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Volume 76, No. 4 November 2013

STRANGE BREW

Food Safety Guidelines to Control Potential Hazards From Kombucha Brewing

Published by the National Environmental Health Association

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WHAT IS THE PROCESS FOR FIELD EVALUATION OF EQUIPMENT?
WHY DO WATER SAMPLES HAVE SUCH A SHORT SHIPPING WINDOW?
WHEN DO THE NEW FEDERAL LEAD LAW REQUIREMENTS TAKE EFFECT?
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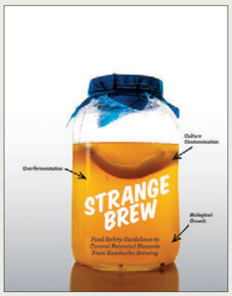

The purpose of this month's special report, "Kombucha Brewing Under the Food and Drug Administration Model *Food Code*: Risk Analysis and Processing Guidance," was to provide a hazard analysis and critical control points (HACCP)–based risk analysis of the process to help both operators and regulators maintain safe production of kombucha. Kombucha is a fermented beverage made from brewed tea and sugar whose fermentation process is similar to vinegar's. Hazards from brewing and drinking kombucha include pathogen and mold growth, overfermentation, cross contamination, and acidosis.

See page 8.

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Official Publication

National Environmental Health Association

Journal of Environmental Health
(ISSN 0022-0892)

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Published monthly (except bimonthly in January/February and July/August) by the National Environmental Health Association, 720 S. Colorado Blvd., Suite 1000-N, Denver, CO 80246-1926. Phone: (303) 756-9090; Fax: (303) 691-9490; Internet: www.neha.org. E-mail: kruby@neha.org. Volume 76, Number 4. Subscription rates in U.S.: $135 per year and $250 for two years. International subscription rates: $160 per year and $300 for two years (airmail postage included). Single copies: $12, if available. Reprint and advertising rates available at www.neha.org/JEH/. CPM Sales Agreement Number 40045946.

Full text of this journal is available through Bigchalk.com at www.bigchalk.com and from ProQuest Information and Learning, (800) 521-0600, ext. 3781; (734) 973-7007; or www.umi.com/proquest. The *Journal of Environmental Health* is indexed by Current Awareness in Biological Sciences, EBSCO, and Applied Science & Technology Index. It is abstracted by Wilson Applied Science & Technology Abstracts and EMBASE/Excerpta Medica.

All technical manuscripts submitted for publication are subject to peer review. Contact the content editor for Instructions for Authors, or visit www.neha.org/JEH/.

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Periodicals postage paid at Denver, Colorado, and additional mailing offices. POSTMASTER: Send address changes to *Journal of Environmental Health*, 720 S. Colorado Blvd., Suite 1000-N, Denver, CO 80246-1926.

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PRESIDENT'S MESSAGE

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Membership With Benefits: Opportunities for Professional Growth

As a board member and active member of NEHA, I am often asked about membership benefits. NEHA has an assortment of benefits such as opportunities for continuing education and professional growth, helping us to remain current regarding emerging science, best practices, and trends in the environmental health field. NEHA provides a forum that connects its members, whether it is the Annual Educational Conference (AEC) & Exhibition, engagement in a technical work group, or online education and training. Most of the online courses and training sessions are offered to members without tuition or fees.

During the past few years, our communities have been hit hard with natural disasters and a number of large multistate foodborne disease outbreaks. NEHA has taken a proactive role by providing the training needed to prepare our workforce for emergency response, which could mean response and recovery to a natural disaster or a coordinated response to a foodborne disease outbreak. In this column, I will provide a few examples of how NEHA has had an integral role in building capacity in the area of emergency response for environmental health professionals, providing opportunities for professional growth. If you have not had the opportunity to attend the courses noted below, I encourage you to contact NEHA or look at the convenient online options.

NEHA makes the professional growth of its members a priority.

Environmental Health Training in Emergency Response

After Hurricane Katrina and the devastating hurricane season in 2005, the Centers for Disease Control and Prevention (CDC) developed the Environmental Health Training in Emergency Response (EHTER) course. This multiday awareness-level course was designed to increase the level of emergency preparedness among environmental health professionals and other response personnel by providing them with the necessary knowledge, skills, and resources to address the environmental health impacts of emergencies and disasters. It includes 10 modules covering challenges encountered during emergency preparedness and response for various environmental health disciplines such as food safety, drinking water, vectors and pest control, worker safety, and disaster management.

Since 2007, NEHA has provided assistance to CDC in the development and delivery of EHTER and has offered a condensed version at our AEC. The course is available year-round through the Federal Emergency Management Agency at their Anniston, Alabama, location. This version of the course is available free of charge to state and local environmental health professionals. Through this arrangement, thousands of environmental health professionals have either participated in the full five-day EHTER course, the condensed courses, or the online version. In 2012, over 1,100 environmental health professionals completed the online EHTER course and in the first six months of 2013, nearly 700 individuals had completed the online course—that is nearly 2,000 members of our workforce in an 18-month period. And, more than 2,000 individual modules have been viewed for this course outside of full course completions. This is a tremendous service for members who are challenged with travel restrictions.

To view or take the free online course, go to www.nehacert.org. For additional information, contact Christl Tate at ctate@neha.org.

Training Opportunities for Foodborne Outbreak Response

CDC estimates that each year in the U.S., 1,000 foodborne disease outbreaks are reported along with 128,000 hospitalizations and 3,000 deaths related to foodborne disease. This includes approximately 150 national or multistate investigations that require a tremendous amount of coordination and collaboration among environmental and public health agencies and food safety experts. Environmental health professionals from all sectors must continue to be highly trained and ready to respond to foodborne disease outbreak investigations.

NEHA has developed foodborne illness workshops that travel the country. NEHA has also taken official positions that can be shared with your agencies or local associations and is involved in food safety initiatives. These combined efforts help our members grow professionally and prepare to respond to environmental health emergencies.

Epi-Ready

Epi-Ready is a two-day workshop developed specifically for environmental and public health professionals responsible for investigating foodborne disease outbreaks. This course was developed in partnership with CDC and was designed with a team-approach concept for training. The inaugural course was offered in Atlanta, Georgia, in 2003, and over the last 10 years, 64 courses have been offered throughout the country, training nearly 3,000 environmental and public health professionals. Each of our 50 states has been represented along with Jamaica, Guam, and several countries around the globe.

Teams of participants from response agencies are encouraged to attend as a team and include their environmental health specialist, epidemiologist, laboratory staff, public health nurse, public information officer, or any team member who would have a critical role in responding to a foodborne outbreak. This approach helps the participating agency teams strengthen collaboration and work through details of a response as scenarios and case studies are used throughout the training. What I found to be most impressive about this course is that NEHA has a cadre of highly qualified and experienced instructors who travel around the country to teach this course.

NEHA's participation in the Council to Improve Foodborne Outbreak Response (CIFOR, www.cifor.us), which is a national working group formed to increase collaboration and reduce the burden of foodborne illness in the U.S., has been vital to ensuring that the information from CIFOR's guidelines is followed in the curriculum.

In 2008, NEHA was recognized and awarded the 2008 Food Safety Leadership Award by NSF International for Epi-Ready. The success and longevity of this course is due to the perseverance and collaborative work by the NEHA staff and our partners from CDC, CIFOR, and local, state, and federal agencies. Looking ahead, NEHA staff will be working with the Food and Drug Administration (FDA) on a three-day Epi-Ready for Response Teams Training. It will initially be delivered to 10 states that were recently awarded with a cooperative agreement to form Rapid Response Teams to improve response for food and feed emergencies.

For additional information about Epi-Ready, visit our Web site at www.neha.org/epi_ready/index.html or contact Ginny Coyle at gcoyle@neha.org.

Industry-Foodborne Illness Investigation Training and Recall Response Workshop (I-FIIT-RR)

Demand continues for foodborne disease outbreak training inclusive of the food industry. This 1.5 day I-FIIT-RR workshop was developed in 2011 to assist regulatory officials and retail food industry representatives to collaborate and prepare for a rapid and effective recall response or outbreak investigation. Like Epi-Ready, it follows the CIFOR guidelines and the recently released CIFOR industry guidelines.

This workshop was recently enhanced to include food recall and traceback components, incorporating both food safety and food defense perspectives. I-FIIT-RR is a result of collaboration and input by a team of industry representatives, local/state/federal officials, and many others. The principle behind this training approach is that agencies and communities can use existing resources and relationships to improve overall effectiveness and efficiency for retail food protection response activities. Another benefit can be the improved risk communication to the public, whether the need is to inform the local community about an outbreak or a product recall and the potential risks.

NEHA members have received the benefit of this training course in Memphis, Tennessee; Columbus, Ohio; and Washington, DC. In 2012, NEHA received cooperative agreement funding for the enhanced I-FIIT-RR workshop from FDA. It launched at this year's AEC in Washington, DC, and I recently received word that three courses will be offered around the country within the next year, with three more to follow.

To learn more about attending this workshop or bringing this workshop to your area, visit our Web site at www.neha.org/ifiit/index.html or contact Elizabeth Landeen at elandeen@neha.org.

Registry of Food Safety Credentials

In 2011, NEHA was awarded cooperative agreement funding from FDA to develop an online repository of food safety credential holders and experts. This registry is being designed to help meet requirements set forth in the Food Safety Modernization Act to implement an integrated food safety system and build the global capacity of food safety professionals. Another function of this database will be for use during foodborne illness outbreaks and in food defense situations.

The final product will be an online database of food safety experts noting their verifiable food safety credentials. The pilot project has begun for the North American region with the intention of expanding to a database that holds data for food safety experts around the world. The foundation for this sizable database will be NEHA's current database of food safety credential holders. Some of the key goals for this tool include 1) being user-friendly for credential holders and for entities searching for nearby experts, 2) being easily maintained and updated by a credential holder, 3) having easily verifiable information, 4) being a secure site, and 5) establishing an understanding of equivalencies for credentials and skills across borders.

Development of this registry is a five-year project and is being led by Rance Baker of NEHA. Rance is working with a team of NEHA staff and a stakeholder group comprised of public and private sector representatives. The testing phase is underway now and both the North American and international launches are scheduled for 2014! Thanks to Rance and his team and our partners at the Division of Human Resources Development in the Office of Regulatory Affairs at FDA for their work on this innovative project, which will serve as a resource for food safety experts and the food industry throughout the world.

For additional information about the registry, contact Rance Baker at rbaker@neha.org.

In Closing

Remember that each of the courses mentioned above is usually offered at no cost to NEHA members. These opportunities have been developed and funded through cooperative agreements with our federal partners. NEHA members can also enjoy the benefit of receiving continuing education credits for each of the courses offered by NEHA, whether they are offered in person or online!

These are just a few examples of training opportunities and progressive activities that are being provided as member benefits. For

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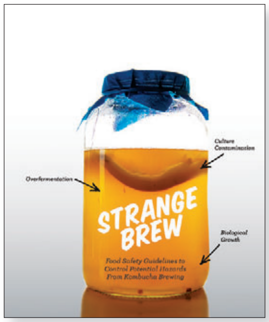
SPECIAL REPORT



Kombucha Brewing Under the Food and Drug Administration Model *Food Code*: Risk Analysis and Processing Guidance

Brian A. Nummer, PhD
Retail-Foodservice Food Safety Consortium
Utah State University Cooperative Extension

Abstract **Kombucha is a fermented beverage made from brewed tea and sugar. The taste is slightly sweet and acidic and it may have residual carbon dioxide. Kombucha is consumed in many countries as a health beverage and it is gaining in popularity in the U.S. Consequently, many retailers and food service operators are seeking to brew this beverage on site. As a fermented beverage, kombucha would be categorized in the Food and Drug Administration model *Food Code* as a specialized process and would require a variance with submission of a food safety plan. This special report was created to assist both operators and regulators in preparing or reviewing a kombucha food safety plan.**

Introduction

Kombucha is a fermented beverage made from brewed tea and sugar. The taste is slightly sweet and acidic and it may have residual carbon dioxide. Kombucha is consumed in many countries as a health beverage. It is believed to have prophylactic and therapeutic benefits toward a wide variety of ailments (Greenwalt, Steinkraus, & Ledford, 2000).

The kombucha process resembles a vinegar fermentation. Like vinegar, kombucha is a yeast fermentation of sugar to alcohol followed by a bacterial fermentation of alcohol to acetic acid. The symbiotic culture forms a pellicle or biofilm on the surface of the brew often called a mushroom or SCOBY (symbiotic culture of bacteria and yeast). The yeasts in the mixture metabolize sucrose into glucose and fructose, then into ethanol and carbon dioxide (Mayser, Fromme, Leitzmann, & Gründer, 1995). Ethanol is then oxidized by the bacteria (in the presence of air) to acetaldehyde, then to acetic acid (Mayser et al., 1995). Typically, the alcohol and acetic acid content of kombucha is less than 1%, respectively, but each can rise to 3% during a long ferment (~30 days; Mayser et al., 1995). The acetic acid bacteria also utilize glucose to produce gluconic acid to approximately 2%. Fructose is used to a lesser extent and some remains after the fermentation. Some glucose will remain unmetabolized, and together with the remaining fructose, provides sweetness.

As a fermented beverage, kombucha would be categorized in the Food and Drug Administration (FDA) model *Food Code* as a specialized process. A retail or food service operator would need to request a variance from their regulatory authority as defined in the *Food Code* section 3-502.11 (Food and Drug Administration [FDA], 2009). This section also requires that the operator submit a food safety plan to the regulatory authority for approval before commencing operations. Below is a hazard analysis and critical control points (HACCP)–based risk analysis of the process to help both operators and regulators maintain safe production of kombucha.

Process Flow

Naturally, kombucha recipes will vary. The general process has been described by Greenwalt and co-authors (2000) and includes infusing tea leaves (~4–5 g/L) into freshly boiled water. Sugar (sucrose) is added at 50–150 g/L (5% to 15%). The tea is allowed to brew for approximately 10 minutes and the tea leaves are removed. The tea is cooled to room temperature and approximately 100 ml/L (10%) of fresh-fermented kombucha containing the microbial mat from a previous batch is added to the sweetened tea. It is then covered with a clean porous cloth (e.g., cheese cloth) and incubated at room temperature for about 7–10 days. If the fermentation is allowed to continue beyond 10 days, acidity *may* rise to levels potentially harmful to consumers (equivalent to drinking undiluted vinegar).

Kombucha Hazards Analysis (Table 1)

Biological Hazards

Most boiling water with black or green tea infusions start at a pH of ≤5. Once fermentation starts that pH is reduced in approximately seven days to a finishing pH of ≤2.5. Fermentations such as wort to beer have a similar pH reduction during fermentation, although beer will finish closer to pH 4. Since the initial infusion uses boiling water we consult Table A of section 1-201.10(B) (FDA, 2009) to determine if this is a potentially hazardous food (PHF). The tea infusion would not be a PHF if the pH were ≤4.6. Since the tea is heated but not packaged, however, it may be subject to contamination after cooling. Therefore, we must also consult Table B of section 1-201.10(B) (FDA,

TABLE **1**

Kombucha Hazards Analysis

Step	Description	Hazards Created, Eliminated, or Reduced	Preventative Measures
1	Boil water.	Potable water should be free of hazards.	Boiling water will kill vegetative pathogens.
2	Add tea and sugar and steep 10 minutes.	Biological: sporeformers may be heat shocked and germinate.	*Clostridium perfringens* and *Bacillus cereus* do not grow well or at all at pH ≤5. *Clostridium botulinum* can grow down to pH 4.7. The addition of an active fermentation culture will outcompete sporeformers to prevent growth.
3	Remove tea leaves and cool.	Biological: cross contamination.	Use clean and sanitized utensils. Keep container covered with clean and sanitized porous cloth (e.g., cheese cloth). The pH of ≤5 will prevent *C. perfringens* outgrowth. Therefore cooling parameters need not be monitored.
4	Add 10% inoculum.	Biological: mold or wild culture cross contamination.	Use a commercially purchased culture on first use. Reuse only culture from kombucha that shows no signs of mold or unusual contamination. The pH of the reused culture should be ≤4.2 to minimize the potential for acid resistant pathogens.
5	Ferment at room temperature 7–10 days.	Biological: pathogen, mold, or wild culture growth. Chemical: acetic acid can leach metal.	Ferment aerobically (in the presence of air) to ensure acetic acid production to pH ≤4.2. The typical end point is pH 2.5. Ferment in a safe, nonmetallic food-grade container.
6	Refrigerate covered.	Biological: overfermentation may increase acetic acid to hazardous levels. As fermentation slows, mold growth potential increases.	Refrigeration at pH ≤4.2 would not be required for food safety, but it should be used for quality and to prevent spoilage from molds. Refrigerated kombucha should be covered, preferably with a tight fitting lid. This way a small amount of carbon dioxide will build up and minimize mold growth.
7	Filter or remove culture mass.	Biological: cross contamination.	Use clean and sanitized utensils.
8A	Option 1: consume on premises.	Chemical: a potential for acidosis or acid ingestion exists. If mold is present mycotoxins could form.	The pH end point should be ≥2.5. Overfermentation can increase acetic acid to hazardous levels. Consumers should be notified that no more than 4 oz. per day is recommended and that they should not be immunocompromised.
8B	Option 2: package for retail sale.	Biological: spoilage with mold or yeasts. Over fermentation producing excessive acetic acid.	Option 1: Pasteurize—hot fill at 180°F into clean containers. Cap and invert 15 seconds. Cool. Option 2: Fill packaging at any temperature and store refrigerated with a shelf life that precludes mold development, excessive acetic acid, or excessive carbon dioxide buildup. Option 3: Same as option 2, but add 0.1% sodium benzoate and 0.1% potassium sorbate to prevent mold growth.
	Option 2: labeling.	Chemical: a potential for acidosis or acid ingestion exists.	Consumers should be notified that no more than 4 oz. per day is recommended and that they should not be immunocompromised. They also should be made aware that small amounts of alcohol may be present. Labeling claims are outside the scope of this article, but health claims would not be recommended (e.g., "cures health problems").

2009) that requires a pH ≤4.2 to be a non-PHF. Since kombucha starts at a potentially hazardous pH (~5) and finishes below 4.2 this process would require food safety monitoring to ensure safety. This is also confirmed in the *Food Code* under section 3-502.11 (FDA, 2009), where it requires a food safety plan for any process that uses acidification to make a PHF into a non-PHF.

Chemical Hazards

FDA has evaluated the practices of several commercial producers of the kombucha and found no pathogenic organisms or other hygiene violations (Centers for Disease Control and Prevention [CDC], 1996). Kombucha consumption has proven to be harmful in only a few documented instances (Srinivasan, Smolinske, & Greenbaum, 1997). The possibility of toxic effects when kombucha is consumed in large quantities became a concern after two incidents in the U.S. in 1995. One individual died from perforations of the intestinal tract and severe acidosis. It was *speculated* that because she had recently increased her consumption threefold to 12 oz. that kombucha was the cause. The surviving victim mentioned that she increased the length of the fermentation time from 7 days to 14 days, and she could hardly manage swallowing the very acidic tea but did anyway. It was later determined that the individuals had severe preexisting conditions that made them susceptible to acidosis. These two cases of illness were investigated to determine if kombucha played a role in the development of metabolic acidosis or other toxic effects. It was concluded that kombucha is not harmful at about 4 oz. per day; however, potential risks are associated with excessive consumption or consumption by an individual with preexisting health problems (CDC, 1995).

Alcohol is certainly debatable as a hazard, but is not debatable as an impetus for taxes. Recently Severson (2010) reported some commercial producers of kombucha were forced to recall unpasteurized versions from grocery store shelves when the alcohol content exceeded 0.5%. Some brands continued to ferment and may produce up to 3% alcohol in the bottle. This happens because yeast continues to ferment sugars producing alcohol and carbon dioxide. In a closed container the buildup of carbon dioxide inhibits the conversion of alcohol to acetic acid.

TABLE **2**

Kombucha pH Log

#	Start Date/pH	Date/pH	Date/pH	Date/pH	Date/pH	Date/pH	Date/pH
1							
2							
etc.							

TABLE **3**

pH Calibration Log

Date/pH/*	Date/pH/*	Date/pH/*	Date/pH/*	Date/pH/*	Date/pH/*

Note. Record date of calibration, calibration pH, and *initials of calibrator. Indicate manufacturer's suggested calibration interval (usually daily).

Controlling Food Safety

Critical Control Points, Critical Limits, Monitoring, Corrective Actions, and Record Keeping

Of all of the steps in Table 1, only one is *critical* to prevent the potential for acid-resistant pathogens: step 5. In this step the fermentation proceeds from pH ~5 to ≤4.2. Therefore the critical limit is pH ≤4.2. The pH should be monitored using a calibrated digital pH meter for ease and accuracy (versus paper). The main corrective action if the pH > 4.3 would be to continue fermentation and remeasure. If the pH does not reach pH ≤4.2 in seven days the culture is most likely contaminated or the fermentation temperature is too cold. In this case discard is recommended. Start a new batch with a newly purchased commercial culture. A record of the pH of kombucha should be kept to verify that the safe pH level has been reached. An example would be to create a simple table (Table 2). For each batch, mark the start date (manufacture date) and starting pH, then mark each successive pH measurement until pH ≤4.2. You may optionally continue to measure pH since the operational target is 2.5. Operators will also need to keep a calibration log (Table 3). If the pH goes below 2.5 the operator can add fresh brewed tea to return it to pH ≥2.5. A pH measurement guide including calibration instructions can be found at http://extension.usu.edu/files/publications/publication/FN_Food_Safety_2008-01.pdf.

Good Manufacturing Practices

Controls and preventative measures that don't meet the threshold of being critical, but nonetheless are needed to ensure safety, are contained in good manufacturing practices and standard operating procedures (SOPs). These controls are found in Table 1 under preventative measures. Using these preventative measures is recommended.

1. Use hot (≥165°F) water to steep tea (kills vegetative pathogens if present).
2. Use only clean and sanitary equipment and utensils.
3. Use a commercially purchased culture on first use. Reuse only culture from kombucha that shows no signs of mold or unusual contamination.
4. Kombucha with a pH of below 2.5 or that tastes especially acidic should not be offered to consumers. A corrective action would be to dilute the high acidity with fresh brewed tea until pH ≥ 2.5, but never higher than pH 4.2.
5. Discard all kombucha that is showing signs of mold contamination. Do not reuse for inoculum.
6. Consumer warnings: Consumers *should* be notified that no more than 4 oz. per day is recommended (see CDC references) and that they should not be immunocompromised. Furthermore, they should be made aware that minor amounts of alcohol may be present.
7. Health claims: kombucha is *suggested* to offer health benefits. Operators are discouraged from marketing or labeling health claims such as drinking will "cure" some ailment.

SOPs

SOPs are written, step-by-step instructions to accomplish a food safety objective. The following are recommended.

1. A detailed pH measurement and calibration SOP.
2. A detailed process instruction sheet to tell employees how to make kombucha using the food safety measures outlined in this report. The SOP must describe how employees will measure and record on a pH log.

Retail Sale of Kombucha (Packaging)

Retail sale of kombucha is beyond the scope of this report. Described below, however, are some minimum concerns to this specialized process.

Many commercial processors bottle kombucha. The main food safety hazard is acid-resistant pathogens. Bottling kombucha at a pH ≤4.2 will ensure no pathogen growth. Another hazard is bottling an actively fermenting kombucha beverage. Carbon dioxide will build up inside the container causing pressure. As the pressure exceeds the ability of the container to hold it, leakage or breakage occurs. Bottles can explode, forming projectile hazards. The last concern is shelf life, where spoilage from mold can occur or alcohol can build up ≥0.5%. Typically, as a little carbon dioxide builds up, acetic acid production will cease. So an excess acid hazard is unusual.

Fermented beverages (foods) are exempt from acidified foods canning regulations. Therefore they do not need any filings or notifications to FDA. Likewise, any refrigerated beverage (food) is also exempt from these same regulations.

Option 1: The best method is to pasteurize kombucha for bottling. Pasteurization will kill the culture preventing carbon dioxide or alcohol buildup in bottles. A simple recommendation is to heat kombucha to 180°F and bottle immediately. After 30 seconds invert bottle and hold for another 30 seconds. Allow bottles to cool. Pasteurized and bottled kombucha with a pH ≤ 4.2 is shelf stable (room temperature).

Option 2: This method relies on refrigeration and antifungal preservatives to minimize hazards and spoilage. Add 0.1% sodium benzoate **and** 0.1% potassium sorbate to kombucha with a pH ≤4.2. Bottle kombucha at any temperature. Keep refrigerated until use. Benzoate and sorbate will prevent mold growth and minimize yeast growth. Minimal to no growth of acetic acid bacteria will occur in bottles without significant oxygen. A refrigerated shelf life will need to be determined based on eventual yeast growth with carbon dioxide and alcohol production. If this proves difficult the operator may want to find a commercial kombucha culture with yeasts that do not grow well at refrigeration temperature.

Option 3: This method relies on refrigeration alone to minimize hazards and spoilage. Bottle kombucha at any temperature. Keep refrigerated until use. A refrigerated shelf life will need to be determined based on eventual yeast growth with carbon dioxide and alcohol production. If this proves difficult the operator may want to find a commercial kombucha culture with yeasts that do not grow well at refrigeration temperature.

Operators seeking to package kombucha for retail sale must also address labeling. Labeling issues are not covered here and operators are encouraged to inquire with their regulator or their state's department of agriculture. Generally, regulators who oversee grocery (retail) have information on requirements for retail labels.

Questions and Answers

Can I make diet or low-sugar kombucha?

No. The sugar is required as part of the fermentation process. Without sugar no alcohol is produced and without alcohol no acetic acid can be produced.

I make kombucha using tea and other ingredients (e.g., fruit). Can I still use this guideline?

Yes, provided the added ingredient does not raise the starting pH over that of the original tea (~pH 5). It might still be safe to brew using higher starting pH levels, but the operator would need to consult a processing authority.

Can I use this report as my HACCP Plan?

This report contains some of the information needed for an HACCP plan, just not in the typical table format. If the regulatory authority will accept it, it is sufficient. Copies of the recipe(s), a pH log, pH meter calibration log, and SOPs would need to be added to complete the food safety plan. If the kombucha is bottled, information on safe bottling and labels must also be included.

How strict is the recommendation from the CDC about limiting consumption of kombucha to 4 oz. per day?

The CDC recommendations are exactly that—recommendations. They are in response to two older and ill persons who became ill. One died. The analysis suggested they drank 12 oz. per day of very acidic kombucha. So, the recommendations are not to overferment kombucha and limit servings.

I've read that the kombucha culture is sensitive to sanitizers. How can I sanitize utensils and wares so the culture is not harmed?

FDA model *Food Code* section 4-703.11 permits submerging previously cleaned wares and utensils in hot water (≥160°F) for ≥30 seconds. This will sanitize the wares and not leave any chemical residue.

Corresponding Author: Brian Nummer, Associate Professor, Nutrition, Dietetics and Food Sciences, Utah State University, 8700 Old Main Hill, Logan, UT 84322. E-mail: brian.nummer@usu.edu.

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Preschool Children's Environmental Exposures: A Case-Control Epidemiological Study of the Presence of Asthma-Like Symptoms

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Abstract **The heterogeneity of asthma and asthma-like symptoms results in difficulty defining, diagnosing, and therefore estimating environmental exposures and associations with wheezing or asthma-like symptoms. Determining the disease burden for young children is particularly challenging. In the study described in this article, counter-matched sampling design was used to select participants from the Woman, Infants, and Children (WIC) program for this nested case-control study (*N* = 691, with 412 controls). Data were collected through structured interviews. Exposure to wood or oil smoke, soot, or exhaust was significantly associated with early-life asthma, as was exposure to cockroaches. Multivariate analyses showed that increasing age, male gender, presence of allergies (although not the type of allergies), and the presence of eczema at birth predicted wheezing behaviors in the authors' study. The authors estimated the prevalence of wheezing behavior in a population of low-income preschool children was 31% with prevalence rates higher among African-American children as compared to other races/ethnicities. Fifty-one percent of those children whose caregivers reported wheezing, however, had not received a diagnosis of asthma. Further study is recommended to compare the differences in the wheezing experiences between those diagnosed with asthma and those who are undiagnosed, with the intent of designing primary prevention interventions tailored to parents and caregivers of young children.**

Introduction

Popular belief holds that the prevalence of asthma in children is increasing. Does the evidence, however, support this perception? Before this question can be addressed, a definition of asthma is warranted. Although the features of asthma are well documented (Beasley, Crane, Lai, & Pearce, 2000; Gergen, Mullally, & Evans, 1988; Martinez, 2002; Martinez et al., 1995), defining asthma remains a problem (Castro-Rodriguez, Holberg, Martinez, & Wright, 2000; Taylor & Newacheck, 1992). Asthma is characterized by inflammation of the airways linked to hyper-responsiveness (Nowak et al., 1996), meaning that the airways leading to the lungs can narrow when individuals are exposed to anything to which they are sensitive. Inflammation and bronchial constriction are characterized by wheezing, coughing, and chest tightness (Belanger et al., 2003). Scientists and clinicians have agreed that asthma is not a single disease; it exists in many forms (Bacharier et al., 2004).

The past decade has been characterized by proliferation of expert practice guidelines (Fuhlbrigge et al., 2002; National Asthma Education and Prevention Program, 1997), all with the goals of disseminating scientific knowledge to the practicing clinician and the widespread implementation of anti-inflammatory therapy to improve asthma outcomes (Adams et al., 2001; Diaz et al., 2000; Halterman, Aligne, Auinger, McBridge, & Szilagyi, 2000). To this extent, much emphasis has been on early diagnosis and longitudinal care of patients with asthma, along with ensuring adherence to the recommended therapies (Stempel, McLaughlin, Stanford, & Fuhlbrigge, 2005). Yet, as exciting as changes have been in asthma research and practice, many controversies abound when considering asthma and asthma-like symptoms in children aged five and younger.

Data on asthma in children younger than five years of age are sparse. Establishing a diagnosis of asthma in young wheezing children can be challenging because the type, severity, and frequency of asthma symptoms vary widely among children and sometimes even with an individual child (Martinez, 2002). Also, not all wheezing or coughing is caused by asthma (Martinez et al., 1995). Asthma in children usually has many causes or triggers that may change as a child ages (Melén, Wickman, Nordvall, van Hage-Hamsten, & Lindfors, 2001). A child's reaction to a trigger may also change with treatment. In children under five years of age, the most common cause of asthma-like symptoms is upper respiratory viral infections such as the common cold (Lemanske et al., 2005).

Diagnostic tools and current treatment recommendations do not address adequately the needs of children age five and under (van Schayck, van Der Heijden, van Den Boom, Tirimanna, & van Herwaarden, 2000). Asthma is often difficult to diagnose in infants, but in older children the disease can be diagnosed based on the child's medical history, symptoms, and physical exam (Castro-Rodriguez et al., 2000). The majority of the asthma estimates contained in most reports are dependent on conjecturing diagnoses and documenting these results in patients' records, with the potential of either underestimates or overestimates of cases (Kuehni, Davis, Brooke, & Silverman, 2001; van Schayck et al., 2000). Surveillance will help determine the true disease burden of asthma in children younger than five years of age. Our study was conducted to gather preliminary data regarding the prevalence of asthma-like symptoms in young children and to explore environmental exposure sources that may be impacting symptoms.

Methods

Background and Subject Selection

Our study was approved in accordance with Allegheny County Health Department (ACHD) procedures, with approval granted by the ACHD director rather than an institutional review board. All participants gave written informed consent.

To determine prevalence of asthma in preschool children below the usual age of spirometry (e.g., 5–6 years), subjects for our exploratory case-control study were selected from the Woman, Infants, and Children (WIC) program—a nutrition program that provides food, infant formula, and breast-feeding/nutrition education to income-eligible pregnant, breast-feeding, and bottle-feeding women. The program targets infants, toddlers, and children up to five years of age who meet certain medical or nutritional risk criteria. The WIC program in Allegheny County, Pennsylvania, serves an average of 15,640 individuals per month, with approximately 50% self-identifying as members of a racial/ethnic minority. To best capture those individuals who would potentially be at greatest risk of reporting asthma-like symptoms, the investigators focused on five WIC program sites. These sites were selected because of their proximity to air monitoring stations and the number of asthma hospitalizations reported by local hospitals. The local health department reported that these geographical areas had potentially poor air quality (Allegheny County Health Department, 2010).

A counter-matched sampling design (Langholz & Goldstein, 2001) was utilized to select subjects for this nested case-control study. The study base consisted of 5% (n = 810) of the individuals served by Allegheny County WIC, who were caregivers of children five years of age and younger at the time of the interview and had completed active follow-up of WIC services. Of this study base, 14.7% (n = 119) refused participation. From those caregivers of children who chose to participate, all children with histories of wheezing episodes or asthma diagnosis before age five were assigned to the case group (n = 279). Matched controls (n = 412) were asthma-free children randomly selected from each of the qualifying target sites, with approximately equal numbers of children who were exposed or unexposed to maternal smoking within each sampling stratum.

Inclusion Criteria

Individuals who had appointments to receive WIC services were approached in waiting rooms of WIC providers. Individuals who were WIC participants were eligible for study participation if they were current WIC members with a child five years of age or younger. Because some of the WIC clinics shared office space and waiting room areas with other health agencies, any person coming to these clinics with a child approximately five years of age or younger was also approached. Potential study participants were informed that ACHD was conducting a study on asthma, that the interview would probably take less than five minutes, and that they would receive a grocery store gift card for their participation. Mothers, fathers, grandparents, and foster parents were interviewed. Pregnant women who were pregnant with their first child, or whose other children were older than five were not included in the sample. For convenience, all participants are referred to as caregivers.

Data Collection

The caregiver of each case and control provided detailed information on demographics, family history of asthma, feeding practices in infancy, day care attendance, and the household environment (cockroaches, pets, herbicides, and pesticides), through a structured interview. When the caregiver did not state the child's racial data, the interviewer inserted this information based on physical appearance.

Exposure Assessment

For the environmental exposures, including exposures to cockroach, pets, and pesticides, mutually exclusive categories of exposure were recorded as "ever exposed" or "never exposed." To have a surrogate measure of particulate air pollutant exposures at home, caregivers provided a self-report of the child's exposure to wood or oil smoke, soot, dust, or exhaust (specified as referring to home heating sources rather than exposure to auto exhaust in the greater environment). While a subjective measure of air pollution, exposure to wood or oil smoke, soot, dust, or exhaust best captured what respondents understood to be descriptive patterns of air pollution exposure in the home for participating children. It is noteworthy that most participants were not aware of the geographical locations of local air monitoring stations. Although air monitoring data and residential proximity to monitoring stations would have been useful data sources to triangulate reporting, such data collection was beyond the scope of our preliminary study. Maintaining respondent confidentiality and anonymity was a primary concern for this vulnerable population. On the basis of the patterns of exposure in participating children, exposure was defined in three periods: (a) never exposed, (b) exposed since first year of life that continued after one year of age, and (c) exposed only after first year of life.

Outcome Assessment

Asthma status was defined using the response to the question, "Do you have any children four years of age or younger who have ever wheezed when they breathe for any reason?" Wheezing was defined as a high pitched whistling sound during breathing occurring when air flowed through narrowed breathing tubes. Responses to this question were subjective (i.e., self-report) and not based on clinical findings. The age of onset was classified into mutually exclusive categories of early (by three years of age) and late (after three years of age) onset. An asthma case was assigned as having persistent wheezing if the child had (a) one or more episodes of wheezing in the 12 months before study entry, or (b) used prescribed medication for asthma in the 12 months before study entry or after starting preschool. Of the 279 cases, 47 (16.8%) had early transient wheezing, 166 (59.5%) had early persistent asthma, and 166 (59.5%) had late-onset asthma. Children were grouped into two wheezing status categories: those children who "never wheezed" and those children who "wheezed."

Assessment of Confounders and Effect Modifiers

Maternal smoking during pregnancy was coded as yes (had ever smoked) or no (did not smoke). Secondhand tobacco smoke exposure was defined using the number of household smokers (none, 1, >1) during infancy. Family history of asthma or allergy was defined as any first-degree relative with a diagnosis of asthma or allergy. The yearly family income limits were an annual gross income of $17,224 for a family of one; $23,107 for two; $28,990 for three; $34,873 for four; $40,756 for five; $46,639 for six; $52,522 for seven; and $58,405 for eight. Unborn children were counted in determining family size when the woman was pregnant. Maternal or caregiver education at study entry was categorized into five groups: <12th grade education, completed 12th grade, some college, completed college, and some graduate education. Race/ethnicity was grouped into five categories: non-Hispanic Whites, Hispanics, African-Americans, Asians, and others.

Statistical Analysis

Odd ratios (*ORs*) of physician-diagnosed asthma patients were estimated by fitting conditional likelihood logistic regression models accounting for the counter-matched sampling using the methods described by Langholz and Goldstein (2001). The number of nonparticipants, including those who declined to participate, was considered in the likelihood. Pairwise conditional logistic regression models were used to assess the role of the exposures in different subgroups of levels and intensity of asthma (i.e., early transient wheezing, early persistent, and late-onset asthma) and on age of onset at asthma diagnosis (i.e., asthma diagnosis by age three versus diagnosis after age three). Education, income, race/ethnicity, secondhand smoke, and maternal or family history of asthma confounded the associations between the exposures of interest and asthma. Potential confounding covariate factors were included in final models if their inclusion resulted in a 10% change in the parameter estimate. To investigate whether any of these characteristics modified the associations of the exposures of interest with asthma, conditional logistic regression models were compared with and without appropriate interaction terms using likelihood ratio tests. All tests were two-sided at a 5% significance level.

TABLE **1**

Selected Demographic Characteristics of the Study Sample

Characteristics	Case # (%)	Control # (%)
Gender		
Male	177 (63.4)	234 (56.8)
Female	102 (36.6)	178 (43.2)
Race/ethnicity		
Non-Hispanic white	133 (43)	177 (57)
African-American	220 (58)	160 (42)
Asian and other	3 (1)	3 (1)
Maternal/caregiver education		
<12th grade	82 (29.7)	155 (38.4)
12th grade	137 (49.6)	195 (48.3)
Some college	24 (8.7)	22 (5.4)
College	33 (12.0)	32 (7.9)
Annual family income ($) for family sizes of two or more children		
<7,500	37 (14.8)	86 (23.6)
7,500–14,999	40 (16.0)	59 (16.2)
15,000–29,999	174 (69.2)	220 (60.2)
Health insurance coverage		
Yes	250 (90.6)	346 (84.8)
No	26 (9.4)	62 (15.2)
Family history of asthma		
Yes	150 (58.1)	296 (79.4)
No	108 (41.9)	77 (20.6)

Results

Table 1 summarizes the demographic characteristics of the study subjects. Most of the study subjects (55%, *n* = 380) were African-American and male (59%, *n* = 411) and had low socioeconomic status with an annual family income of nearly $20,000 for a family of two or more. Family history of asthma was more common among cases than among controls. No statistical difference occurred in maternal or caregiver education level, yearly family income, or access to health care measured in terms of health insurance coverage between cases and controls.

Table 2 summarizes the associations between various risk factors that were examined. Exposure to wood or oil smoke, soot, or exhaust was significantly associated with early-life asthma. Children exposed to wood or oil smoke, soot, or exhaust were at a 1.6-fold higher risk of asthma than those who were never exposed (*OR* = 1.61; 95% confidence interval [*CI*], 1.03–2.51). This association appeared stronger when exposure occurred in the first year of life (*OR* = 1.74; 95% *CI*, 1.02–2.96). In subgroup analysis, exposure to wood or oil smoke, soot, or exhaust was positively associated with both early- and late-onset

TABLE **2**

Associations Between Any Asthma, Early Transient Wheezing, Early-Onset Persistent Asthma, and Late-Onset Asthma and Selected Environmental Exposures

Exposure	Control #	Any Asthma		Early Transient Wheezing		Early-Onset Persistent Asthma		Late-Onset Asthma	
		#	*OR*[a] (95% *CI*[a])	#	*OR*[a] (95% *CI*)	#	*OR*[a] (95% *CI*)	#	*OR*[a] (95% *CI*)
Wood/oil smoke, soot, or exhaust									
Never	310	201	1.0	32	1.0	122	1.0	47	1.0
Ever	102	78	1.61 (1.03–2.51)	15	4.32 (1.80–10.38)	44	1.59 (0.94–2.70)	19	1.12 (0.52–2.43)
In first year and later	60	46	1.74 (1.02–2.96)	10	5.65 (1.97–16.20)	22	1.62 (0.84–3.10)	14	1.35 (0.58–3.16)
Not in first year	42	32	1.44 (0.77–2.68)	5	2.99 (0.86–10.41)	22	1.57 (0.77–3.21)	5	0.73 (0.22–2.42)
Cockroaches									
Never	364	240	1.0	38	1.0	143	1.0	59	1.0
Ever	102	78	1.61 (1.03–2.51)	15	4.32 (1.80–10.38)	44	1.59 (0.94–2.70)	19	1.12 (0.52–2.43)
In first year and later	60	46	1.74 (1.02–2.96)	10	5.65 (1.97–16.20)	22	1.62 (0.84–3.10)	14	1.35 (0.58–3.16)
Not in first year	42	32	1.44 (0.77–2.68)	5	2.99 (0.86–10.41)	22	1.57 (0.77–3.21)	5	0.73 (0.22–2.42)
Pets									
Never	82	58	1.0	9	1.0	34	1.0	15	1.0
Ever	330	221	1.42 (0.88–2.29)	38	2.61 (0.89–7.71)	132	1.41 (0.80–2.47)	51	0.73 (0.32–1.64)
In first year and later	224	146	1.48 (0.88–2.47)	23	2.34 (0.72–7.55)	90	1.47 (0.80–2.68)	33	0.78 (0.32–1.90)
Not in the first year	106	75	1.35 (0.78–2.33)	15	2.90 (0.91–9.25)	42	1.32 (0.69–2.53)	18	0.67 (0.27–1.67)
Aerosols/indoor pesticides									
Never	387	257	1.0	46	1.0	151	1.0	60	1.0
Ever	25	22	1.20 (0.58–2.47)	1	0.26 (0.02–4.36)	15	1.36 (0.61–3.01)	6	1.21 (0.40–3.68)
In first year and later	5	11	4.58 (1.36–15.43)	0	–	10	10.08 (2.46–41.33)	1	2.26 (0.19–27.43)
Not in the first year	20	11	0.58 (0.24–1.39)	1	0.26 (0.02–4.36)	5	0.36 (0.12–1.11)	5	1.09 (0.33–3.58)
Exclusive breast-feeding									
<4 months	280	163	1.0	32	1.0	100	1.0	31	1.0
≥4 months	121	111	1.34 (0.88–2.04)	14	1.34 (0.54–3.33)	62	1.27 (0.77–2.11)	35	1.98 (0.96–4.07)

[a] *OR* = odds ratio; *CI* = confidence interval. *OR*s are matched on age, sex, and community of residence (i.e., proximity to air monitoring station), counter-matched on in utero maternal smoking and adjusted for race/ethnicity.

asthma. The *OR*s were statistically significant for early transient wheezing, for which exposure since the first year of life was associated with a more than five-fold increased risk (*OR* = 5.65; 95% *CI*, 1.97–16.20).

Children exposed to cockroaches were also at significantly higher risk for childhood asthma. Children exposed to cockroaches in their infancy had a nearly two-fold higher risk of asthma than those not exposed (*OR* = 1.74, 95% *CI*, 1.02–2.96). Any cockroach exposure was associated with early transient wheezing (*OR* = 5.65; 95% *CI*, 1.97–16.20). This association derived from exposure to cockroaches after the first year, which was associated with increased risk for early transient wheezing. Exposure to pets was not associated with asthma in our data. Furthermore, specific types of pets (e.g., dogs, cats, birds, and other furry animals) were not associated with asthma (results not shown).

Children exposed to aerosols and indoor pesticides in the first year of life were significantly at higher risk of asthma (*OR* = 4.58, 95% *CI*, 1.36–15.43) although exposure beginning after the first year of life was not associated with increased risk of asthma. When aerosols and indoor pesticide exposures were considered together, children exposed to any aerosol or pesticide in the first year of life were at a 2.53-fold higher risk of asthma compared with children who were never exposed (*OR* = 2.53; 95% *CI*, 1.25–5.09). The *OR*s for the association of exposure to aerosols and indoor pesticide and early persistent asthma were largest for exposure beginning in the first year of life (*OR* = 3.78, 95% *CI*, 1.70–8.41).

No association was found between exclusive breast-feeding and any asthma outcome. Family or maternal history of asthma, secondhand tobacco exposure, maternal smoking during pregnancy, gestational age, yearly family income, health insurance coverage, and maternal education level did not confound the association between any of the early-life exposures and asthma outcomes. Therefore, these variables were not included in the final models. Furthermore, none of the associations between the exposures and early-life asthma varied by family or maternal history of asthma or allergy.

In our study, the estimate of prevalence of wheezing behavior in a population of low-income preschool children was found to be 31%; however, 51% of those children with wheezing, as reported by caregivers, had not received a diagnosis of asthma.

Multivariate analyses showed that increasing age, male gender, presence of allergies (although not the type of allergies), and the presence of eczema at birth predicted wheezing behaviors in children in the WIC population. The data showed gender as a predictor of wheezing. For example, males were 1.6 times more likely to wheeze than females. When breathing problems after physical activity or after exposure to cigarette smoke were considered, the presence of eczema at birth and breathing problems after exposure to cigarette smoke were significantly associated with wheezing behaviors.

Discussion

The diagnosis of asthma in young children may well be more challenging than previously appreciated. The difficulty of accurate diagnosis is often underestimated by clinicians who may link it to a passing cold or other nonserious condition rather than relating it to asthma, a chronic and potentially serious disease. What accounts for the widespread perception that the prevalence of asthma is increasing in children, particularly in those younger than five years of age?

Being diagnosed as having asthma is closely related to receiving specific treatment for the condition (Kuehni et al., 2001; van Schayck et al., 2000) and good reason already exists to suppose that pediatricians are seeing more children whom they recognize as having asthma-like symptoms. Increases in hospital admissions and general practice consultations for asthma have been reported (Homer et al., 1996; Ordonez, Phelan, Olinsky, & Robertson, 1998). Such increases may reflect changes in diagnosis and treatment of asthma-like symptoms rather than an increase in the prevalence of the disease.

The percentages of wheezing children ranged from 1% of Hispanic children to more than 59% of African-American children. Most children had mild to moderate degrees of severity. Atopy, environmental triggers, and tobacco smoke exposure were common risk factors.

Our study found that older children, males, those with allergies, and those with eczema at birth were at increased risk for wheezing behavior that is common to asthma. The greatest proportional increase among the boys, and a substantial increase among the girls, was in those with persistent symptoms but no diagnosis of asthma or asthma-like disease. In view of the close association that is believed to exist between diagnostic labels and treatment, this is particularly troubling. It may indicate an increasing number of untreated cases with moderately severe disease.

Our study had several limitations. It examined children participating in the Allegheny County, Pennsylvania, WIC program, which serves families of low socioeconomic status, so the findings do not represent the general population. This sample was also not representative of the racial distribution, or of the access to health care and health-related products and practices of the general population. Other limitations of our study include the extremely limited ability to draw causal inferences due to the cross-sectional nature of the study, as well as the recall bias associated with asking questions about events and conditions that may have occurred up to five years ago for some participants.

Other study limitations relate to operational definitions. Our study was designed to explore a wide range of environmental exposures that may impact asthma-like symptoms. Case definitions of asthma-like symptoms were broadly defined in an effort to capture the widest possible range of asthma and asthma-like symptoms, whether or not a participant had ever received a formal diagnosis of asthma. Likewise, exposure status was defined using mutually exclusive categories of occurring or not occurring in an effort to capture the widest possible range of exposure factors. Detailed exposure data such as frequency, duration, or magnitude of exposure were not collected, thus limiting statistical analysis capabilities. Although reported air quality and the number of asthma hospitalizations were used to select interview sites, our study was based solely on subjective caregiver self-report. Residential addresses would have provided the ability to triangulate empirical air quality data, but protecting participant anonymity was an overriding concern for our study, so no personally identifying information was collected.

Conclusion

The results from this exploratory study suggest that nearly 30% of the low-income preschool population may be at risk for asthma or asthma-like symptoms, and that African-American children may be at higher risk for wheezing behavior than other racial groups. Of those at risk, approximately half reported no diagnosis of asthma. Despite a greater awareness and better understanding of asthma, the problem of definition and diagnosis remains unresolved. Further research is necessary to improve understanding of the differences between children who wheeze and those who do not, as well as comparing the experiences of children who have been diagnosed with asthma and those who have not. Such studies would benefit from an examination of medical records, particularly regarding diagnosis of asthma or repeated doctor or hospital visits for breathing problems.

Future studies will also benefit from inclusion of empirically based indicators of environmental exposures, such as air monitoring data and the frequency, duration, and magnitude of exposures. This line of research is important for designers of primary prevention efforts in this population. Because environmental exposures may increase risk for development of asthma-like symptoms, educational outreach to parents and caregivers of young children about environmental exposures may be one such prevention method.

Acknowledgements: The authors would like to thank the Allegheny County WIC Program and ACHD for assistance in conducting this study.

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Radon-Contaminated Drinking Water From Private Wells: An Environmental Health Assessment Examining a Rural Colorado Mountain Community's Exposure

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Abstract **In the study discussed in this article, 27 private drinking water wells located in a rural Colorado mountain community were sampled for radon contamination and compared against (a) the U.S. Environmental Protection Agency's (U.S. EPA's) proposed maximum contaminant level (MCL), (b) the U.S. EPA proposed alternate maximum contaminate level (AMCL), and (c) the average radon level measured in the local municipal drinking water system. The data from the authors' study found that 100% of the wells within the study population had radon levels in excess of the U.S. EPA MCL, 37% were in excess of the U.S. EPA AMCL, and 100% of wells had radon levels greater than that found in the local municipal drinking water system. Radon contamination in one well was found to be 715 times greater than the U.S. EPA MCL, 54 times greater than the U.S. EPA AMLC, and 36,983 times greater than that found in the local municipal drinking water system. According to the research data and the reviewed literature, the results indicate that this population has a unique and elevated contamination profile and suggest that radon-contaminated drinking water from private wells can present a significant public health concern.**

Introduction

During the reclamation of a Superfund site located along the Colorado front range, an employee of a private company contracted by the U.S. Department of Energy began setting off radiation security alarms while entering the facility. After months of investigation to determine the source of this radiation, it was discovered that the drinking water from the individual's private well was so highly contaminated with radon that simply showering with this water left enough radiation on his body to trigger the alarms.

The purpose of our study was to identify and evaluate the potential extreme occurrence of natural radon contamination in private well water sources in this rural Colorado mountain community.

Review of Literature

Radon and Health

Radon is a well-established human carcinogen and is the principal source of radioactivity exposure among the general population in most countries around the world (Catelinois et al., 2006). For many years scientists have sought to assess cancer risk associated with long-term radon exposure, and in 2005, the U.S. surgeon general issued a national health warning reporting that radon causes at least 20,000 lung cancer deaths per year in the U.S. and that all homes should be tested for elevated levels (Catelinois et al., 2006; U.S. Environmental Protection Agency [U.S. EPA], 2010). Also, in 1998, the International Agency for Research on Cancer declared radon as a group I carcinogen in humans based on results from animal and human epidemiological studies (Catelinois et al., 2006).

Occupational and Residential Exposure

The first evidence of the relationship between radon exposure and lung cancer was observed in occupational studies of miners exposed to high levels of radon underground (Al-Zoughool & Krewski, 2009; Cothern & Smith, 1987; Graves, 1987; Levy, 2009). Decades of subsequent research assessing this association has been firmly established and many cohort studies have shown statistically significant positive associations between radon inhalation and the risk of developing lung cancer (Darby et al., 1995; Howe, Nair, Newcombe, Miller, & Abbatt, 1986; Kusiak, Ritchie, Muller, & Springer, 1993; Laureir et al., 2004).

Many studies have also been conducted in estimating the risk of residential radon exposure among the general population showing a reasonable risk between such exposure and the development of lung cancer (Alavanja, Lubin, Mahaffey, & Brownson, 1999; Auvinen et al., 1996; Barros-Dios, Barreiro, Ruano-Ravina, & Figuerias, 2002; Catelinois et al., 2006; Darby et al., 1998; Pearce & Boyle, 2005; Wichmann et al., 2002, 2005). In one study, the risk of lung cancer associated with residential radon exposure examined a collaborative analysis of individual data obtained from 13 case-control studies related to lung cancer and residential radon. It was found that cases of lung cancer increased as the level of radon exposure in the home increased with a linear dose-response relationship (Darby et al., 2005).

Radon and Drinking Water

Because radon is completely soluble in water, high concentrations of radon can accumulate in groundwater and pose a potential health risk for those who use it for drinking and domestic purposes (Al-Zoughool & Krewski, 2009; Cothern & Rebers, 1991; Cothern & Smith, 1987; Graves, 1987; National Research Council [NRC], 1999a). In fact, one environmental radon assessment study found that private well water supplies in the U.S. were as much as 3–20 times higher in radon concentrations compared to that of public drinking water systems (Hess, Horton, Prichard, & Coniglio, 1985).

At increased concentrations, radon-contaminated water used for drinking and domestic purposes can contribute to the added radon concentrations in a home (Collman, Loomis, & Sandler, 1991; Cothern & Smith, 1987; Graves, 1987; NRC, 1999a; Prichard, 1987). With agitation and heating, radon in water is released into the air and scientists have estimated that 10%–15% of total radon in air may actually be attributed to radon off-gassing from domestic water (Collman et al., 1991). Also, the ingestion of high concentrations of radon in drinking water represents a particular concern for the stomach and gastrointestinal tissues, and scientists have estimated that up to 90% of the ingested dose of radon is delivered directly to the stomach tissue (Kendall & Smith, 2002). In fact, it has been estimated that radon in drinking water causes approximately 168 cancer deaths per year—89% from lung cancer caused by breathing radon released to the indoor air from the water, and 11% from stomach cancer caused by the ingestion of radon-contaminated water (NRC, 1999a, 1999b; U.S. EPA, 2012).

Radon Regulatory Limitations

In comparison to other group I carcinogens, radon health and safety regulations tend to lack in overall progress and backing within the U.S. Currently, no federal regulations exist for radon exposure in indoor air; however, U.S. EPA has set a recommended action limit of 4 picocuries per liter (pCi/L) (U.S. EPA, 2011a). Similarly, no federally enforced standards currently exist that protect individuals from radon-contaminated drinking water. In 1991, the U.S. EPA did propose to regulate radon levels in public drinking water supplies; however, this regulation has yet to be adopted and would not include oversight for private wells (Abdallah, Habib, Nuwayhid, Chatila, & Katul, 2007; NRC, 1999b; U.S. EPA, 2011b). In this 1991 proposal, U.S. EPA proposed a new National Primary Drinking Water Regulation that recommended a maximum contaminant level (MCL) of 300 pCi/L. In addition to the proposed MCL, U.S. EPA also proposed a debated alternative MCL (AMCL) of 4,000 pCi/L. This AMCL would be allowed only if states or the local community water system developed a U.S. EPA–approved indoor air quality program, also called multimedia mitigation programs, to educate and provide radon consultation to area residents. Overall, this AMCL is often referred to as a mechanically influenced standard as opposed to a relevant health protection standard (Abdallah et al., 2007; NRC, 1999b; U.S. EPA, 2011c).

Methods

Sample, Instrumentation, and Data Collection

The population in our study was considered a convenience sample of 29 private wells located in a rural Colorado mountain community. A total of 27 wells were sampled in our study.

All water samples were sent to a local U.S.EPA–certified laboratory for analysis. The laboratory used the *Standard Method of the Examination of Water and Wastewater* 7500-Rn Liquid Scintillation Method, which is specific for determining radon concentrations in drinking water obtained from ground or surface water sources (Clescerl, Greenberg, & Eaton, 1999).

Water sampling occurred over a four-week period and each private well was sampled once for radon, uranium, and radium. Uranium and radium levels were sampled only to account for the potential positive bias resulting from interference of these radionuclides if present in concentrations greater than the radon (Clescerl et al., 1999). All radon water samples were collected in glass sample containers (two at each well), while the uranium and radium samples were collected in plastic containers (three at each well) as specified by laboratory analysis methods. All sample instruments were provided by the laboratory and inspected prior to use for sound condition. Sample bottles found to be damaged or altered in any way were not used for sample collection in this study (Koren & Bisesi, 2003; Salvato, Nemerow, & Agardy, 2003).

All water samples were collected from a non-aerated spigot that had been allowed to run for at least 10 minutes to ensure the sample was representative of water directly in the well (Clescerl et al., 1999). Samples were collected by a registered environmental health specialist or a research assistant trained in water sample collection techniques and procedures. After samples had been collected, a record of the sampling date, time, and sample identification number was recorded on a chain of custody form. The sample number corresponded to the well being sampled, numbered 1 to 27. To compare radon levels measured between the sample population and the local municipal drinking water system, radon level data was requested from the local municipal drinking water quality laboratory. The local municipality provided the researchers with a record of radon samples taken between 2003 and 2010.

Data Analysis

All water samples were analyzed by a U.S. EPA–certified laboratory using the *Standard Method for the Examination of Water and Wastewater* 7500-Rn. Radon levels measured in the private wells were compared against the following study standards: (a) the U.S. EPA MCL of 300 pCi/L, (b) the U.S. EPA AMCL of 4,000 pCi/L, and c) the average radon level measured in the local municipal drinking water system at 5.8 pCi/L. All water quality results were entered into SPSS and Microsoft Excel for data analysis.

Results

Descriptive Statistics

The results of our study indicated that the minimum radon contamination level was 360 pCi/L (well #10), the maximum level was 214,500 pCi/L (well #2), and the mean radon contamination level was 15,776 pCi/L (N = 27, SD = 41,565.94) (Table 1).

All wells (100%) had radon contamination greater than the U.S. EPA MCL of 300 pCi/L as well as the average level found in the local municipal drinking water system of

5.8 pCi/L. The sample maximum of our study (well #2) was 715 times greater than the U.S. EPA MCL and 36,983 times greater than the average level found in the local municipal drinking water system. Furthermore, the mean radon contamination level of the study population (15,776 pCi/L) was found to be 53 times greater than the U.S. EPA MCL and 2,720 times greater than the mean level found in the local municipal drinking water system.

With regard to the U.S. EPA AMCL of 4,000 pCi/L, 37% of the wells in our study were in excess of this standard. The sample maximum (214,500 pCi/L) was 54 times greater than the U.S. EPA AMCL and the population average of 15,776 pCi/L indicated a level four times greater than the U.S. EPA AMCL. The results of the water sample analysis can be seen in Table 2.

TABLE **1**

Descriptive Statistics Table of Water Sample Data (*N* = 27)

Measure	#	Minimum	Maximum	Mean	Median	*SD*
Value	27	360	214500	15775.56	2600	41565.940

TABLE **2**

Water Sampling Results (*N* = 27)

Well #	Radon (pCi/L[a])	Uranium (ug/L)	Radium (pCi/L)
1	35400	12	3.8
2	214500	100	16
3	46000	15	18
4	17700	12	28
5	2500	6.4	0.2
6	1820	11	0.4
7	2120	10	0.6
8	38600	25	6.1
9	13400	14	6.3
10	360	1.1	0.2
11	3570	4.8	2.1
12	880	6.6	0.6
13	5390	3.7	0.7
14	720	8.5	1.4
15	3130	0.7	0.0
16	2580	4.2	0.6
17	7750	10	6
18	2720	0.7	0.2
19	1770	19	0.6
20	8360	4.6	1.7
21	2600	10	0.3
22	2200	33	5.2
23	1200	5	0.4
24	6700	10	4.2
25	2010	1.4	1.2
26	1100	26	2.9
27	860	3	0.3

[a]pCi/L = picocuries per liter.

Alternative Results (Exclusion of Outlier)

Because well #2 (214,500 pCi/L) was significantly greater than all other water quality results and acted as an extreme value and significant outlier affecting the sample average and further statistical analyses in our study, data analysis also included its exclusion (further referred to as the "alternative") to provide a more comprehensive analysis of the data. With the removal of well #2, the alternative maximum level was 46,000 pCi/L. The results also indicated an alternative mean level of 8,132 pCi/L. In this case, the alternative maximum of 46,000 pCi/L (well #3) was still 153 times greater than the U.S. EPA MCL level and still 7,931 times greater than the average level found in the local municipal drinking water system. Also, the alternative mean level ($n = 26$) was found to be 27 times greater than the U.S. EPA MCL and 1,402 times greater than the mean level found in the local municipal drinking water system.

With regard to the U.S. EPA AMCL of 4,000 pCi/L, the alternative sample maximum (46,000 pCi/L) was shown to be 11.5 times greater than the U.S. EPA AMCL and the alternative mean (8,132 pCi/L) indicated a level twice that of the U.S. EPA AMCL.

Analytic Statistics

Because the data did not meet the assumption of normality, a one sample Wilcoxon signed rank test using SPSS was performed to examine the relationship between the radon levels in the study population and that of the study standards to determine if the observed differences had statistical significance. The one sample Wilcoxon signed rank test found statistical significance when compared to the U.S. EPA MCL and when compared to the level found in the local municipal drinking water system. The results of the test indicated that with a sample size of 27, a mean of 15,776.56 pCi/L, and median of 2,600 pCi/L, this test was significant at $p < .001$ for both standards.

With regard to the U.S. EPA AMCL, the test was found not to be statically significant. The results of the one sample Wilcoxon signed rank test indicated that with a sample size of 27, a mean of 15,776.56 pCi/L, and a median of 2,600 pCi/L, this test was not significant at $p = .701$. This indicates that the difference between the study population and the U.S.

TABLE 3

Wells With Levels in Excess of the U.S. Environmental Protection Agency Maximum Contaminant Level (U.S. EPA MCL) for Radium (*N* = 27)

Well #	Radium (pCi/L[a])	U.S. EPA MCL (pCi/L)
4	28	5
3	18	5
2	16	5
9	6.3	5
8	6.1	5
22	5.2	5

[a]pCi/L = picocuries per liter.

EPA AMCL was not statically significant and that a larger sample size may be necessary to determine significance.

Furthermore, the one sample Wilcoxon signed rank test was also performed with the removal of well #2 (n = 26); however, the significance did not change to any great extent for the three standards.

Uranium and Radium (Quality Control)

Because no well was found to have uranium or radium levels in excess of the radon contamination levels found in our study, literature indicates that the increased radon levels were most likely not caused by a positive bias in the sample analysis procedure influenced by the uranium or radium radionuclides (Clescerl et al., 1999). It is important to note, however, that several wells were found to be in excess of the U.S. EPA MCL for radium (5 pCi/L) and the MCL for uranium (30 ug/L).

The results show that only well #2 had a level of uranium greater than the U.S. EPA MCL with a measurement of 100 ug/L, which is 3.3 times the acceptable level for drinking water (Table 2).

With regard to radium levels, six wells (22%) were found to be in excess of the U.S. EPA MCL of 5 pCi/L. In this case, well #4 had a level of 28 pCi/L, which is 5.6 times the acceptable drinking water standard; well #3 had a level of 18 pCi/L, which is 3.6 times the acceptable drinking water standard; and well #2 had a level of 16 pCi/L, which is 3.2 times the acceptable drinking water standard. Other wells in excess of the MCL were well #9 with 6.3 pCi/L, well #8 with 6.1 pCi/L, and well #22 with 5.2 pCi/L (Table 3).

Discussion

Our study did discover significant radon-contaminated drinking water from private wells within this rural Colorado mountain community. The results provide evidence of the increased risk of radiation exposure from private well water sources, which may in turn lead to the increased risk of developing subsequent health effects such as cancer. Also, the results were found to be in support of the reviewed literature, indicating that individuals who obtain their drinking water from private wells have a significantly increased risk of radon exposure than those who obtain their drinking water from a local municipal drinking water system (Al-Zoughool & Krewski, 2009; Catelinois et al., 2006; Mose, Mushrush, & Simoni, 2001; NRC, 1999b; Pachocki et al., 2002; Senior, 1998; Villalba et al., 2005). It is important to note, however, that this study population may have a unique geographical profile and be located in an area suspected to have elevated levels of underground uranium and radon. This is a U.S. EPA radon zone 1 area.

Comparison to the Local Municipal Drinking Water System

It has been reported that radon concentrations in surface water tend to be relatively low and usually measure less than 110 pCi/L, while groundwater concentrations are usually much higher (Al-Zoughool & Krewski, 2009). Our study supports the literature indicating the mean radon level found in the local municipal drinking water to be only 5.8 pCi/L (obtained from a surface water source) while the mean level found in the study population (groundwater from private wells) was 15,776 pCi/L, with an alternative mean of 8,132 pCi/L, and with a maximum level observed at 214,500 pCi/L. In a study conducted by Hess and co-authors (1985), it was found that private well water supplies in the U.S. were as much as 3–20 times higher in radon concentrations compared to public drinking water systems. In our study, however, it was determined that the mean level of 15,776 pCi/L was 2,720 times greater than the mean level found in the local municipal drinking water system and the alternative mean was still 1,402 times greater.

Comparison to Other Well Water Studies

In comparing the results of our study to others found in the reviewed literature, our study population has much greater radon contamination levels. A study by Senior (1998) examined 665 samples taken from 534 wells in Pennsylvania and reported a mean concentration of 1,400 pCi/L, with the highest concentration measured at 53,000 pCi/L. Similarly, a study conducted by the U.S. Geological Survey sampled water from 160 wells in Pennsylvania and found radon levels up to 32,000 pCi/L with a mean of 2,400 pCi/L (Senior & Vogel, 1995).

In more modest sampling studies that may be more comparable to this study, Abdallah and co-authors (2007) observed that in 20 wells tested in Lebanon, a mean level of 308 pCi/L was found with a sample maximum of 1,339 pCi/L. Yalim and co-authors (2007) sampled 10 wells in Turkey and found radon levels between 11 and 778 pCi/L, while Silva and co-authors (2000) studied 97 wells in Brazil and obtained a radon level range of 143 to 2,560 pCi/L with a mean level of 756 pCi/L. Also, Walia and co-authors (2003) reported that samples from 38 wells in India had a radon range of 8 to 21,384 pCi/L with a minimal average of 103 pCi/L.

Overall, in comparison to the reviewed literature, the results of our study indicate a much greater sample mean (15,776 pCi/L), alterative mean (8,132 pCi/L), and a much greater sample maximum (214,500 pCi/L). In fact, our study found that 15% of the samples were greater than 30,000 pCi/L (Figure 1). Overall, our study yields the highest levels of radon contaminated well water from the reviewed literature and therefore suggests a unique contamination profile in need of environmental mitigation.

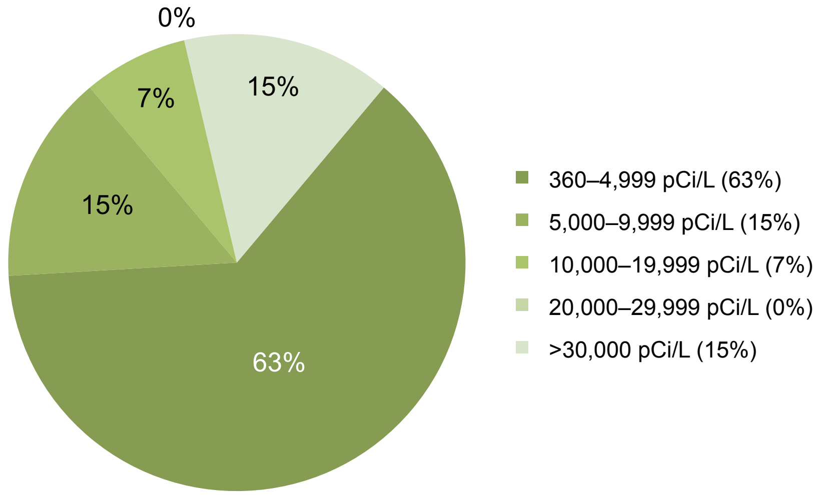
Potential Health Risks

Because radon is completely soluble in water, high concentrations of radon can accumulate in well water and pose a potential health risk for people who use this water as a drinking source (Al-Zoughool & Krewski, 2009; Cothern & Rebers, 1990; Cothern & Smith, 1987; Graves, 1987; NRC, 1999a; Senior, 1998). In a study conducted by Kendall and Smith (2002), it was estimated that 90% of the ingested dose of radon is delivered directly to the stomach tissue. In relation to the literature, the results of this study would then suggest that from the sample mean of 15,776 pCi/L, this study population would experience on average a 14,198 pCi/L dose of radiation delivered directly to the stomach tissue, and with the alternative mean, a 7,319 pCi/L dose.

Also noted in the literature, radon-contaminated water used for drinking and domestic purposes can contribute to the added indoor air radon concentrations within the home (Collman et al., 1991; Cothern & Smith, 1987; Graves, 1987; NRC, 1999a; Prichard, 1987). It has been estimated that in North America, it can be assumed that an increment of 1 pCi/L of radon gas will be released into the air for every 10,000 pCi/L measured in water (U.S. EPA recommends a level below 4 pCi/L in air) (Collman et al., 1991; Cothern & Smith, 1987; NRC, 1999a, 1999b; Prichard, 1987; U.S. EPA, 2011a). In comparing the current study results to literature, it can then be assumed that from the average radon level found in this rural Colorado mountain community (15,776 pCi/L), study residents could see on average a 1.6 pCi/L rise in indoor radon concentrations, and a 0.81 rise when compared to the alternative mean (8,132 pCi/L). In comparison to the sample maximum of this study (214,500 pCi/L), this would then contribute to a 21 pCi/L increase of radon within the home, which would immediately place the home at more than five times the U.S. EPA–recommended radon action limit of 4 pCi/L. In examining the second highest radon level in this study at 46,000 pCi/L, this would still place the home immediately over the U.S. EPA–recommended radon action limit of 4 pCi/L with an indoor air level of 4.6 pCi/L.

FIGURE **1**

Radon Sample Distribution



pCi/L = picocuries per liter.

Remediation Recommendations

In relation to the study data and reviewed literature, it would be recommended that residents of this community establish radon water mitigation safeguards to bring their radon levels below the MCL of 300 pCi/L to protect themselves from the future added effects of excess radiation exposure (NRC, 1999a, 1999b; U.S. EPA, 2011c). If levels cannot be mitigated below this level, it would then be recommended that the homeowners seek an alternative drinking water source (NRC, 1999b). Mitigation of radon-contaminated water is typically completed in one of two ways. The most commonly used method is aeration devices that are installed before the water is distributed to the faucets. These devices bubble air through the water to agitate and release the radon, which is then collected and carried out into the atmosphere through an exhaust fan and pipe (NRC, 1999a, 1999b; U.S. EPA, 2011c). The other method, which is less commonly used, is a granular-activated carbon filter installed to remove radon from the water. These filters tend to cost less than aeration devices; however, as radon collects on the filter, it can become radioactive, proving difficult to safely and legally dispose of (NRC, 1999a, 1999b; U.S. EPA, 2011c).

Conclusion

In conclusion, our study offers value in beginning to understand the implications and presence of radon-contaminated drinking water in private wells. It adds substantial evidence to the reviewed literature suggesting that radon-contaminated drinking water from private wells is a significant public health issue and that residents who use private wells may be at an increased risk for radiation exposure and future cancer development (Al-Zoughool & Krewski, 2009; Catelinois et al., 2006; Mose et al., 2001; Pachocki et al., 2002; Villalba et al., 2005).

Acknowledgements: This study was made possible with the help and guidance of several individuals. Special thanks are given to Dr. Aimee Ferraro, Dr. Aaron Mendelsohn, and Dr. Angela Prehn.

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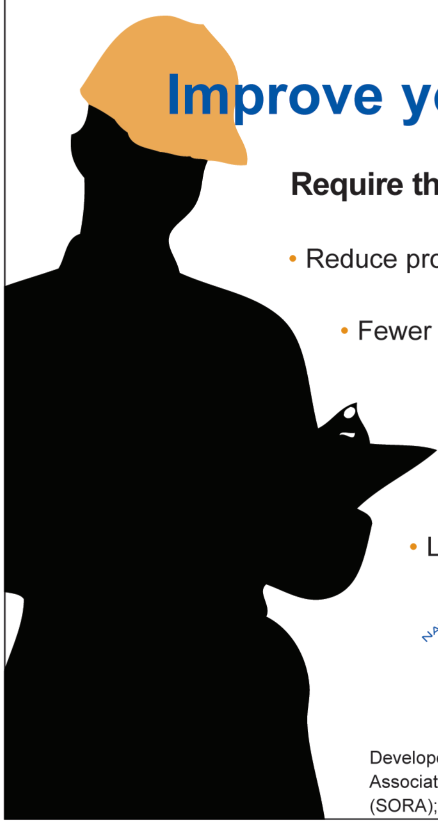

The Efficacy of a Theory-Based, Participatory Recycling Intervention on a College Campus

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Abstract **Recycling solid waste is an important primary prevention focus to protect environmental resources and human health. Recycling reduces energy consumption and emissions and the need to harvest raw material, which protects air, water, and land. In the study described in this article, the authors conducted an eight week field study to test the efficacy of an intervention aimed to increase can and bottle recycling on a college campus. Recycling volume was assessed in three campus buildings (two treatments and one control) over eight weeks. The control building had standard outdoor-only recycling. The treatment buildings had standard outdoor recycling plus four weeks with the treatment indoor recycling. Total can and bottle recycling volume increased 65%–250% in the treatment buildings compared to the control building. Recycling significantly increased in both the classroom (t = -2.9, p < .05) and administrative (t = -12.4, p < .001) treatment buildings compared to the control building (t = -.13, p = .91). Results suggest that convenience of receptacles alone, without education or additional promotion, resulted in significantly more recycling. Health promoters should prioritize efforts to make recycling easy and convenient.**

Introduction

Protecting the environment is increasingly recognized as a centerpiece of public health in the U.S. and around the world (McMichael, Butler, & Folke, 2003). Environmental resources such as soil, water, air, and biodiversity provide the building blocks necessary for human health. As environmental consumption increases and consequences of climate change exacerbate, consensus is growing that public health action is needed to protect environmental resources necessary for human health (Costello et al., 2009; McMichael, Butler, & Folke, 2003; McMichael et al., 2003; Patz et al., 2000).

Howard Frumkin, a past director of the National Center for Environmental Health/Agency for Toxic Substances and Disease Registry at the Centers for Disease Control and Prevention and current dean of the School of Public Health at University of Washington, and Anthony McMichael wrote (2008), "Health professionals should motivate people toward both appropriate personal behaviors and collective decisions that will protect health from the effects of climate change (p. 405)." This recent call for primary prevention action calls on health promoters to utilize behavior change theory and evidence to guide health behavior change efforts related to environmental issues (Frumkin, Hess, Luber, Malilay, & McGeehin, 2008; Howze, Baldwin, & Kegler, 2004; Largo-Wight, 2011). Environmental health efforts that involve changing human behavior should utilize health education and health promotion theories and approaches.

"Environmental health promotion" is a term representing an emerging and needed collaboration between environmental health and health education and health promotion. Environmental health promotion is the bridge between environmental health and health education (Howze et al., 2004); it is the application of preventative health approaches and behavior change theories to environmental problems. This collaboration enables two critical public health goals to be addressed—*promoting* the environment for the health of the public and *protecting* the environment for the health of the public. *Promoting* the environment involves cultivating and creating healthy places and communities that foster health outcomes among residents. *Protecting* the environment involves both strategies for development and conservation that foster and protect the health of the environment and its residents. Thus, the promotion of "environmental" health behaviors, such as recycling, to protect the environment and Earth's resources necessary for human life and health are important (Largo-Wight, 2011).

Recycling and College Campuses

An environmental health behavior that needs immediate attention is recycling solid waste (Castro, Garrido, Reis, & Menezes, 2009). Recycling solid waste protects the environment and natural resources and therefore protects and promotes the health of the public (Frumkin, Hess, Luber, Malilay, & McGeehin, 2008). Recycling is healthful in that it reduces the emissions related to waste disposal, reduces the need to harvest raw material for production of new goods, and reduces energy consumption related to production of new materials (Lansana, 1992; U.S. Environmental Protection Agency [U.S. EPA], 2013). For example, Americans recycled about 33% of total municipal solid waste in 2009, which is equivalent to saving almost 225 million barrels of oil (U.S. EPA, 2009). Despite the healthier land, air, and water-related benefits of waste recycling, recycling behavior still needs public health attention. Approximately 90% of the waste generated in the U.S. could be recycled, but Americans are recycling only about 30% of their trash (Castro et al., 2009). In a call to action, *Healthy People 2020: Improving the Health of Americans* prioritized the need to increase recycling in the U.S. over the next 10 years. Objective EH-12 aimed to increase municipal waste recycling behavior by 10% (Office of Disease Prevention and Health Promotion, 2011).

Schools and college campuses represent a recycling intervention priority worldwide because of the potential for colleges and universities to contribute to a community's waste stream and impact environmental-related human health (American College Health Association, 2002; Ana et al., 2011; Creighton, 1998; Largo-Wight, Bian, & Lange, 2012). In recognition of the impact colleges and universities have on their communities, most higher education campuses in the U.S. provide recycling opportunities through the availability of basic recycling infrastructure on campus (Mason, Brooking, Oberender, Harford, & Horsley, 2003). Public universities' recycling rates should be improved, however. Previous studies concluded that campus recycling rates are similar to the national household and municipal recycling statistics in the U.S.; only about one-third of recyclable waste is diverted from the landfills and recovered for recycling (Chase, Dominick, Trepal, Bailey, & Friedman, 2009). Intervention studies have shown that campus recycling can be increased with effective campaigns. Previous findings have shown that multifaceted campaigns that involved increasing recycling convenience along with various education, awareness, and communication strategies increased recycling on campus (e.g., Chase et al., 2009).

Behavior Change Theory

Health behavior theories are used to guide evidenced-based behavior change programs. Theories are practical tools, based on aggregate behavioral research findings, that target the determinants of behavior change to guide study and primary prevention intervention (Glanz, Rimer, & Lewis, 2002). The Theory of Reasoned Action and Planned Behavior (TPB) is commonly used to study recycling behavior (Valle, Rebelo, Reis, & Menezes, 2005). TPB assumes that *behavioral intention*, one's commitment to act, is the strongest predictor of behavior. *Perceived behavioral control, attitude toward behavior*, and *subjective norm* are the theory's direct constructs that inform behavioral intention. Programs and interventions that are guided by TPB should involve enhancing the theory's constructs in order to facilitate behavioral intention and ultimately behavior change (Glanz et al., 2002). Essentially, health promoters using TPB to guide behavior change programs should strive for participants to assess the desired behavior as good (*attitude toward behavior*), cool (*subjective norm*), and easy (*perceived behavioral control*).

Cross-sectional findings suggest that one of TPB's constructs, *perceived behavioral control,* was a particularly strong predictor of recycling behavior (Chase et al., 2009; Chu & Chui, 2003; Kelly, Mason, Leiss, & Ganesh, 2006; Largo-Wight et al., 2012; Terry, Hogg, & White, 1999; Valle et al., 2005). In fact, *perceived behavioral control* was the single strongest predictor of recycling intention across several studies (Chase et al., 2009; Chu & Chui, 2003; Kelly et al., 2006; Terry et al., 1999). TPB's *perceived behavioral control* to recycle is similar to what some researchers call "situational factors" or "external facilitators" to recycle, which have also been shown to be an important predictor of recycling behavior (Hornick, Cherian, Madansky, & Narayana, 1995; Shultz, 2002; Stern, 2000).

Based on TPB's assumptions, *perceived behavioral control* is comprised of "self-efficacy" and "external factors" that influence the adoption of a health behavior. Thus, a behavior change program aimed to increase recycling based on TPB's *perceived behavioral control* construct should enhance self-efficacy or one's confidence in his/her ability to recycle and/or external or situational factors to recycle (convenience of receptacles on campus) (Glanz et al., 2002; National Cancer Institute [NCI], 2005; Valle et al., 2005).

Purpose

In our pilot study, we developed and tested an intervention program aimed to increase *perceived behavioral control* to recycle and ultimately recycling behavior through external factors only. We developed and tested an intervention program aimed to increase the convenience of recycling receptacles on a university campus. Specifically, we tested the efficacy of a can and bottle recycling intervention aimed to increase external factors of *perceived behavioral control* and ultimately recycling behavior as measured by recycling volume by adding more convenient and easy opportunities to recycle.

Methods

Design and Intervention

Our quasi-experimental pilot field study took place at a large southeastern university over eight-weeks. The study was designed to test the efficacy of a can and bottle recycling intervention on a college campus. This community-based participatory research (CBPR) study involved academic and community partners who collaborated to design the study and collect the data (Braun et al., 2012; Wallerstein & Duran, 2010). University custodial, grounds, and administrative staff as well as student volunteers participated in the study's conception, implementation, and data collections.

Three campus buildings were used in our study: two treatment buildings and one control building. The control building was a classroom building that maintained the university's standard recycling program. The university's standard can and bottle recycling program consisted of the presence and maintenance of outdoor recycling receptacles for cans and bottles. The outdoor recycling receptacles were large and located near the entrance of campus buildings. No indoor recycling receptacles were in the control building or on campus.

The two treatment buildings were of similar square footage to the control building. One treatment building was an administrative building that housed office and administrative staff. The other treatment building was a classroom building, like the control building, that had classrooms utilized for course meetings daily. The treatment buildings, like the control building, also had the university's standard outdoor recycling receptacles as well as our study's recycling intervention, the addition of indoor recycling receptacles for can and bottle recycling. The indoor recycling receptacles were married with the existing trash cans in each classroom, hallway, and office. The intervention consisted of the addition of indoor receptacles only; no education or promotion efforts were conducted.

For the entirety of the eight week study, the control building offered only one recycling option: outdoor recycling receptacles. In the treatment buildings, the recycling options varied. During the first four weeks of the study, only outdoor recycling receptacles were available in the two treatment buildings. This four week period was used to establish baseline data. During the second four weeks of the study, both indoor and outdoor recycling receptacles were available in the two treatment buildings.

Data Collections

Data collections involved measuring the can and bottle recyclable volume from the study's campus buildings for eight weeks. The unit of analysis was the buildings rather than the individual. No human participants were involved in our study.

Data were collected from the treatment buildings' outdoor receptacles for eight weeks total. Treatment buildings' outdoor data were collected for four weeks during the baseline data collection period and for four weeks during the treatment condition period. The treatment buildings' indoor data were also collected during the treatment condition period. Data were collected from the control building's outdoor receptacle for four weeks total: two weeks during the baseline data collection period and two weeks during the treatment condition period (Table 1).

TABLE **1**

Ordinal Recycling Volume Measurement

Measurement	Recycling Data Form							
Ordinal data	1	2	3	4	*5*	*6*	*7*	*8*
Capacity full	0%–25%	26%–50%	51%–75%	76%–100%	*101%–125%*	*126%–150%*	*151%–175%*	*176%–200%*

Note. Italicized ordinal 5–8 were used by the researchers to normalize weekly data when a receptacle needed to be emptied twice in a week.

Outdoor recycling data were measured by university grounds staff. When collecting the recyclables from the outdoor receptacles, the grounds staff indicated the receptacle's fullness of cans and bottles as a percentage. The grounds staff completed the "recycling data form" by choosing one of four ordinal options to best represent the receptacle's can and bottle volume. The data form measured the weekly volume with short ordinal scales with natural order categories or ordered levels. The form's natural order or categories or levels were 0%–25% full, 26%–50% full, 51%–75% full, and 76%–100% full. Additional natural order categories of fullness were added during data analysis to normalize the data to represent total volume by week. The natural order percentage form options were converted to ordinal numbers for data analysis (Table 1).

The intervention data collections were collected by an administrative staff and trained students. The indoor recycling receptacles were smaller than the outdoor receptacles. To maintain consistent data collection methods, the contents from indoor receptacles were transferred into a bag used in the outdoor receptacles prior to volume estimation.

Results

The normalized data are presented in Table 2. When indoor recycling opportunities were made available, total recycling volume increased in the treatment classroom and administrative buildings by 65% and 250%, respectively. An independent samples t-test revealed that the total building recycling volume significantly increased in both of the treatment buildings and did not change in the control building. The recycling volume in the treatment classroom building ($t = -2.9$, $p < .05$) and treatment administrative building ($t = -12.4$, $p < .001$) had a significant increase in recycling from the baseline to the posttest. No significant increase in recycling volume in the control building occurred ($t = -.13$, $p = .91$).

Discussion

The findings from our pilot field intervention study support previous cross-sectional findings on the importance of TPB's *perceived behavioral control* construct for increasing recycling behavior (Chase et al., 2009; Chu & Chui, 2003; Kelly et al., 2006; Largo-Wight et al., 2012; Terry et al., 1999; Valle et al., 2005). In our study, the increase in the external factor to recycle—added recycling bins for behavioral ease and convenience—resulted in significant increases in can and bottle recycling behavior in both treatment buildings compared to the control building.

Prior to our study, a concern was that adding receptacles would result in a less efficient recycling program. The concern was that adding recycling receptacles without education or promotion would not increase recycling behavior, but instead would result in a distribution of the recycling volume among the many receptacles, adding to university staff workload. This did not happen. The findings of our pilot study demonstrate that the volume of recycling significantly increased as a result of the increase of receptacles alone. And the increase was dramatic: the total volume increased by 130% when indoor recycling receptacles were made available.

Our intervention study had many strengths. Our study was grounded in the emerging field of environmental health promotion and guided by behavior change theory with impor-

TABLE 2

Normalized Ordinal Recycling Volume

Buildings	Baseline Period				Treatment Period			
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Treatment *Administration*	**1.8**	**2.8**	**2.8**	**3.1**	**1.5** 7.0[i]	**3.5** 7.0[i]	**3.0** 6.0[i]	**2.8** 6.0[i]
Treatment *Classroom*	**7.0**	**5.6**	**4.2**	**3.0**	**4.0** 7.0[i]	**3.1** 4.0[i]	**3.1** 3.0[i]	**5.6** 3.0[i]
Control *Classroom*	–	**3.0**	**3.0**	–	–	**3.0**	–	**3.0**

Note. **Bold** denotes outdoor data; [i] = indoor data and treatment condition.

tant public health application (Frumkin & McMichael, 2008; Largo-Wight, 2011). Our study effectively utilized social and behavioral public health theories and approaches to address a critical environmental need. In addition, the intervention was simple and practical. Simply adding convenient recycling receptacles, without education or promotional efforts, dramatically increased recycling behavior and volume. Evidenced-based simple and practical solutions are public health's "best buys" (Brownson, Fielding, & Maylahn, 2009; Hawe, Shiell, & Riley, 2004). This pilot study identified a "best buy" for increasing recycling behavior—add receptacles to make recycling easy and convenient. Based on the findings of this field study and past cross-sectional findings, environmental heath promoters should strive to make recycling convenient and easy first and this should be the priority over other more complex behavioral and educational strategies.

Limitations and Future Research

The primary limitation of our pilot study was the lack of experimental control as a result of the CBPR approach. In this study, like all CBPR studies, academic and community partners collaborated to design the study and collect the data (Braun et al., 2012; Wallerstein & Duran, 2010). In our study, grounds staff measured outdoor recycling volume during routine waste disposal. Recording the recycling volume for our study was added workload for the staff and required collaboration, approval, and flexibility from both partners. Although the lack of experimental control during the data collections is a noted weakness, the CBPR approach is also a strength of this study. In fact, CBPR field design and community partner involvement bridge research and practice and enhance the relevance of the findings to best inform policy and decision making (Braun et al., 2012; Wallerstein & Duran, 2010).

A second and related weakness was the level of measurement. The data collected in this study were ordinal as opposed to continuous. A data collection form was used to measure ordinal level data with short order natural form categories or ordered levels (ordered percentage full). In this study, the level of data is a minor limitation because the data collection methods were the most precise measure of the data (Agresti, 1996; Shavelson, 1996) given the CBPR design. In addition, ordinal and even lower-order dichotomous data are common in health-related research studies. In fact, many times continuous data are effectively dicotomitized into categorical or ordinal data for ease of data collection (Agresti, 2010) in CBPR health research (e.g., Chobanian et al., 2003), as was done in our study.

If feasible, future replication studies should collect continuous data by counting recycled items. This would provide continuous data and account for the size of recycled cans and bottles and crushed items. If such data collections prove infeasible due to the enormous effort and labor that would be needed, however, future researchers should consider height-volume estimations, similar to the data collection form used in our study, with the noted confidence in ordinal data with ordered levels (Agresti, 2010). And because of the dramatic increase in recycling volume (65%–265%) in our study, it may be less practically important for replication studies to invest in counting items as these precise data collection methods may not significantly add to evidenced-based practice recommendations.

Future field studies may also assess the efficacy of additional conditions, such as educational and social marketing, moral obligation, social norms, and pro-environmental self- identity (e.g., Largo-Wight et al., 2012), to examine the potential benefit, if any, of the additional program investment. Community and other settings should also be included in future research.

Conclusion

Our study focused on promoting recycling behavior in a high-impact waste setting, college campuses (Creighton, 1998; Largo-Wight et al., 2012). Our study's intervention aimed at increasing *perceived behavioral control* to recycle, a theory-based, strong predictor of recycling in previous studies (Chase et al., 2009; Chu & Chui, 2003; Kelly et al., 2006; Largo-Wight et al., 2012; Terry et al., 1999; Valle et al., 2005) among university students and staff. The findings of this pilot suggest that simply pairing recycling receptacles with garbage cans within treatment buildings resulted in a dramatic increase in recycling volume (65%–265%) over the eight week study. This may represent a public health "best-buy" in that the solution was practical and cost-effective with a huge environmental health return on investment (Brownson et al., 2009; Hawe et al., 2004). Environmental heath promoters should prioritize efforts to make recycling easy and convenient above other efforts such as education, health communication, or promotion campaigns.

Acknowledgements: This project could not have been completed without the support of Derrick Bacon, assistant director of the physical plant, and Dale Morris, recycling and solid waste coordinator, at the University of Florida.

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▸ INTERNATIONAL PERSPECTIVES

Investigation of Radon and Heavy Metals in Xuanwei and Fuyuan, High Lung Cancer Incidence Areas in China

Although most of the information presented in the Journal refers to situations within the United States, environmental health and protection know no boundaries. The Journal periodically runs International Perspectives to ensure that issues relevant to our international membership, representing over 30 countries worldwide, are addressed. Our goal is to raise diverse issues of interest to all our readers, irrespective of origin.

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Abstract **Xuanwei and Fuyuan, two counties located in southwest China, are areas with known high lung cancer incidence. Pollution relative to coal combustion, especially serious air pollution generated by burning smoky coals in unvented households, has been thought to be the most predominant cause. Possible inorganic carcinogenic matter including radon in air and arsenic, lead, chromium, cadmium, nickel, and beryllium in water, soil, and coal were sampled and examined to find the current pollution status, distributions, characteristics, and relationships to the lung cancer incidence. The concentrations of mercury in air of Xuanwei and Fuyuan ranged from 1.7 to 205.3 ng/m^3 (indoor), 1.3 to 7.5 ng/m^3 (ambient). No radon concentration exceeded the World Health Organization standard. Results indicated that household stove improvement by changing stoves from unvented to vented obviously alleviated the indoor air pollution of carcinogenic metals. Most of the carcinogenic metals were also found at very low levels in water and soil, which therefore had little influence on human health. Concentrations of these elements at different sites did not vary in any relation to lung cancer incidence. The study described in this article added basic data; the results of the authors' study will be helpful in determining pollution status and to future studies on the etiology of lung cancer.**

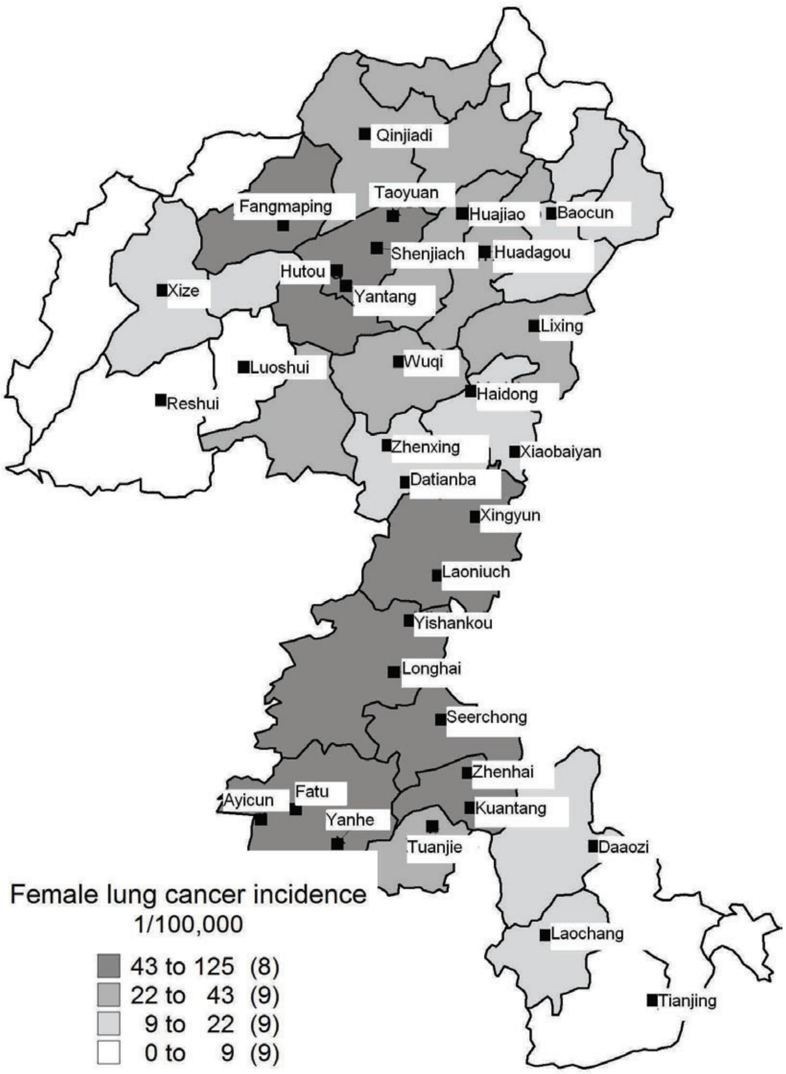
Introduction

Xuanwei and Fuyuan (E 103°35′30″–104°49′48″, N 25°02′38″–26°44′50″) cover around 9,300 km^2 in Yunnan province in southwest China. Xuanwei, with a population of more than 1.4 million people, was found to have unusually high female lung cancer incidence, i.e., eight times the national average for women. It has a lung cancer incidence four times higher than the national average for men as well (Mumford, He, & Chapman, 1987). Lung cancer incidence in Fuyuan, which is adjacent to Xuanwei with a population of more than 700,000 people, is also among the highest in the world (Lu, Ding, & Li, 2003) (Figure 1). Indoor polycyclic aromatic hydrocarbon emission generated by burning smoky coals in unvented households (Figure 2) has been considered the most important cause of the unusual incidence, while other possible carcinogens, e.g., specific trace metals and radon in Xuanwei and Fuyuan, have not been emphasized enough. Their pollution levels, distribution in different communities, and relation to lung cancer have not been studied before.

Many trace metals and metallic compounds are harmful to humans. The International Agency for Research on Cancer (IARC) has classified arsenic and arsenic compounds, cadmium and cadmium compounds, hexavalent chromium, and nickel compounds into Group 1 (carcinogenic to humans); inorganic lead compounds into Group 2A (probably carcinogenic to humans); and many other metals into Group 2B (possibly carcinogenic to humans) (IARC, 2006). Trace metals in water and soil can be accumulated in the human body via the food chain and then distributed to many organs, e.g., liver, kidneys, and lungs by the circulation system, and impact these organs negatively. Trace metals in soil are a significant source of those in

FIGURE **1**

Sampling Sites



air particles, which can be easily transported deep into the respiratory system and become an important cause of lung cancer.

Radon was classified as a Group 1 carcinogen (carcinogenic to humans) in 1987 (IARC, 2006). The isotope ^{222}radon in the atmosphere decays into ^{218}polonium and ^{214}polonium that can emit radioactive α-rays, damage people's respiratory epithelia, and finally lead to lung cancer (Henderson, 1989). Li and co-authors also reported the incidences in Fuyuan were remarkably correlated with the types of local coal used (Li, Tang, & Yin, 2004). The difference in composition of coal in the two communities might be an important cause of different lung cancer incidence. Considering the high lung cancer incidence in Xuanwei and Fuyuan, a survey on radon levels in air and hazardous metal concentrations in soil, water, and coal was performed in our study. Our study will be helpful for a future detailed environmental survey and in exploring the relationship of these substances to lung cancer. To the best of our knowledge, no previous studies have determined the concentrations and distributions of these substances except radon in air in Xuanwei by Deng and co-authors (2001).

Methods

Water and soil samples at 25 sites were collected. Most sites were chosen in communities with high lung cancer incidence to evaluate the current situation of hazardous elements pollution as shown in Figure 1 and the previous study in our lab (Lü et al., 2009). Wude and Diandong, which have the lowest lung cancer incidence and where wood is used as fuel and no industrial pollution sources are nearby, were chosen as reference sites in Xuanwei and Fuyuan, respectively. Sites of radon and mercury in indoor and outdoor air are listed in Table 1. Sites of coal samples were located according to He and co-authors (2012). A total of 18 and 14 coal samples were collected in Xuanwei and Fuyuan, respectively, which represented all four and six coal types, eight and seven main mining regions, and were supplied as main fuel for 14 and 9 communes in the two counties, respectively. Well water is the main drinking water source for the local residents, so all the water samples were collected from wells except Kuaize River. About 1-L water samples were collected using polyethylene (PE) bottles at the surface (0–20 cm) and stored in darkness before transporting and frozen in laboratory. Soil samples (0–10 cm soil layer) were collected from different locations. Each soil sample (about 2 kg) collected with a stainless steel scoop was composed of 20–30 soil samples at different locations in an area of about 10 m x 10 m. Samples were packed in PE bags and transported to the laboratory where they were air dried at room temperature, ground, sieved through a 2 mm sieve, and stored at -20°C before analysis. Coal samples were all collected directly from mines according to the local lifestyle except for Ayicun, a site with very high lung cancer incidence, where coal samples were collected from local farmers' homes. About 5 kg of coal composed of samples the size of 1–30 cm^3 were collected in PE bags, transported to the laboratory, ground until all passed through a 75-µm sieve, and prepared for use.

Radon in air was monitored by RCM-2 online radon analyzer. Mercury in air was monitored by Lumex RA-915+. Both elements were monitored for two or three hours, and we acquired the hourly average concentration. RCM-2 online radon analyzer could monitor radon in air ranging from 1 to 9,999 Bequerels per cubic meter (Bq/m^3) with a detection limit of 0.7 cph/Bq/m^3. The error should be less than 2% in a working period of 200 hours. The detection limit of mercury in air by Lumex RA-915+ was 0.3 ng/m^3. The acquired data were averaged every hour.

Element analysis in water was carried out by direct injection to Agilent 7500 inductively coupled plasma-mass spectrometry (ICP-MS) after the water samples were passed through 0.45-μm filters. A pressure bomb digestion in combination with ICP-MS method modified from Sun and co-authors (2001) was employed in the elemental analysis of soil and coal samples. Briefly, a 0.1-g sample was weighed into the polytetrafluoroethylene pressure bomb and then 1 mL nitric acid, 1 mL hydrogen chloride, and 1 mL hydrogen fluoride were added. The vessels were placed in heating block at 180°C for 10 hours. After cooling down to room temperature, the supernatant was poured out, drawn through a 0.45-μm filter, and diluted to 50 mL with deionized water for ICP-MS analysis. Mercury in oil and coal samples was measured by Braic AF-620 atomic fluorescence spectroscopy (AFS) instead of IPC-MS. The concentrations of heavy metals were calculated by a five-point calibration curve with ICP-MS and AFS in which linearity of all target elements was higher than 0.99. Samples were measured three times. The data were considered acceptable when relative standard deviation was less than 20%. Chinese standard reference material coal fly ash (GBW08401) was employed to monitor the performance of the method. The recovery of mercury was 112.50% and the possible carcinogenic elements were chromium, 77.91%; arsenic, 101.36%; cadmium, 81.25%; and lead, 109.85%.

Results and Discussion

Radon and Mercury

The Agency for Toxic Substances and Disease Registry (ATSDR) has set a minimum risk level for mercury in air at 200 ng/m^3 as the level below which continuous residential exposure is not associated with detectable adverse effects. ATSDR also reported that the general range of values in the U.S. is 2–10 ng/m^3 (Agency for Toxic Substances

FIGURE **2**

Pit Types

A, B, C, without chimney and the vented stoves popularly used now. D, with chimney.

TABLE **1**

Mercury and Radon in the Air in Xuanwei and Fuyuan

County	Sites	Mercury (ng/m^3)		Radon (Bq/m^3)		Lung Cancer Rate
		Indoor	Outdoor	Indoor	Outdoor	
Xuanwei	Urban area	205.3	NA	272.0	NA	184/100,000
	Dalishu	3.3	3.8	71.0	120.0	21/100,000
	Dalishu2	5.6	7.5	NA	82.0	21/100,000
	Xize	NA	4.5	NA	134.0	7/100,000
	Laobao	NA	4.4	NA	112.0	184/100,000
	Mujiatun	NA	6.3	NA	192.0	107/100,000
	Hutou	2.5	4.3	96.0	94.0	107/100,000
	Longhua	NA	2.3	NA	74.0	184/100,000
	Longhua2	NA	1.3	NA	86.0	184/100,000
Fuyuan	Housuo	1.5	5.3	32.0	58.0	98/100,000
	Xingyun	NA	3.0	NA	95.0	98/100,000
	Waihousuo	NA	3.6	NA	62.0	98/100,000
	Duole	30.1	4.0	NA	52.0	115/100,000
	Zhongan	NA	3.5	NA	96.0	115/100,000
	Shenggp	NA	3.4	NA	52.0	115/100,000
	Dahe	10.4	NA	141.0	NA	121/100,000
	Ayicun	2.7	2.3	49.0	186.0	59/100,000
	Dahe2	1.7	3.5	NA	NA	121/100,000

TABLE **2**

Elements in Water of Xuanwei and Fuyuan (µg/L)

Site	Mercury	Beryllium	Chromium	Nickel	Arsenic	Cadmium	Lead
Kuaize	0.08	0.41	1.2	6.26	0.68	3.46	1.27
Diandong	0.09	0.37	0.68	1.15	0.32	0.26	0
Dalishu	0.14	0.37	0.68	0.1	0.29	0.26	0
Duole	0.19	0.37	0.73	0.6	0.98	0.28	0
Shenggp	0.12	0.37	0.44	0	0.22	0.27	0
Gala	0.19	0.37	1.06	1.17	0.35	0.28	0.05
Housuo	0.13	0.37	1.04	1.78	0.43	0.31	0
Hutou	0.11	0.37	1.13	4.77	0.59	0.47	0.47
Xutun	0.11	0.38	0.61	1.46	0.63	0.38	0.11
Longhua	0.11	0.37	0.78	0.92	0.95	0.42	0.28
Longjin	0.09	0.41	1.4	0.49	0.23	0.35	0
Laobao	0.13	0.37	0.58	0.16	0.31	0.31	0
Mafang	0.09	0.39	1.76	0.34	0.38	0.36	0
Laibin	0.11	0.37	1.21	1.66	0.54	0.31	0
Fucun	0.16	0.37	0.46	2.16	0.26	0.27	0
Sege	0.11	0.37	0.47	0.9	0.77	0.28	0
Shenjiach	0.14	0.37	2.63	0.32	0.33	0.32	0
Tianba	0.07	0.4	0.82	1.17	0.25	0.3	0
Ayicun	0.08	0.38	1	0.6	0.26	0.28	0
Xize	0.16	0.37	0.35	0	0.19	0.26	0
Waihousuo	0.14	0.37	0.38	0	0.24	0.26	0
Xincun	0.1	0.37	0.39	0.05	0.3	0.29	0
Xiabz	0.12	0.37	1.01	0.44	0.27	0.26	0
Yangchang	0.12	0.37	0.7	0.14	1.36	0.3	0.82
Daaozi	0.11	0.38	0.77	1.66	0.4	0.28	0

and Disease Registry [ATSDR], 1999). As seen in Table 1, the mercury concentration in indoor air of Xuanwei and Fuyuan ranged from 1.7 to 205.3 ng/m^3. Among nine samples, only one (collected in Chengguan, 205.3 ng/m^3) exceeded the standard of ATSDR, which should be ascribed to pollution from indoor decorations since no indoor coal combustion was observed there. Hutou, Housuo, and Ayicun, three villages with very high lung cancer incidence using smoky coal as the main fuel, had low levels of mercury concentration, which were 2.5, 1.5, and 1.7 ng/m^3, respectively. It seems that indoor coal combustion in the two counties had little relation to mercury pollution. Previous studies have suggested that mercury in coal should almost completely emit to the air when the temperature is higher than 800°C, while the average combustion temperature for the household fire pit is about 900°C for bituminous coal in Xuanwei (Tian, 2005), at which almost all mercury in coal will evaporate to the air. Low mercury concentration in indoor air could be attributed to household stove improvement in recent years, which changed unvented stoves to vented to discharge the smoke outside the house (Lan, Chapman, Schreinemachers, Tian, & He, 2002). The same situation could occur in other carcinogenic metals. No obvious mercury pollution was observed in ambient air, either. Concentrations of 16 samples ranged 1.3–7.5 ng/m^3, which might be attributed to the rapid cooling, condensing, and deposition of mercury on its emission from chimneys.

The maximum indoor radon level recommended by the World Health Organization (WHO) and U.S. Environmental Protection Agency (U.S. EPA) is 200 Bq/m^3 and 150 Bq/m^3, respectively. Among six samples, only one exceeded the WHO or U.S. EPA standard, which was collected from a hotel in Chengguan with high lung cancer incidence. Indoor decorations should account for the indoor radon pollution at this site. Detailed research had performed a more comprehensive survey and proven that indoor radon pollution had no significant relation to the incidence of lung cancer in Xuanwei and Fuyuan (Deng et al., 2001), so outdoor radon pollution was focused on in our study. Radon concentration varied greatly even within the same district. No radon pollution in ambient air in general was observed. Only concentrations at two of the total 15 sites exceeded the U.S. EPA standard and none exceeded the WHO standard. In some villages, e.g., Ayicun, radon concentration and lung cancer rate were found very high simultaneously. Concentrations turned out to be relatively low, however, in some villages with known high lung cancer incidence, e.g., Hutou, Xingyun, Duole. Wude, with the lowest rate in Xuanwei, was found with the second highest radon concentration. This result indicates that no significant relation existed between radon in ambient air and lung cancer.

Elements in Water and Soil

Table 2 lists the distribution of several hazardous elements relative to lung cancer in the water from Xuanwei and Fuyuan. Concentration of mercury in water ranged 0.07–0.19 µg/L with average value 0.12 µg/L. Beryllium ranged 0.37–0.41 µg/L, 0.38 µg/L on average; chromium ranged 0.35–2.63 µg/L, 0.89 µg/L on average; nickel ranged 0–6.26 µg/L, 1.13 µg/L on average; arsenic ranged 0.19–1.36 µg/L, 0.46 µg/L on average; cadmium ranged 0.26–3.46 µg/L, 0.43 µg/L on average; and lead ranged 0–1.27 µg/L, 0.12 µg/L on average. WHO guideline values for mercury that are of health significance in drinking water are 6 µg/L; chromium, 50 µg/L; nickel, 70 µg/L; arsenic, 10 µg/L; cadmium, 3 µg/L; lead, 10 µg/L; and beryllium has not been regulated yet (World Health Organization [WHO], 2004). Water samples from 24 sites were all drinking water and the sample at Kuaize was from the largest river in Fuyuan. The concentrations of these hazardous elements were less than the guidelines of WHO, which indicated that all drinking water samples could be classified as having no significant influence on human health. The concentration of mercury, beryllium, cadmium, and lead varied slightly among the samples at different sites. No significant relationship between all seven metal concentrations and the lung cancer incidence occurred.

Distribution of six elements in soil relative to cancer is illustrated in Table 3. The concentration ranges and principle component analysis (PCA) are summarized in Table 4. The concentrations of beryllium and cadmium varied slightly at different sites, while arsenic, chromium, lead, and nickel varied greatly. They were all far less than the Chinese national standard for heavy metals in arable soil and had no significant influence on human health except cadmium (GB 15618, 1995). Cadmium was the only element that exceeded this standard. Fourteen samples of 25 were slightly higher than 0.3 µg/g with the average value of 0.37 µg/g. Cadmium was also proven to have no relation to local lung cancer, however. For example, in Ayicun and Hutou with known extremely high lung cancer incidence, cadmium concentration in soil was 0.19 and 0.57 µg/g, respectively, while in Wude, the reference site in Xuanwei with the lowest lung cancer incidence, cadmium concentration was 0.31 µg/g. No positive or negative relationship between cadmium concentration and lung cancer rate was found at these three sites.

The results of the PCA indicated that these six metal concentrations could be reduced to two principle components, which accounted for 92.2% of the total variance for the data (Table 4). All six elements were well represented by two principle components. The first principle component (PC1) can explain 72.9% of the total variance and the second (PC2) explained 17.3%. PC1 had significant correlations with beryllium, cadmium, lead, arsenic, and nickel. PC2 had a significant correlation with chromium. Beryllium, cadmium, lead, and arsenic were negatively correlated with PC2. Nickel and chromium were distributed in both PC1 and PC2. The loading value of nickel in PC1 was much higher than in PC2 while chromium was just the reverse. This implies that some of the beryllium, cadmium, lead, arsenic, and nickel in the soils may originate from similar pollution sources and chromium and nickel may have another similar source.

TABLE **3**

Elements in Soil of Xuanwei and Fuyuan (µg/g)

Site	Beryllium	Chromium	Arsenic	Cadmium	Lead	Nickel
Yangchang	0.18	9.4	3.59	0.3	18.58	8.81
Mujiatun	0.19	14.41	1.65	0.46	4.9	10.79
Longhua	0.25	13.76	3.21	0.55	7.74	8.21
Sege	0.22	14.8	2.54	0.46	6.84	9.34
Seerchong	0.19	18.54	2.75	0.26	7.45	9.09
Duole	0.22	12.7	1.83	0.21	4.85	9.58
Xingyun	0.32	22.42	0.86	0.27	3.04	12.88
Ayicun	0.27	12.54	0.79	0.19	2.91	9.29
Gala	0.15	21.03	1.69	0.28	7.98	7.96
Longjin	0.2	13.92	3.81	0.48	24.27	7.86
Dawayao	0.32	17.17	2.54	0.32	7.42	10.17
Xincun	0.18	17.32	2.05	0.29	8.54	8.01
Dahe	0.24	18.89	1.3	0.25	4.19	9.84
Waihousuo	0.21	26.15	0.72	0.12	4.58	10.71
Wude	0.16	10.98	1.73	0.31	9.03	8.68
Shenjiach	0.2	39.3	0.79	0.33	6.94	14.01
Shenggp	0.17	15.37	1.2	0.22	4.61	10.14
Diandong	0.29	9.45	6.05	0.24	4.73	6.69
Tianba	0.24	21.69	2.34	0.33	13.26	10.31
Mafang	0.7	41.24	9.17	1.38	74.84	35.71
Laobao	0.15	12.23	1.11	0.43	8.62	11.05
Dalishu	0.18	10.48	1.46	0.34	6.76	6.02
Xutun	0.21	42.04	0.74	0.43	4.58	14.07
Housuo	0.27	20.55	1.24	0.19	8.36	13.43
Hutou	0.27	27.94	0.81	0.57	8.64	14.76

TABLE **4**

Concentration and Principle Component (PC) Analysis of Elements in Soil (µg/g)

Element	PC1 (72.9%)	PC2 (17.3%)	Min	Max	Average	Standard
Beryllium	0.92	-0.04	0.15	0.70	0.24	N.R.
Chromium	0.58	0.78	9.40	42.04	19.37	150
Arsenic	0.77	-0.56	0.72	9.17	2.24	40
Cadmium	0.92	-0.07	0.12	1.38	0.37	0.3
Lead	0.94	-0.19	2.91	74.84	10.55	250
Nickel	0.94	0.28	6.02	35.71	11.10	40

Elements in Coals

Mumford and He suggested an etiologic link between lung cancer incidence and domestic smoky (bituminous) coal burning (Mumford et al., 1987). The same trend was observed in Fuyuan. Six kinds of coal were in Fuyuan and lung cancer incidence varied greatly among the areas using different types of coal. From north to south, gas-fat coals, coking coals, 1/3 coking coals, lean coals, meager coals, and anthracite coals were mined in large amount separately. From Figure 1 and He (He et al.,

TABLE **5**

Elements in Coal Samples (µg/g)

Site	Lead	Cadmium	Chromium	Arsenic	Beryllium	Nickel
Lixing	17.2	1.12	12.31	46.13	1.04	21.8
Taoyuan	26.99	1.88	9.93	93.66	6.67	34.32
Wuqi	17.78	0.68	9.06	39.35	1.45	32.27
Xingyun	7.95	2.82	16.32	90.22	0.56	14.21
Ayicun	16.27	1.88	11.13	176.49	1.53	20.19
Kuantang	12.91	2.54	10.51	109.63	0.89	33.53
Fatu	20.31	4.14	21.49	284.68	1.7	12.04
Datianba	9.14	0.27	3.72	35.9	1.02	13.31
Shenjch	8.16	2.24	18.98	144.99	0.45	14.89
Reshui	25.84	0.59	1.5	128.81	0.24	17
Huajiao	15.47	0.95	6.55	138.73	1	26.84
Yishankou	10.36	2.18	15.65	135.74	0.86	31.3
Yanhe	23.1	3.44	20.95	101.25	1.38	26.05
Tuanjie	16.34	3.49	6.92	136.61	0.75	15.35
Laochang	26.03	1.01	0.61	111.95	0.17	19.84
Zhenhai	12.84	2.79	17.79	90.28	1.19	32.18
Xiaobaiyan	17.43	2.01	18.01	42.55	0.96	23.24
Daaozi	12.36	2.1	20.52	100.48	0.8	12.01
Huadagou	31.7	0.74	1.22	122.45	0.15	13.12
Luoshui	84.11	1.69	4.6	136.61	0.38	31.99
Haidong	16.2	1.6	7.24	109.44	1.19	25.95
Yantang	11.89	2.29	8.62	51.34	1.29	22.96
Xize	32.09	1.92	22.39	152.5	0.86	7.7
Tianjing	8.63	1.31	2.59	143.16	0.31	5.98
Longhai	7.8	1.51	7.16	45.98	0.5	14.8
Mixed	6.44	1.19	5.06	103.95	0.23	7.08
Zhenxing	27.9	1.85	13.02	51	2.13	71.76
Qijiadi	19.81	4.66	8.43	64.75	1.26	28.95
Baocun	11.46	1.99	11.35	62.45	0.76	27.29
Fangmaping	30.67	1.77	21.11	43.25	1.88	29.28
Hutou	14.4	1.58	9.76	58.42	0.42	13.85
Laoniuchang	13.21	1.26	7.84	44.88	0.94	15.89
Seerchong	11.36	1.46	13.39	56.29	1.03	21.47

2012), lung cancer rate in Fuyuan decreased in the same direction. Carcinogenic elements were examined in different kinds of coals to explore the potential cause of local lung cancer. Two main ways exist for the inorganic carcinogens to penetrate the human respiratory system in coal burning. For the carcinogens with lower boiling points, e.g., mercury and arsenic, evaporation may be the predominant way. For carcinogens with higher boiling points, e.g., lead, chromium, nickel, and cadmium, they may be condensed in particle matters and then transported to the respiratory system in emission stream. Coal burning temperature is the most important factor among its multiple properties that may influence the emission of inorganic matters (Xu et al., 2003). Average arsenic concentration at five sites of anthracite (Laochang, Reshui, Luoshui, Xize, and Tianjing) was 134.6 µg/g, which was much higher than the average level of the total 33 (98.6 µg/g). Mercury in five sites of anthracite was 80 µg/g on average, also much higher than the total average level (30 µg/g) in exception of Fatu, the site with abnormal mercury concentration (4,950 µg/g). Fire pits were the most popular burning equipment during the early exposure of residents in both Xuanwei and Fuyuan, and the average combustion temperature for the household fire pit was below 900ºC for bituminous coals (Xian et al., 1994), whereas the flame temperature of the pulverized coal combustion, which was popularly used in the anthracite area in Xuanwei and Fuyuan, was 1,480ºC–1,590ºC (Tillman, 1994). People in the anthracite area therefore suffered more exposure to mercury and arsenic. But, as seen in Figure 1, lung cancer rates in anthracite areas were found all less than 22/100,000, much lower than other areas. Results revealed that arsenic and mercury exposure in coal combustion was not the significant cause to local abnormal lung cancer incidence. As shown in Table 5, people in Haidai would suffer most from cadmium and nickel exposure from air particles, while people in Longtan would suffer most from lead, chromium, and beryllium exposure. But lung cancer incidences in both Haidai (21/100,000) and Longtan (37/100,000) were much lower than that in Laibin (107/100,000). It appeared that beryllium, lead, chromium, cadmium, and nickel exposure though air particles also had no relationship to local lung cancer incidence.

Conclusion

In conclusion, exposure of radon in indoor or outdoor air had no significant relationship to lung cancer in Xuanwei and Fuyuan. Household stove improvement changing the unvented stoves to vented stoves obviously alleviated the indoor air pollution of mercury and many other carcinogenic metals. Most of the carcinogenic metals were at very low levels in water and soil, which therefore had little influence on human health. No relationships between metal pollution (beryllium, arsenic, lead, chromium, cadmium, and nickel) and cancer were observed. Our study was the first to determine these hazardous pollutants in these areas. Excluding these interfering factors from the causes of local lung cancer is necessary and will be helpful to the future etiology and epidemiology studies.

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Mansoor A. Baloch,
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Groundwater Vulnerability Assessments: Prioritizing Water Safety in Times of Austerity

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

In this column, EHSB and guest authors from across CDC will highlight a variety of concerns, opportunities, challenges, and successes that we all share in environmental public health. EHSB's objective is to strengthen the role of state, local, tribal, and national environmental health programs and professionals to anticipate, identify, and respond to adverse environmental exposures and the consequences of these exposures for human health.

The conclusions in this article are those of the author(s) and do not necessarily represent the views of CDC.

Mansoor Baloch is a consultant hydrologist/environmental engineer with the Environmental Health Specialists Network (EHS-Net) Water Program at EHSB. He has more than 10 years of research and program experience in water resources management, water quality, and environmental engineering.

Private Wells—Public Health Risks

For communities using private or unregulated drinking water wells, groundwater vulnerability to microbial contamination poses a significant public health risk. Historically, a significant number of drinking-water-associated waterborne illness outbreaks and contamination events have been attributed to unregulated water systems (Craun & Calderon, 2003; DeSimone, Hamilton, & Gilliom, 2009; Yoder et al., 2008). Although many environmental health programs are required to inspect and test private wells only at the time of permitting (when a new well is constructed or repaired), illnesses and problems associated with these systems constitute a major part of water safety initiatives pursued by these programs.

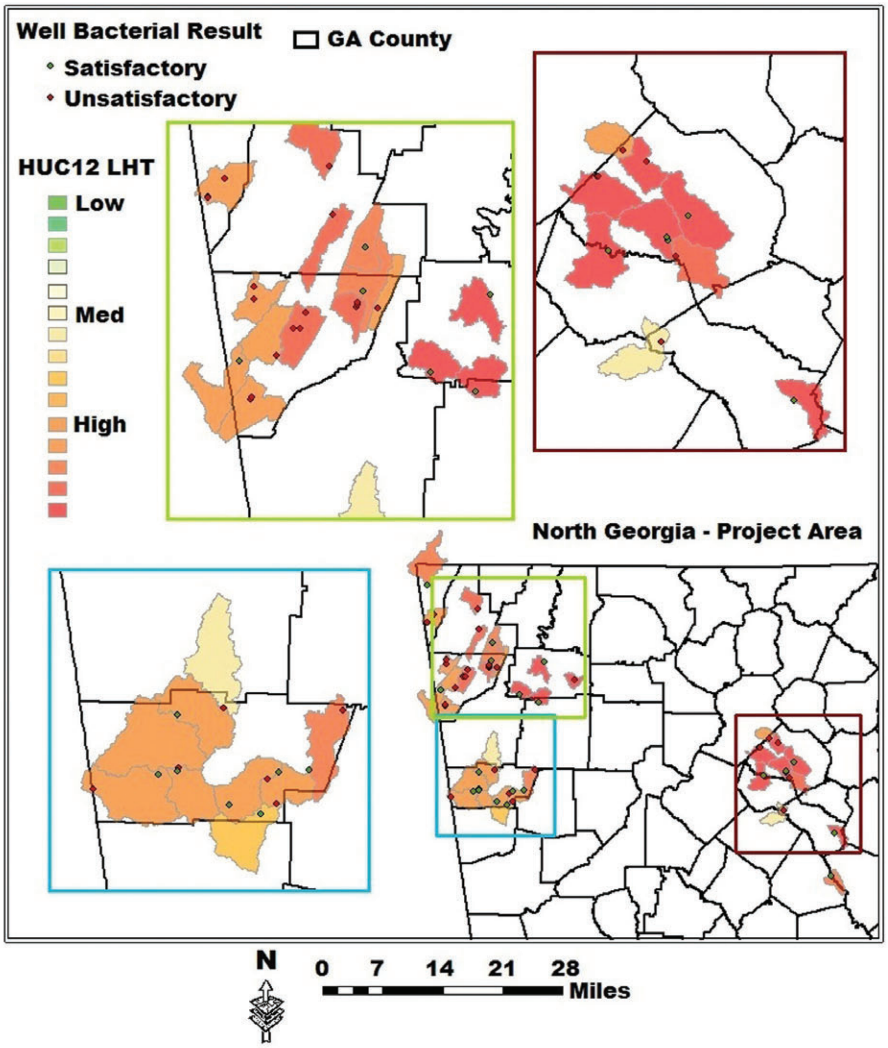
In the wake of government austerity measures, many environmental health permitting programs will curtail services associated with private wells. In its efforts to support local environmental health programs, the Centers for Disease Control and Prevention's Environmental Health Specialists Network (EHS-Net) Water Program has developed a groundwater vulnerability assessment tool, Land-use Hydrology and Topography (LHT), piloted in 18 counties in the state of Georgia to assess the effectiveness of this approach for identifying unregulated wells for prioritized intervention (Baloch & Sahar, 2011). This column presents a case for using a groundwater vulnerability mapping approach to prioritize intervention programs for those private or individual wells most vulnerable to contamination.

Groundwater Vulnerability Assessment Approach

The U.S. Environmental Protection Agency (U.S. EPA) defines a public water system (PWS) as a water system serving a minimum of 15 connections or 25 persons for at least 60 days in a year (U.S. EPA, 2003, 2004). Unlike unregulated or private wells, wells supplying water to PWSs are protected by state wellhead programs (WHPs). These programs provide a localized approach to protection by focusing on the critical surface and subsurface areas surrounding a well connected to the PWS known as wellhead protection areas (WHPAs). This exact approach is not a viable option for unregulated or private wells because identifying and delineating WHPAs for every private well in a jurisdiction is not practical given the large number and sparse locations of these systems. Furthermore, budget cuts across government agencies necessitate sound planning and project prioritization to direct limited funds available for environmental health programs to projects that can have the most positive public health impacts. Elements of the WHPs can be adapted, however, to a groundwater vulnerability approach to help identify, prioritize, and protect private wells in contamination-prone areas.

FIGURE **1**

Land-Use Hydrology Topography (LHT) Model Results Identifying Groundwater Vulnerability to Microbial Contamination in Subwatersheds of Pilot Counties in North Georgia (Baloch & Sahar, 2011)



HUC = hydrologic unit code.

Groundwater vulnerability or susceptibility is a system property that refers to "groundwater sensitivity to contamination and describes the relative tendency or likelihood for contaminants to reach a specified position in the ground water system after introduction at some location above the uppermost aquifer (Ligget & Talwar, 2009; National Research Council, 1993)." A groundwater vulnerability assessment approach may help prioritize groundwater protection measures and direct limited resources to the most vulnerable locations for further investigation, protection, and monitoring. Groundwater vulnerability assessments use a systems theory approach that considers the entire watershed hydrologic system to understand the influences of variability in the watershed conditions and events on the groundwater. This approach can thus identify the root causes leading to contamination of the groundwater system.

With the use of GIS, complex hydrogeological and environmental data are processed to create a single vulnerability map by using an index and overlay method. Such methods are well suited to produce regional scale screening tools for use in decision making and for prioritizing focus areas and site assessments. In a GIS, digital data layers of variables of concern are rated and assigned weights and then combined into a vulnerability score (Rahman, 2008). Based on the score, a given study area is classified into contamination risk categories (e.g., high, medium, and low) depicting the relative vulnerability of groundwater in that region on a simple map (Figure 1). Vulnerability maps are inexpensive to produce, easy to implement, and often use readily available data. Furthermore, a vulnerability map is easy to understand and can be used as a powerful educational tool for raising public awareness about groundwater contamination issues (Ligget & Talwar, 2009).

Summary and Further Information

Groundwater vulnerability assessments provide meaningful tools to identify areas that are more likely than others to become contaminated. Such tools are particularly relevant in the absence of site-specific monitoring and process-based evaluation. With budget reductions, environmental health practitioners can use vulnerability assessment maps to identify areas for prioritized intervention. This information can also be used during water outbreak investigations as an indicator in the environment for possible sources of contamination and may assist in tracing back to identify the source of the outbreak.

EHS-Net Water Program's LHT, a groundwater contamination vulnerability assessment tool, can be replicated and used in other areas of the country. Further details regarding the LHT tool, its input data requirements, and technical support can be obtained by contacting the EHS-Net Water Program at CDC (www.cdc.gov/nceh/ehs/ehsnet/).

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DEMYSTIFYING THE FUTURE

Thomas Frey

By 2030 Over 50% of Colleges Will Collapse: Part 2

Editor's Note: **Significant and fast-paced change is occurring across society in general and our profession in particular. With so much confusion in the air, NEHA is looking for a way to help our profession better understand what the future is likely to look like. The clearer our sense for the future is, the more able we are to both understand and take advantage of trends working their way through virtually every aspect of our lives today. To help us see what these trends are and where they appear to be taking us, NEHA has made arrangements to publish the critical thinking of the highly regarded futurist, Thomas Frey.**

The opinions expressed in this column are solely that of the author and do not in any way reflect the policies and positions of NEHA and the *Journal of Environmental Health*.

Thomas Frey is Google's top-rated futurist speaker and the executive director of the DaVinci Institute®. At the Institute, he has developed original research studies enabling him to speak on unusual topics, translating trends into unique opportunities. Frey continually pushes the envelope of understanding, creating fascinating images of the world to come. His talks on futurist topics have captivated people ranging from high-level government officials to executives in Fortune 500 companies. He has also authored the book *Communicating with the Future*. Frey is a powerful visionary who is revolutionizing our thinking about the future.

Last month's column explored the different metrics impacting the world of higher education: rising costs and student loan backlash, digital-era trends and the demand for online courses, employment statistics, and shifting trends. This month's column will now look at several reasons why some colleges will collapse in the future.

Eight Reasons Why Over 50% of Colleges Will Fail by 2030

So what happens when the legacy power of an institution meets a rapidly changing business environment driven by emerging technology? Some will survive but many will not.

For this reason I've decided to focus in on eight core issues for colleges that will drive a wedge between business-as-usual and the unstoppable forces of change.

1. **Overhead costs too high**—Even if the buildings are paid for and all money-losing athletic programs are dropped, the costs associated with maintaining a college campus are very high. Everything from utilities, to insurance, to phone systems, to security, to maintenance and repair are all expenses that online courses do not have. Some of the less visible expenses involve the bonds and financing instruments used to cover new construction, campus projects, and revenue inconsistencies. The cost of money itself will be a huge factor.
2. **Substandard classes and teachers**—Many of the exact same classes are taught in thousands of classroom simultaneously every semester. The law of averages tells us that 49.9% of these will be below average. Yet any college that is able to electronically pipe in a top 1% teacher will suddenly have a better class than 99% of all other colleges.
3. **Increasingly visible rating systems**—Online rating systems will begin to torpedo tens of thousands of classes and teachers over the coming years. Bad ratings of one teacher and one class will directly affect the overall rating of the institution.
4. **Inconvenience of time and place**—Yes, classrooms help focus our attention and the world runs on deadlines. But our willingness to flex schedules to meet someone else's time and place requirements is shrinking, especially when we have a more convenient option.
5. **Pricing competition**—Students today have many options for taking free courses without credits versus expensive classes with credits and very little in between. That, however, is about to change. Colleges focused primarily on course delivery will be facing an increasingly price-sensitive consumer base.
6. **Credentialing system competition**—Much like a doctor's ability to write prescriptions, a college's ability to grant credits has given them an unusual competitive advantage,

something every startup entrepreneur is searching for. Traditional systems for granting credits, however, only work as long as people still have faith in the system. This "faith in the system" is about to be eroded with competing systems. Companies like Coursera, Udacity, and iTunesU are well positioned to start offering an entirely new credentialing system.

7. **Relationships formed in colleges will be replaced with other relationship-building systems**—Social structures are changing and the value of relationships built in college, while often quite valuable, are equally often overrated. Just as a dating relationship today is far more likely to begin online, business and social relationships in the future will also happen in far different ways.
8. **Sudden realization that "the emperor has no clothes!"**—Education, much like our money supply, is a system built on trust. We are trusting colleges to instill valuable knowledge in our students, and in doing so, create a more valuable workforce and society. But when those who find no tangible value begin to openly proclaim, "the emperor has no clothes!" colleges will find themselves in a hard-to-defend downward spiral.

Ironically, we are entering into a period where the demand for education will rise substantially. Yet traditional colleges are such a mismatch for what future consumers will want that dropping enrollments will cause many to fail.

At the same time many new opportunities will begin to surface, and future learning centers will make use of former college facilities. Some may even resurrect the former institution under an entirely new business model.

Declining Enrollment Scenario

With several new alternative education options arising, many colleges will begin to experience a decline in their enrollment. When revenues run short, the first instinct will be to arrange short-term financing. This, coupled with long-term bonds and other obligations, will create a growing mountain of debt.

As less expensive schools with extensive online capabilities begin to "steal" students, several colleges will engage in a pricing war to "keep their numbers up." Many will spend heavily on marketing to change their image and boost enrollment. Others will spend heavily on lobbyists in hopes of gaining more support from government.

Some will experience declining revenues, others will experience declining enrollment. Most, however, will experience both.

How many colleges that experience a 10% decline in enrollment and/or revenue per year will still be around after five years?

In the business world, declining metrics like this are referred to as a "death spiral." How long will it take before dramatic changes are made? At what point will layoffs begin, assets be sold, or mergers be considered?

For state-supported institutions, at what point will an emergency session of the state legislature be called? If three to five state-supported colleges are all experiencing enrollment/revenue declines at the same time, at what point will the state decide to "walk away" from what they perceive to be a never-ending money pit?

How many colleges or universities will have the ability to reinvent themselves as this is occurring?

Final Thoughts

Imagine coming across a job opening that requires a specific certification you currently don't have. You match up well with all of the other job requirements but you're only missing this one certification.

A few clicks later you find out the certification can happen online with 20 hours of training. So you spend your weekend getting certified.

Yes, a big difference exists between having a cursory understanding of a topic and working level proficiency. But for many of us our future careers will hinge on situations like the scenario I just described.

As a society we've grown complacent, thinking smart people in colleges are doing a good job preparing our kids for the future. Yet higher ed has become a lumbering giant, slow to adapt and increasingly out of sync with the needs of business and society.

The same top-down institutional systems that have preserved colleges for centuries are now becoming their greatest enemy.

Much as failed golf courses, big box retailers, and shopping centers end up in the laps of local communities, failed colleges will also become local problems for city governments to deal with.

Pedestrian campuses that worked well during peak enrollment have a way of becoming white elephants for whatever comes next.

Interested in sharing your thoughts? Go to www.FuturistSpeaker.com.

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Michigan

March 18–21, 2014: 2014 Annual Education Conference, sponsored by the Michigan Environmental Health Association, Big Rapids, MI. For more information, visit www.meha.net.

Texas

December 4–6, 2013: 10th Annual South Texas Chapter Educational Conference, sponsored by the South Texas Chapter of the Texas Environmental Health Association, Isla Grand Beach Resort, South Padre Island, TX. For more information, contact Victor Baldovinos at (956) 761-3226 or tehastc@gmail.com.

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November 18–21, 2013: InFORM 2013: PulseNet, OutbreakNet, and Environmental Health, San Antonio, TX. For more information visit http://www.aphl.org/conferences/InFORM-2013-PulseNet-OutbreakNet-and-Environmental-Health/Pages/default.aspx.

President's Message

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additional information about in-person training opportunities and hundreds of online courses, visit our Web site at www.neha.org. I am proud to share information about our organization and the benefits provided—NEHA is proactive and makes the professional growth of its members a priority. The combined efforts of the NEHA staff, volunteers, stakeholders, and partners have contributed to a workforce that is prepared to respond.

Acknowledgements and special thanks to NEHA staff members Rance Baker, Ginny Coyle, Elizabeth Landeen, and Christl Tate for their contributions to this column and for their excellent work on the training courses and projects summarized.

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Managing Editor's Desk

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the print version of the *Journal*. To update your e-mail address, simply visit neha.org and access your profile through My NEHA. And always, if you need additional assistance with updating your e-mail address, please don't hesitate to pick up the phone and give us a call.

In years to come, I anticipate that our historian (presently Dick Pantages, who serves us so well) will zero in on this article, as this day truly takes the association and our efforts to be of service to you to a whole new level.

Enjoy!

nfabian@neha.org

Did You Know?

NEHA was asked by the Council to Improve Foodborne Outbreak Response (CIFOR) to conduct an assessment of the capacity of local and state agencies to undertake foodborne illness outbreak investigation and response. The summary and detailed results are published in a full report, *Assessment of Foodborne Illness Outbreak Response and Investigation Capacity in U.S. Environmental Health Food Safety Regulatory Programs,* at www.neha.org/pdf/CIFOR_FBIOutbreakCapacityAssessment_ResultsReport_Final.pdf.

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Resource Corner highlights different resources that NEHA has available to meet your education and training needs. These timely resources provide you with information and knowledge to advance your professional development. Visit NEHA's online Bookstore for additional information about these, and many other, pertinent resources!

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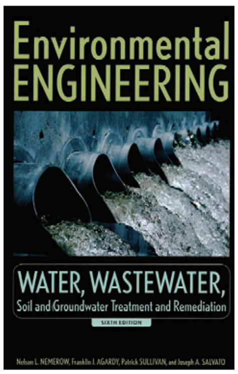
Environmental Engineering: Water, Wastewater, Soil and Groundwater Treatment and Remediation (Sixth Edition)

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

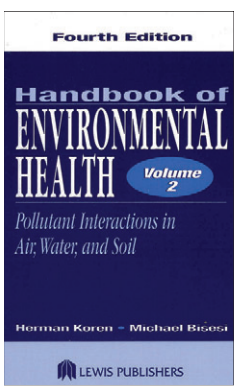


First published in 1958, Salvato's *Environmental Engineering* has long been the definitive reference for generations of sanitation and environmental engineers. This new edition has been completely rewritten by leading experts in the field and offers succinct new case studies, new process and plant design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

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

Handbook of Environmental Health, Volume 2: Pollutant Interactions with Air, Water, and Soil (Fourth Edition)

Herman Koren and Michael Bisesi (2003)

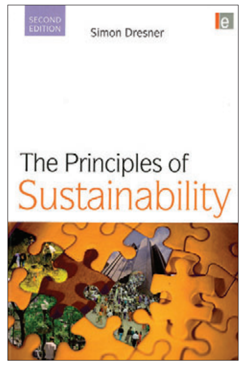


A must for the reference library of anyone with environmental health concerns, this book focuses on factors that are generally associated with the outdoor environment. It was written by experts in the field and copublished with NEHA. A variety of environmental issues are covered, such as toxic air pollutants and air quality control; risk assessment; solid and hazardous waste problems and controls; safe drinking water problems and standards; onsite and public sewage problems and control; plumbing hazards; air, water, and solid waste programs; technology transfer; GIS and mapping; bioterrorism and security; disaster emergency health programs; ocean dumping; and much more. Study reference for NEHA's REHS/RS exam.

876 pages / Hardback / Catalog #215B
Member: $180 / Nonmember: $195

The Principles of Sustainability (Second Edition)

Simon Dresner (2008)

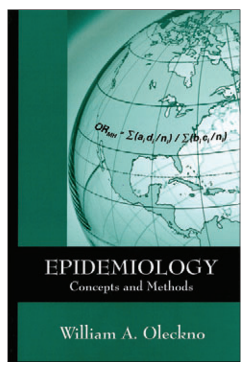


At a time of increasingly rapid environmental deterioration and climate change, sustainability is one of the most important issues facing the world. This edition covers the latest on the climate change front, particularly the advances in scientific understanding and political awareness of climate change. It covers historical development of the concept of sustainability, contemporary debates about how to achieve it, and obstacles and the prospects for overcoming them.

205 pages / Paperback / Catalog # 809
Member: $34 / Nonmember: $37

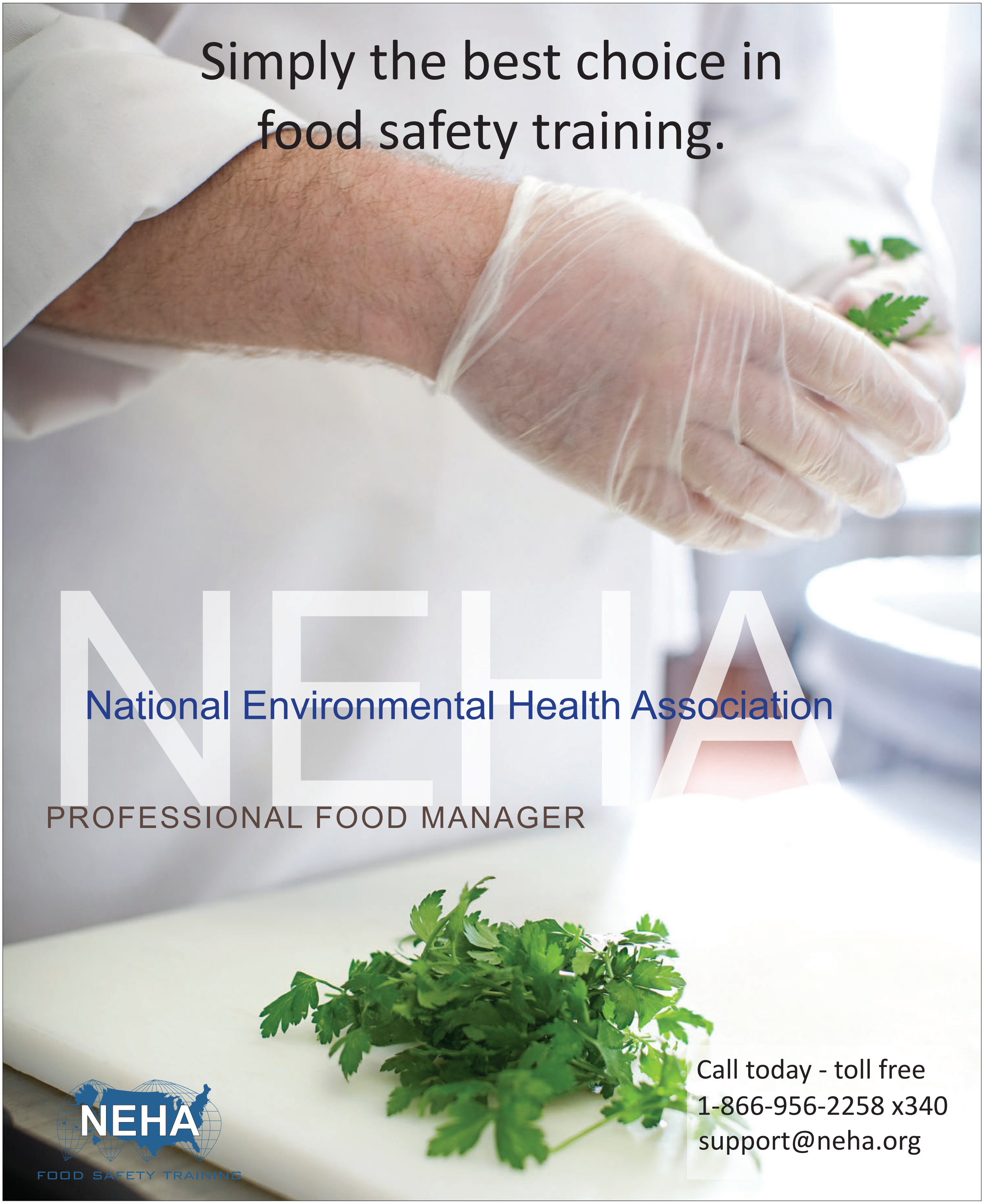
Epidemiology: Concepts and Methods

William A. Oleckno (2008)



Comprehensive in its coverage, this text is a full-scale, pedagogically rich introduction to fundamental ideas and procedures in epidemiology. It covers the major concepts, principles, methods, and applications of both conventional and modern epidemiology using clear language and frequent examples to illustrate important points and facilitate understanding. While the author provides thorough treatment of the more customary aspects of conventional and modern epidemiology, he also introduces several important design and analytical issues that are only rarely approached in fundamental epidemiology textbooks. Concepts as diverse as competing risks, maturation, futility, and the prevalence and bias effects in the context of screening are just a few examples of the broad range of concepts covered in this text.

649 pages / Paperback / Catalog #763
Member: $51 / Nonmember: $54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A Tribute to Our 25-Year Members

The National Environmental Health Association (NEHA) thanks and honors the individuals listed below who have been members of the association for 25 years or longer. NEHA sincerely appreciates their commitment to the association and to the environmental health profession. NEHA asked a few of these members to describe the personal and professional benefits of their tenured membership with the association, as well as why they initially became a NEHA member. Quotes from these responses are sprinkled throughout the tribute.

"I became a member of NEHA for the goal of acquiring professional knowledge and networking with environmental health professionals nationally and internationally. My membership tenure with NEHA has exceeded my expectations. The *Journal* and AEC both provided venues and opportunities to interact with environmental health professionals from multiple professional disciplines and geographical locations. The professional interaction and networking through NEHA has greatly enhanced my professional knowledge and expertise and contributed immensely to my career with the Florida Department of Health."
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Herbert Anderson, RS

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Bennett H. Armstrong, RS

Thomas W. Ashton, REHS

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Jeffrey L. Bain

Denis L. Baker

Ned E. Baker, RS

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James H. Bowles

Nancy Bowser

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Thomas J. Butts, MSc, REHS, RHSP

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Dorothy A. Campbell, RS

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Robert J. Canning, RS

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Enid L. Carruth

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Gary E. Coleman, RS, DAAS, CP-FS

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Diane L. Evans

"I joined NEHA as a student at Old Dominion University. I've retained my membership to keep the professional credentials and CEUs. The AEC is really fun to attend and provides an opportunity for learning new things and seeing old friends. I recommend NEHA to anyone who plans to have a career in environmental public health."
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"I initially became a NEHA member because I wanted a professional venue to exchange ideas regarding my chosen profession and contacts to continue a dialogue to grow the profession. My personal and professional benefits in being a NEHA member have been exposure to national and international leaders and their thoughts on how to apply solutions to environmental health problems we all face."
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Anthony C. Aiken

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NEHA **NEWS**

Staff Profile: Jill Schnipke

I joined NEHA just over one year ago, but have been interested in environmental health since I was a kid playing in the creek! My dad introduced me to environmental health through a water quality study he was contributing to for the city of Lima, Ohio. I became his field sampler and then synthesized the work into a project that I took to the state science fair. During my undergraduate studies, I completed grant-funded summer research projects in both Ohio and Colorado. I earned my bachelor's degree from Ohio Wesleyan University with majors in biology and environmental studies in 2002.

Upon graduation, I worked at a local health department and earned my Ohio Registered Sanitarian credential. Then I moved to quality assurance in private industry for several years. My employers supported my involvement in several professional organizations, including the Ohio Environmental Health Association's Annual Educational Conference planning committee. I fulfilled my dream of moving to Denver and living the outdoor lifestyle in 2008, working with a couple of restaurant chains and food production companies. In 2010, I took a break from environmental health and spent nearly a year traveling globally, which brought me great personal growth and gave me broader perspectives of our profession. During that time, I also completed personal development courses, applied to and then decided against graduate school, and became an aunt and a triathlete.

Now, as NEHA's education coordinator, I really enjoy the creative process of generating a vision, outlining objectives, and clarifying ideas. It's fun to be at the leading edge of what's happening across the disciplines of environmental health and to work those things into the educational agenda of NEHA's Annual Educational Conference (AEC) & Exhibition. The detail work of coordinating NEHA's AEC is satisfying as well. Navigating mentally between the big picture and the details is challenging and exciting. The best part of the job is seeing the culmination of the work when the AEC comes to life! I am currently working with NEHA's Technical Advisors to develop educational content for the 2014 AEC taking place in Las Vegas. To see the abstracts being considered and provide your feedback, visit www.neha2014aec.blogspot.com/.

UNITED STATES POSTAL SERVICE®

Statement of Ownership, Management, and Circulation (All Periodicals Publications Except Requester Publications)

1. Publication Title	2. Publication Number	3. Filing Date
Journal of Environmental Health	2 7 9 - 9 0 0	9/13/2013
4. Issue Frequency: Once per month except for two bi-monthly issues (January/February and July/August)	5. Number of Issues Published Annually: 10 issues	6. Annual Subscription Price: $135.00

7. Complete Mailing Address of Known Office of Publication *(Not printer) (Street, city, county, state, and ZIP+4®)*: 720 S. Colorado Blvd., Ste. 1000-N, Denver, CO 80246-1926
Contact Person: Kristen Ruby
Telephone *(Include area code)*: 303.756.9090, ext. 341

8. Complete Mailing Address of Headquarters or General Business Office of Publisher *(Not printer)*
National Environmental Health Association
720 S. Colorado Blvd., Ste. 1000-N, Denver, CO 80246-1926

9. Full Names and Complete Mailing Addresses of Publisher, Editor, and Managing Editor *(Do not leave blank)*

Publisher *(Name and complete mailing address)*
National Environmental Health Association
720 S. Colorado Blvd., Ste. 1000-N, Denver, CO 80246-1926

Editor *(Name and complete mailing address)*
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Managing Editor *(Name and complete mailing address)*
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10. Owner *(Do not leave blank. If the publication is owned by a corporation, give the name and address of the corporation immediately followed by the names and addresses of all stockholders owning or holding 1 percent or more of the total amount of stock. If not owned by a corporation, give the names and addresses of the individual owners. If owned by a partnership or other unincorporated firm, give its name and address as well as those of each individual owner. If the publication is published by a nonprofit organization, give its name and address.)*

Full Name	Complete Mailing Address
National Environmental Health Association	720 S. Colorado Blvd., Ste. 1000-N, Denver, CO 80246-1926

11. Known Bondholders, Mortgagees, and Other Security Holders Owning or Holding 1 Percent or More of Total Amount of Bonds, Mortgages, or Other Securities. If none, check box ☒ None

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12. Tax Status *(For completion by nonprofit organizations authorized to mail at nonprofit rates) (Check one)*
The purpose, function, and nonprofit status of this organization and the exempt status for federal income tax purposes:
☒ Has Not Changed During Preceding 12 Months
☐ Has Changed During Preceding 12 Months *(Publisher must submit explanation of change with this statement)*

PS Form **3526**, August 2012 *(Page 1 of 3 (Instructions Page 3))* PSN: 7530-01-000-9931 **PRIVACY NOTICE:** See our privacy policy on *www.usps.com*.

13. Publication Title: Journal of Environmental Health
14. Issue Date for Circulation Data Below: September 2013

15. Extent and Nature of Circulation	Average No. Copies Each Issue During Preceding 12 Months	No. Copies of Single Issue Published Nearest to Filing Date
a. Total Number of Copies *(Net press run)*	5,375	5,200
b. Paid Circulation *(By Mail and Outside the Mail)* (1) Mailed Outside-County Paid Subscriptions Stated on PS Form 3541 (Include paid distribution above nominal rate, advertiser's proof copies, and exchange copies)	5,013	4,841
(2) Mailed In-County Paid Subscriptions Stated on PS Form 3541 *(Include paid distribution above nominal rate, advertiser's proof copies, and exchange copies)*	0	0
(3) Paid Distribution Outside the Mails Including Sales Through Dealers and Carriers, Street Vendors, Counter Sales, and Other Paid Distribution Outside USPS®	0	0
(4) Paid Distribution by Other Classes of Mail Through the USPS (e.g., First-Class Mail®)	0	0
c. Total Paid Distribution *(Sum of 15b (1), (2), (3), and (4))*	5,013	4,841
d. Free or Nominal Rate Distribution *(By Mail and Outside the Mail)* (1) Free or Nominal Rate Outside-County Copies included on PS Form 3541	0	0
(2) Free or Nominal Rate In-County Copies Included on PS Form 3541	0	0
(3) Free or Nominal Rate Copies Mailed at Other Classes Through the USPS (e.g., First-Class Mail)	0	0
(4) Free or Nominal Rate Distribution Outside the Mail *(Carriers or other means)*	0	0
e. Total Free or Nominal Rate Distribution *(Sum of 15d (1), (2), (3) and (4))*	0	0
f. Total Distribution *(Sum of 15c and 15e)*	5,013	4,841
g. Copies not Distributed *(See Instructions to Publishers #4 (page #3))*	363	359
h. Total *(Sum of 15f and g)*	5,375	5,200
i. Percent Paid *(15c divided by 15f times 100)*	100%	100%

16. ☐ **Total circulation includes electronic copies. Report circulation on PS Form 3526-X worksheet.**

17. Publication of Statement of Ownership
☒ If the publication is a general publication, publication of this statement is required. Will be printed in the November 2013 issue of this publication.
☐ Publication not required.

18. Signature and Title of Editor, Publisher, Business Manager, or Owner: Managing Editor
Date: 9/13/2013

I certify that all information furnished on this form is true and complete. I understand that anyone who furnishes false or misleading information on this form or who omits material or information requested on the form may be subject to criminal sanctions (including fines and imprisonment) and/or civil sanctions (including civil penalties).

PS Form **3526**, August 2012 *(Page 2 of 3)*

NEHA MEMBERSHIP

WHAT DOES MEMBERSHIP IN THE NATIONAL ENVIRONMENTAL HEALTH ASSOCIATION OFFER YOU?

As a member of the National Environmental Health Association (NEHA), you join over 4,500 environmental health and protection professionals from across the nation and around the world in the public and private sectors as well as academia and the uniformed services in the only association serving ALL of environmental health and protection and ONLY environmental health and protection!

Benefits of NEHA membership include:

A Free Subscription to the Esteemed Journal of Environmental Health

- Find out why subscribers from around the world go to the *Journal of Environmental Health (JEH)* to stay current on the latest technological, legal, and research-based advancements in environmental health and protection. The *JEH* is an esteemed, peer-reviewed journal published ten times a year to keep you informed!
- **NEW!** Get an electronic copy of the *JEH*. Beginning with the November 2013 issue, NEHA members will receive the *JEH* in an electronic format for free in addition to receiving it in print.

Continuing Education

- Maintain your NEHA credential(s) with access to free educational courses and continuing education credits through NEHA's e-Learning site.
- Study environmental health abroad through the NEHA/UL Sabbatical Exchange Program!
- Take advantage of unique training opportunities through NEHA workshops on topics such as indoor air quality, radon resistant new construction, and Epi-Ready at little or no cost!

Savings and Discounts

- Receive big discounts on attendance to the NEHA Annual Educational Conference & Exhibition where you can acquire practical and real-world information, expertise, and training on a variety of environmental health topics and network with other professionals and experts in the field.
- Get significant discounts on credentialing fees as you look to advance yourself professionally by earning a credential offered by NEHA.
- Receive discounts on more than 150 environmental health and protection publications available in NEHA's online Bookstore!

Join/Renew Today at neha.org/member

NEHA is also working hard to bring you a membership that fits your particular wants and needs. We are working to evolve the NEHA membership options available to you including a multiyear dues option and the opportunity to receive an electronic version of the Journal of Environmental Health*. Updates and information are available at neha.org.*

2014 Environmental Health Innovation Award

This award was established by NEHA's board of directors to recognize a NEHA member or organization for creating a new idea, practice, or product that has had a positive impact on environmental health and the quality of life. Innovative change that promotes
or improves environmental health protection is the foundation of this award.

Environmental health professionals face the dilemma of finding and implementing new ways of doing business without sacrificing the quality of their environmental health programs. This annual award recognizes those who have made an innovative contribution to the field, as well as encourages others to search for creative solutions. Take this opportunity to submit a nomination to highlight the innovations being put into practice in the field of environmental health!

Nominations are due in the NEHA office by March 17, 2014.

For more information, please visit **www.neha.org/about/awardinfo.html.** Nomination materials can be obtained by e-mailing Terry Osner at **tosner@neha.org**.

National Environmental Health Association

2014 Educational Contribution Award

This award was established by NEHA's board of directors to recognize NEHA members, teams, or organizations for an outstanding educational contribution within the field of environmental health. This award provides a pathway for NEHA members and environmental health agencies to share 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 works of your colleagues!

Nominations are due in the NEHA office by March 17, 2014.

For more information, please visit **www.neha.org/about/awardinfo.html.**
Nomination materials can be obtained by e-mailing Terry Osner at **tosner@neha.org.**

National Environmental Health Association

ACCEPTING NOMINATIONS NOW

2014 Walter S. Mangold Award

The Walter S. Mangold Award recognizes an individual for extraordinary achievement in environmental health. Since 1956, this award acknowledges the brightest and the best in the profession. NEHA is currently accepting nominations for this award by an affiliate 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.

Nominations are due in the NEHA office by Monday, March 17, 2014.

For information, please visit www.neha.org/about/awardinfo.html. Nomination materials can be obtained by e-mailing Terry Osner at tosner@neha.org.

NEHA OFFERS Exchange PROGRAM TO ENGLAND OR CANADA

NEHA offers wide-ranging opportunities for professional growth and the exchange of valuable information on the international level through its longtime Sabbatical Exchange Program. The sabbatical may be taken in England, in cooperation with the Chartered Institute of Environmental Health (CIEH), or in Canada, in cooperation with the Canadian Institute of Public Health Inspectors (CIPHI). The sabbatical lasts from two to four weeks, as determined by the recipient. The exchange ambassador will receive up to $4,000 as a stipend, depending on the length of the sabbatical, and up to $1,000 for roundtrip transportation.

The application deadline is **March 3, 2014**. Winners will be announced at the NEHA 2014 Annual Educational Conference & Exhibition in Las Vegas, Nevada, in July 2014. The sabbatical must be completed between August 1, 2014, and June 1, 2015.

For more information, contact Terry Osner at tosner@neha.org.

To access the online application, visit www.neha.org/about/awardinfo.html.

MY NEHA:

YOUR KEY TO EASY PROFILE MANAGEMENT AND SELF-SERVICE ONLINE

Because of our growth, the National Environmental Health Association (NEHA) is implementing a new and more powerful system to manage data and operate the association. You, the NEHA members and customers, will benefit greatly from this new system as it provides you with the ability to more easily manage your personal profile and transactions with NEHA.

With just one login and password you will create your My NEHA profile. Through this profile you can easily manage your profile and update your contact information, join NEHA as a member or renew a current membership, review your credentials and continuing education credit requirements, buy products, register for events, and review your purchase history!

Visit neha.org to create your My NEHA profile.

My Name

My Membership and My Professional Development

Manage Your Membership and Credentials

- View your member record to see when your membership expires and automatically renew online
- View your credential record to see your credential number, expiration date, and other pertinent information related to each credential you hold
- Review your continuing education credit submissions to see which were approved/rejected, how many credits were applied, and to which credential the credits were applied

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Easy Profile Management and Self-Service

- Change your profile password or request a new password in the event of a forgotten password
- Update your contact information
- Manage your e-mail preferences to receive e-mails only on the topics most important to you

Shop Online

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- Purchase membership, books, and more
- Handle open orders, invoices, and other transactions
- Receive a receipt automatically via e-mail for your purchases

My Transactions

Access Your Transaction History

- View all of your transaction history within your profile whether it is products you've purchased, events you've attended, and/or memberships and credentials you hold
- Review invoices and pay any outstanding balances through the online store
- Access receipts for previous purchases

NATIONAL ENVIRONMENTAL HEALTH ASSOCIATION
My NEHA

Questions?
Visit neha.org for an introductory video to My NEHA or call us at 303-756-9090.

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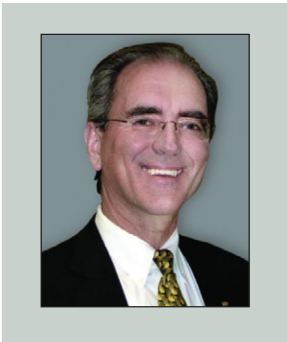

Nelson Fabian, MS

The NEHA E-*Journal* Is Here!

After more twists and turns than a Formula One Grand Prix, it gives NEHA, the NEHA staff, the NEHA board, and me great pleasure to finally announce that the "E"-*Journal of Environmental Health* is finally here!

Starting with this, the November issue, every NEHA member will now receive, in addition to their print *Journal*, an electronic version of the same.

As many of you know, we have been enduring the process of transitioning to a new association management system, all for the purpose of having more capability with our records and data and for making the NEHA experience richer for the NEHA member. This transition hasn't been easy. It has also caused us to delay making this announcement.

Notwithstanding the ups and downs of this process and the delays to the best-laid plans we've had, we've now made it to the point where we can finally offer the NEHA membership a full *Journal* in an electronic mode. This represents yet another milestone in NEHA's ongoing efforts to be a contemporary association of ever-increasing value to the NEHA member and even the full profession.

The original plan for the E-*Journal* was to embed it in yet another initiative: a multiyear membership program. While that remains the overall plan (target implementation date is one year from now), we decided that it would be a greater benefit to the NEHA member to first have the opportunity to experience both the print edition as well as the E-*Journal* … and at no additional cost. In that way, when the day comes when we ask you to choose between the three options of 1) print *Journal* only, 2) E-*Journal* only, or 3) both, you will have a much better base of experience to draw from in making your decision. We felt that by proceeding with this special one-year "get acquainted with the E-*Journal* program," we were being more respectful of you and the need for you to have the time to decide what your preference will be.

Starting with this, the November issue, every NEHA member will now receive, in addition to their print Journal, an electronic version of the same.

In opening up this new member benefit, we're also tapping into the latest in e-book technology. As we gain experience with using this technology, we even look to include video in the E-*Journal* experience.

We're also excited about the prospect of how the environmental health supplier community can use this technology to showcase what products and services are available to you, the environmental health practitioner.

On yet another front, we've been preparing for this day for some time. Accordingly, we have converted the past two years of the *Journal* into an e-product. If you wish to find material in an e-format that was published over the past two years, you now have the capability of doing that through the NEHA Web site.

The availability of the E-*Journal* is also a boon to our growing efforts to better integrate with the international community of environmental health professionals. By having access to such a product, many colleagues in other countries around the world will have a substantially easier experience in using what we regard to be one of the most valuable educational resources for the environmental health community in the world.

This initiative also ties into the work we are doing to connect more deeply to the international community through the joint annual conference (with the International Federation of Environmental Health) that we will be conducting this coming July in Las Vegas.

We all experience e-mail issues, so to help ensure that your E-*Journal* will reach you upon delivery, we'd like to ask you to take a couple of simple steps: 1) add staff@neha.org to your "safe senders" list to help prevent the E-*Journal* from going into your spam folder, and 2) ensure that NEHA has an e-mail address for you on file and that it is correct. If we do not have your correct e-mail address, then we will continue to serve you with only

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