In pursuit of these goals, NEHA features this column on environmental health services from the Centers for Disease Control and Prevention (CDC) in every issue of the *Journal*.

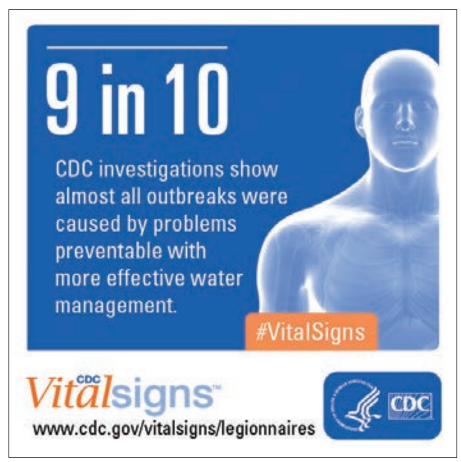
In these columns, authors from CDC's Water, Food, and Environmental Health Services Branch, as well as guest authors, will share insights and information about environmental health programs, trends, issues, and resources. The conclusions in these columns are those of the author(s) and do not necessarily represent the official position of CDC.

Elaine Curtiss is a public health analyst. Janie Hils is a fellow with the Oak Ridge Institute for Science and Education (ORISE). CDR Jasen Kunz is an environmental health subject matter expert for Legionnaires' disease. All work at the National Center for Environmental Health and the Water, Food, and Environmental Health Services Branch within CDC.

In summer 2021, several U.S. public health jurisdictions reported increases in Legionnaires' disease cases above their respective 5-year baseline averages (Michigan Department of Health & Human Services, 2021). While the Centers for Disease Control and Prevention (CDC) does not know to what extent building water systems might have contributed to these increases, periods of reduced building occupancy or building closure and low water usage can create hazards for occupants. Reopening schools, workplaces, and businesses—and more people traveling and staying in hotels—can elevate the risk of exposure to *Legionella* bacteria if appropriate steps are not taken. Environmental health professionals have an important role in reminding building owners, building operators, and cooling tower operators of ways to safely reopen buildings to prevent the growth of *Legionella*.

Water management programs help people identify hazardous conditions and take steps to minimize the growth and spread of *Legionella* and other waterborne pathogens in building water systems. Developing and maintaining a water management program is a multistep process that requires continuous review. Such programs are now an industry standard for many buildings in the U.S.

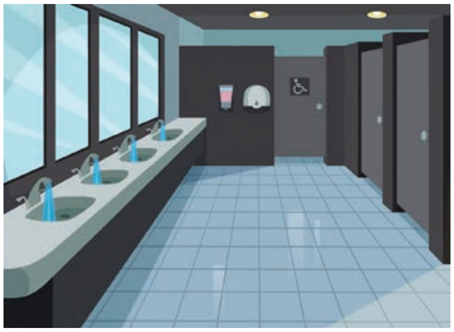
CDC recently released a plain language summary on findings from a review of CDC-led Legionnaires' disease outbreak investigations from 2015–2019 (www.cdc.gov/nceh/ehs/activities/water-mgt-gaps-ld-outbreaks.html). The analysis found that the most common (4 in 10) deficiency in water management programs was that a building lacked one altogether (Clopper et al., 2021). CDC investigations show, however, that almost all (9 in 10) Legionnaires' disease outbreaks were caused by problems preventable with more effective water management (Garrison et al., 2016).



CDC's toolkit—Developing a Water Management Program to Reduce *Legionella* Growth and Spread in Buildings (www.cdc.gov/legionella/wmp/toolkit/index.html)—is designed to help people understand

- which buildings and devices need a *Legionella* water management program to reduce the risk for Legionnaires' disease,
- the key elements of a water management program, and
- how to develop it.

Remind Building Owners and Operators of the Risk From Stagnant or Standing Water in a Plumbing System



Ensuring that the building water system is safe to use after a prolonged shutdown can minimize the risk of Legionnaires' disease and other diseases associated with water.

Stagnant or standing water in a plumbing system can increase the risk for growth and spread of *Legionella* and other biofilm-associated bacteria. When water is stagnant, the hot water temperatures in buildings can fall into the favorable range for *Legionella* growth (77–113 °F [25–42 °C]). Stagnant water can also lead to low or undetectable levels of disinfectant, such as chlorine. Ensuring that the water system is safe to use after a prolonged shutdown can minimize the risk of Legionnaires' disease and other diseases associated with water.

CDC recommends steps to minimize risk when reopening buildings, such as flushing water systems. Resources for creating a water management program, special considerations for hotels and hot tubs, and much more are available at www.cdc.gov/nceh/ehs/water/legionella/building-water-system.html.

Remind Cooling Tower Operators of the Importance of Following Best Practice Operation and Maintenance Guidance

Safe operation and regular cooling tower maintenance help protect building operators, staff, visitors, and the adjacent community from exposure to *Legionella*. The frequency of these activities depends on the cooling load, the environmental conditions present in the area where the cooling tower is located, and the design of the cooling tower. A water management program can help cooling tower operators establish, track, and improve operation and maintenance activities.

CDC has information to help evaluate hazardous conditions associated with all types of cooling towers and evaporative condensers, implement *Legionella* control measures for cooling towers per ASHRAE Guideline 12-2020, and more at www.cdc.gov/legionella/wmp/control-toolkit/cooling-towers.html.

Explore More Tools for Preventing Growth and Spread of *Legionella* and Responding to Outbreaks of Legionnaires' Disease

The Toolkit for Controlling *Legionella* in Common Sources of Exposure (www.cdc.gov/legionella/wmp/control-toolkit/index.html) provides public health professionals and building owners and operators with concise, actionable information on controlling *Legionella* in commonly implicated sources of Legionnaires' disease outbreaks.

This toolkit can:

- Help its users evaluate hazardous conditions in systems that are commonly associated with *Legionella*.
- Guide implementation of *Legionella* control measures per ASHRAE Guideline 12-2020.
- Complement existing resources for water management programs, including the Water Management Program Toolkit.
- Support public health professionals when conducting environmental assessments during investigations.

Take the Preventing Legionnaires' Disease training from the Centers for Disease Control and Prevention and partners on creating a water management program to reduce the risk for Legionnaires' disease.

A *Legionella* water management program consists of:

- Establishing a water management program team.
- Describing the building water system using words and diagrams.
- Identifying areas where *Legionella* could grow and spread.
- Deciding where control measures should be applied and how to monitor them.
- Establishing ways to intervene when control limits are not met.
- Making sure the program is running as designed and is effective.
- Documenting and communicating all the activities.

The Preventing Legionnaires' Disease: A Training on *Legionella* Water Management Programs (PreventLD Training, www.cdc.gov/nceh/ehs/elearn/prevent-LD-training.html) addresses the 7 steps of a *Legionella* water management program. These steps, outlined in CDC's Water Management Program Toolkit, operationalize ASHRAE Standard 188 for minimizing the risk of Legionnaires' disease.

Environmental health practitioners have essential expertise for responding to and preventing outbreaks of Legionnaires' disease. CDC has additional tools and information for environmental health professionals to better understand how to control and manage the growth of *Legionella* in a variety of settings at www.cdc.gov/nceh/ehs/activities/legionella.html.

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References

Clopper, B.R., Kunz, J.M., Salandy, S.W., Smith, J.C., Hubbard, B.C., & Sarisky, J.P. (2021). A methodology for classifying root causes of outbreaks of Legionnaires' disease: Deficiencies in environmental control and water management. *Microorganisms*, *9*(1), 89. https://doi.org/10.3390/microorganisms9010089

Garrison, L.E., Kunz, J.M., Cooley, L.A., Moore, M.R., Lucas, C., Schrag, S., Sarisky, J., & Whitney, C.G. (2016). Vital signs: Deficiencies in environmental control identified in outbreaks of Legionnaires' disease—North America, 2000–2014. *Morbidity and Mortality Weekly Report*, *65*(22), 576–584. http://doi.org/10.15585/mmwr.mm6522e1

Michigan Department of Health & Human Services. (2021, July 19). *Michigan experiencing increase in Legionnaires' disease.* https://www.michigan.gov/mdhhs/0,5885,7-339--563995--,00.html

Did You Know?

NEHA thanks all who gave to our Giving Tuesday campaign on November 30 to support the NEHA/AAS Scholarship Program. We raised over $8,000, which makes a lasting impact on deserving students in need and encourages them to continue with their career goals. Read more about our Giving Tuesday campaign at www.neha.org/giving-tuesday.

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EH CALENDAR

UPCOMING NATIONAL ENVIRONMENTAL HEALTH ASSOCIATION (NEHA) CONFERENCE

June 28–July 1, 2022: NEHA 2022 Annual Educational Conference & Exhibition—Now a Hybrid Event, Spokane, WA, https://www.neha.org/aec

NEHA AFFILIATE AND REGIONAL LISTINGS

Iowa
May 3–4, 2022: Public Health Conference of Iowa, Iowa Environmental Health and Public Health Associations, Ames, IA, https://www.ieha.net/PHCI2022

Kentucky
February 7–9, 2022: 2022 KYEHA Annual Conference, Kentucky Environmental Health Association, Lexington, KY, http://kyeha.org/events

Michigan
March 23–25, 2022: 2022 Annual Education Conference, Michigan Environmental Health Association, Traverse City, MI, https://www.meha.net/AEC

Missouri
April 4–8, 2022: Annual Education Conference, Missouri Environmental Health Association, Springfield, MO, https://mehamo.org

Montana
April 11–13, 2022: MEHA/MPHA Conference and Annual Meeting, Montana Environmental Health and Public Health Associations, Helena, MT, http://www.mehaweb.org

New Jersey
March 6–8, 2022: 2022 NJEHA Educational Conference & Exhibition, New Jersey Environmental Health Association, Atlantic City, NJ, https://www.njeha.org/2022-Atlantic-City-Conference

North Carolina
April 27–29, 2022: NCPHA Fall Educational Conference (Rescheduled), North Carolina Public Health Association, Asheville, NC, https://ncpha.memberclicks.net

Ohio
April 14–15, 2022: Annual Educational Conference, Ohio Environmental Health Association, Dublin, OH, http://www.ohioeha.org

Utah
May 4–6, 2022: UEHA Spring Conference, Utah Environmental Health Association, Kanab, UT, http://www.ueha.org/events.html

JEH QUIZ

FEATURED ARTICLE **QUIZ #4**

Quantifying the Rate Copper Leaches From a Copper Drinking Vessel Into Simulated Beverages Under Conditions of Consumer Use

Available to those with an active National Environmental Health Association (NEHA) membership, the *JEH* Quiz is offered six times per calendar year and is an easily accessible way to earn continuing education (CE) contact hours toward maintaining a NEHA credential. Each quiz is worth 1.0 CE.

Completing quizzes is now based on the honor system and should be self-reported by the credential holder. Quizzes published only during your current credential cycle are eligible for CE credit. Please keep a copy of each completed quiz for your records. CE credit will post to your account within three business days.

Paper or electronic quiz submissions will no longer be collected by NEHA staff.

INSTRUCTIONS TO SELF-REPORT A *JEH* QUIZ FOR CE CREDIT

1. Read the featured article and select the correct answer to each *JEH* Quiz question.
2. Log in to your MyNEHA account at https://neha.users.membersuite.com/home.
3. Click on Credentials located at the top of the page.
4. Select Report CEs from the drop-down menu.
5. Enter the date you finished the quiz in the Date Attended field.
6. Enter 1.0 in the Length of Course in Hours field.
7. In the Description field, enter the activity as "*JEH* Quiz #, Month Year" (e.g., *JEH* Quiz 4, January/February 2022).
8. Click the Create button.

JEH Quiz #2 Answers

October 2021

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

➔ Quiz effective date: January 1, 2022 | Quiz deadline: April 1, 2022

1. Copper leaching is problematic for foodstuffs with __ pH.
   a. low
   b. neutral
   c. high

2. According to the Institute of Medicine, the recommended dietary allowance of copper for adults is
   a. 600 µg/day.
   b. 700 µg/day.
   c. 800 µg/day.
   d. 900 µg/day.

3. In this article, the authors used a popular cocktail traditionally served in a copper vessel as a model system to study copper leaching under conditions of simulated consumer use.
   a. True.
   b. False.

4. The authors observed copper leaching into the Moscow Mule solution at a rate of __ copper/min at room temperature.
   a. $0.048 \pm 7 \times 10^{-2}$ ppm
   b. $0.048 \pm 7 \times 10^{-3}$ ppm
   c. $0.048 \pm 7 \times 10^{-4}$ ppm
   d. $0.048 \pm 7 \times 10^{-5}$ ppm

5. The U.S. Environmental Protection Agency mandates that copper levels in drinking water that exceed __ must be reported.
   a. 1.0 ppm
   b. 1.1 ppm
   c. 1.2 ppm
   d. 1.3 ppm

6. At the rate measured, the concentration of leached copper in a copper mug reaches 1.3 ppm in slightly over
   a. 23 min.
   b. 27 min.
   c. 33 min.
   d. 37 min.

7. The Food and Drug Administration model *Food Code* prohibits foodstuffs with a pH __ from coming in contact with copper due to concerns of copper leaching.
   a. <3.0
   b. <4.0
   c. <5.0
   d. <6.0

8. The Moscow Mule solutions used in the article experiments had a measured pH of
   a. 2.5.
   b. 2.6.
   c. 2.7.
   d. 3.0.

9. Acute copper toxicity from consumption of Moscow Mule cocktails in one sitting is unlikely based on the findings of this article.
   a. True.
   b. False.

10. In studying the effect of each ingredient in the Moscow Mule cocktail on the copper leaching rate, the highest leaching rates were observed for
    a. lime juice.
    b. ginger beer.
    c. ethanol.
    d. deionized water.

11. The data in Figures 4 and 5 are consistent with pH being the sole contributor to the copper leaching rate.
    a. True.
    b. False.

12. The authors investigated the mechanism by which metallic copper is transformed to copper(II) and a __ fold increase in copper leaching occurred when oxygen was reintroduced into the Moscow Mule solution.
    a. 2.2
    b. 2.4
    c. 2.6
    d. 2.8

AEHAP

ASSOCIATION OF ENVIRONMENTAL HEALTH ACADEMIC PROGRAMS

STUDENT OPPORTUNITY

2022 AEHAP STUDENT RESEARCH COMPETITION

Environmental health students enrolled in a National Environmental Health Science and Protection Accreditation Council-accredited program at an AEHAP member school are eligible. Undergraduate and graduate students are encouraged to enter. Four winners will be selected.

Award winners will receive **$1,000** and up to **$1,500 in travel expenses** to make a 20-minute platform presentation with poster at the NEHA 2022 Annual Educational Conference & Exhibition.

All entrants will also be welcome to present at the AEHAP 2022 Student Symposium.

Submission period will open January 10, 2022.

Deadline to submit is February 18, 2022.

Submit entries to Jamie Hisel at jamie.hisel@eku.edu.

For more information and research guidelines, visit www.aehap.org/srcandnsf.html.

AEHAP gratefully acknowledges the volunteer time and efforts of program faculty members who serve as judges and advisors for this competition.

DAVIS CALVIN WAGNER SANITARIAN AWARD

The American Academy of Sanitarians (AAS) announces the annual Davis Calvin Wagner Sanitarian Award. The award will be presented by AAS during the National Environmental Health Association (NEHA) 2022 Annual Educational Conference & Exhibition. The award consists of an individual plaque and a perpetual plaque that is displayed in the NEHA office.

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

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

NOMINATIONS MUST BE RECEIVED BY APRIL 15, 2022.

Nomination packages should be emailed to Dr. Robert W. Powitz at powitz@sanitarian.com.

Files should be in Word or PDF format.

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

SPECIAL LISTING

The National Environmental Health Association (NEHA) Board of Directors includes nationally elected officers and regional vice-presidents. Affiliate presidents (or appointed representatives) comprise the Affiliate Presidents Council. Technical advisors, the executive director, and all past presidents of the association are ex-officio council members. This list is current as of press time.

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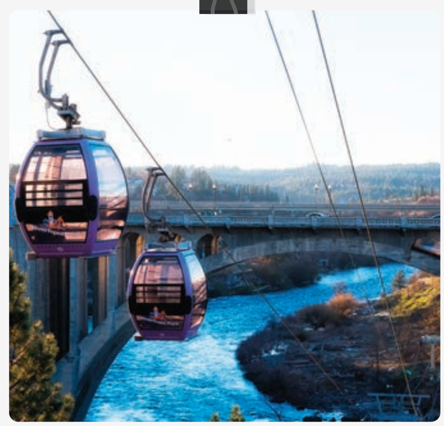

...to the Outdoors

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National Environmental Health Association

NEHA **NEWS**

NEHA Staff Profiles

As part of tradition, the National Environmental Health Association (NEHA) features new staff members in the *Journal* around the time of their 1-year anniversary. These profiles give you an opportunity to get to know the NEHA staff better and to learn more about the great programs and activities going on in your association. This month we are pleased to introduce you to two NEHA staff members. Contact information for all NEHA staff can be found on pages 38 and 39.

Steven Dourdis

Hello to all NEHA members and thank you so much for all that you do for the environmental health profession. I started at NEHA in January 2021 as the human resources business partner. I have found that the best job motivation is commitment to an organization's mission, goals, and impact. When I saw the opportunity to work at NEHA, I knew it was a place that I wanted to learn and contribute whatever I could to advance the cause of environmental health and the vision of NEHA. I would like to build a human resources department that can not only provide comprehensive and seamless support to our staff, board, and members but also strengthen the core of the organization so we can deliver for and optimally serve the environmental health community.

I attended Temple University where I received my bachelor of arts in psychology and did my master's training in industrial and organizational psychology at Montclair State University, specializing in leadership development. I recently relocated from the New York area where I started my career as a family liaison with AmeriCorps supporting low-income families in finding work and having access to healthy foods, as well as promoting educational equity and awareness in the surrounding community. I then took a position as a human resource specialist at a quasigovernment organization called the Metropolitan Transportation Authority for nearly four years where I was responsible for talent acquisition and organizational development.

I am huge sports fan and love to support my favorite teams: Liverpool FC, Florida Gators, Penn State University, and every Philadelphia franchise. My life's passion is without question soccer. My first memory—or what I believe is my first memory—is me playing on the soccer field with my dad. I am one of the hooligans who wake up at 5:30 a.m. every Saturday morning to watch the English Premier League, donning my Liverpool apparel and trying my best to avoid waking the neighbors. My family is the most important thing to me and we have always espoused the Liverpool motto, "You'll Never Walk Alone." I say this motto to myself during especially trying times as a reminder to keep pushing and never give up. One of my goals, therefore, is to incorporate this sentiment into my role at NEHA as I feel it strongly aligns with our One NEHA focus, strategy, and approach.

I look forward to supporting NEHA in a myriad of ways to advance its mission and progress. I cannot emphasize enough the privilege it is to work alongside incredibly talented colleagues whose passion and expertise drive an organization that makes such a tremendously positive impact on both the environmental health community and the general population.

Anna Floyd

I joined NEHA as an instructional designer within the NEHA Entrepreneurial Zone (EZ) in January 2021. I've always been passionate about working on projects that support personal and public health, and I'm delighted to have found myself with NEHA. I work primarily on food safety projects, collaborating with subject matter experts and the creative EZ team to put together online, asynchronous courses. I love the creative synergy of the department and enjoy collaborating to build food safety content into creative, innovative courses. I love working with people who are enthusiastic about their work, bringing humor to the table and taking pride in developing something exceptional. I have been delighted to find such a community at NEHA!

I got my bachelor of art degree in psychology in 2003 from the University of Maryland and my doctoral degree in health psychology from Stony Brook University in New York in 2009. After that, I moved to Colorado for a postdoc at a health communication firm and have been doing health-related work ever since.

Before working at NEHA, I developed online courses for Engineers Without Borders USA and Regis University. I've covered topics including water quality, cultural awareness, psychology, risk perceptions, and many others. I've also spent some time working as a university professor, did a short stint as a nondenominational hospital chaplain, and used to have a small business doing program evaluation for health and public health nonprofits.

When I'm not working, I love trail running, playing music (I've dabbled with the piano, cello, and viola) with a group of friends, and snuggling with our family dog.

Did You Know?

You can stay in the loop every day with NEHA's social media. Find NEHA on

- Facebook: www.facebook.com/NEHA.org
- Twitter: https://twitter.com/nehaorg
- LinkedIn: www.linkedin.com/company/national-environmental-health-association

2022 Walter S. Mangold Award

ACCEPTING NOMINATIONS NOW

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, 2022.

National Environmental Health Association

For application instructions, visit www.neha.org/mangold-award.

2022 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, 2022.

To access the online application, visit www.neha.org/beck-award.

National Environmental Health Association

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program I attended, "People don't care what you know until they know that you care."

A critical element of this story is centered on the authority, responsibility, and influence Dr. Koren was provided outside the domain of traditional public health. In this case, he was successful in amending alarming local policing practices. In other words, the careful exercise of influence in centers of power adjacent to the public health universe, law enforcement, gave rise to conditions resulting in a successful environmental health effort. I asked Dr. Koren if his community priority first approach was a result of his nature or if he was nurtured to employ such a strategy. He seemed uncharacteristically stumped and reflective by my inquiry, but only momentarily. Dr. Koren proceeded to generously share credit for the idea with inspired professionals he had the privilege of working with.

My two hours in person with Dr. Koren and Donna evaporated much too quickly. As I pulled out of their driveway and merged into traffic enroute to Tampa, I was inspired by the words and insight of these two national treasures. I also pondered what I observe to be the distance between us in American society that has been created in large measure by social media and exacerbated by the pandemic. The result is a collective dulled moral imagination. I see the effects all around me. Transactional effectiveness has replaced the relational chemistry that once upon a time bound us and our communities together—the type of relational chemistry Dr. Koren emphasized as critical to progress.

Dr. David Dyjack with Donna and Dr. Hank Koren during their visit in October 2021. Photo courtesy of David Dyjack.

Holocaust survivor Viktor Frankl wrote, "Between stimulus and response there is space. In that space is our power to choose our response. In our response lies our growth and freedom." We should endeavor to learn from the role modeling of Dr. Hank Koren. To remain curious. To honor other's priorities while remaining true to your own. To be a good follower as well as a good leader.

Golden escorts, whether they are people or fish, reveal themselves at unexpected moments. Let's keep our senses open to them, particularly during times when the sting of the surrounding environment might encourage us to do otherwise. They remind us in this time of public health disruption that beauty, wisdom, and courage are abundantly available to us if we use our power to search them out.

Dave

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DirecTalk

David Dyjack, DrPH, CIH

Golden Trevally

Reach and pull. Reach and pull. Banderas Bay provides for an optimal swimming environment. I glanced at my watch and regaled in the endorphin induced euphoria associated with a personal challenge of a 30-min, nonstop swim using only the American crawl. My open eyes endured the sting of salt water as I cruised the 200 m back to shore hoping to catch a blurry glimpse of nearby underwater marine life. Then the most amazing thing happened. A tiny, perhaps 3-cm golden hued fish appeared out of nowhere. It seemed to be escorting me as it swam a few inches from my face the entire journey back to shore. I attributed the experience to some hallucination, or possibly an omen or symbol from beyond.

Several years later I again tested my endurance, this time in Papagayo Bay. Lather, rinse, repeat. A 30-min swim, followed by an exhausted return to shore. True to form I kept my eyes open under water and remarkably once again a single small, brilliant yellow fish appeared inches from my face. My committed escort kept me company to the shallows where it reluctantly drifted off to the depths as I approached the black volcanic sand. A golden escort in Banderas Bay was a magical moment that I felt was a personal sign. Twice? Some other explanation needed unearthing.

Indeed, the escort service I experienced is evidently common and known among the snorkeling and diving community. Juvenile golden trevallies accompany larger fish, sharks, and jellyfish as a form of defense and provide a secondary dining benefit. Marine biologists recognize that large pelagic marine creatures leave behind a mess when capturing and consuming a meal, providing fast food for the trevallies. Those little yellow fish weren't a message from the heavens, they were honoring their survival instincts in the hope I would leave behind some uneaten morsels for their breakfast. Nonetheless, those two moments are joys that bring me a salubrious reminder that keeping my eyes open for golden things can bring meaningful experiences. I had one of those experiences with Dr. Hank Koren and his wife Donna.

> *Transactional effectiveness has replaced relational chemistry.*

Dr. Koren and Donna are the case definition of golden: in age (octogenarians), in character, and in their shared commitment to improving the world around them. After exchanging emails with Dr. Koren for almost seven years, I made a pilgrimage to Belleair Beach, Florida, in early October 2021 to visit in person and soak in the lifetime of reflections from an individual who made countless contributions to environmental health. Dr. Koren is recipient of the Walter S. Mangold and the Davis Calvin Wagner Sanitarian awards, he has been recognized with four distinct National Environmental Health Association presidential citations, is a diplomate laureate of the American Academy of Sanitarians, and the author of 22 books. Soak that in.

Dr. Koren's passion for environmental health is contagious. He regaled me with the story of his life and professional challenges, his work with communities, and his strategies for success. He possesses the wisdom of an elder and the curiosity of a child. I was reminded that almost nothing we encounter today is markedly different from those struggles of an earlier era. The names and dates have been substituted, but the politics, arguments, and solutions are eerily similar. If you doubt me, please read an account of the 1918–1919 flu pandemic. The principles of self-quarantine and closure of nonessential businesses were indispensable to bending the curve of the influenza pandemic 100 years ago. Sound familiar? Professional giants have much to offer, but are we listening and heeding their sage advice?

Dr. Koren shared a poignant story about working with at-risk communities in support of rat control in Philadelphia, Pennsylvania. He first met with, listened to, and addressed nonenvironmental health community concerns before embarking on the rodent mitigation program. His commitment to addressing community priorities first created the trust that eventually led to a successful public health intervention. As risk communication expert Dr. Vincent Covello once said during a training

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Grant awards are coming soon!

We are thrilled to have received a very strong pool of applications for the first year of the NEHA-FDA Retail Flexible Funding Model (RFFM) Grant Program! Grants will be awarded by February.

"The Retail Program Standards are a foundational component of retail food safety programs. The funding has been critical in supporting our efforts, increasing staff resources, and enabling continued growth and collaboration."

Lane Drager
Consumer Protection Program Coordinator
at Boulder County Public Health

"The FDA's commitment to the Retail Program Standards has enabled my division to obtain equipment, conduct a risk assessment, provide staff training, and education that would not have been possible due to budget constraints."

Jim Dingman
Environmental Health Manager at City of Plano

If your jurisdiction was unable to take advantage of the NEHA-FDA RFFM Grant Program in year 1, another opportunity will be available in year 2 to apply for the Development Base Grant as well as Mentorship, Special Projects, and Training grants. Abundant resources and a readily accessible support team are available to aid in this process. Applications will reopen in summer 2022.

The NEHA-FDA RFFM Grant Program is a 3-year funding cycle to leverage and advance state, local, tribal, and territorial retail food regulatory agencies through conformance with the Retail Program Standards. Through this program, NEHA, in partnership with FDA, offers a people-centered grant management process with an emphasis on simplicity and accessibility as well as the opportunity to experience professional growth and recognition while joining an elite group of retail food safety specialists.

RETAIL FLEXIBLE
NEHA - FDA
RFFM GRANT PROGRAM
FUNDING MODEL

Contact the NEHA Retail Support Team at **retailgrants@neha.org** or toll-free at **1-833-575-2404** if you have questions or need guidance.

Visit our Retail Grants webpage for the latest information, resources, and training.

www.neha.org/retailgrants