JOURNAL OF

Environmental Health

twelve dollars

Dedicated to the advancement of the environmental health professional

Volume 77, No. 6 January/February 2015

Special Compendium Issue

HAZARDOUS METALS IN VINTAGE PLASTIC TOYS

Published by the National Environmental Health Association

www.neha.org

Journal of Environmental Health Special Compendium Issue

Volume 77, No. 6 January/February 2015

People are smiling again. When you need to get something done, you need it now. Whether you're a contractor working on a remodel at 2am, a corporate manager researching a facility's violation history, an event organizer paying for a last-minute permit, or an inspector trying to get out the door, no one wants to wait.

Now they don't have to. EnvisionConnect Online works on your phone, tablet, or computer—that makes customers happy. And your staff will appreciate the extra time to complete their own assignments. More happiness.

Join us February 25 for a live demonstration.

See how EnvisionConnect Online makes customers and agencies happy.

- Online payments
- Complaints
- Plan Checks (with attachments)
- Cottage Food
- Inspection History
- Corrective Actions
- And more…

Attend our webinar and see if it's right for you.
And get ready for the knuckle bumps and high-fives.

RSVP: www.decadesoftware.com/LearnAboutECOnline

It's about time.®

With more than 28 years of experience, Decade's award-winning and secure solutions have changed the way data are managed. Find out why Los Angeles County and agencies across the country rely on Decade Software, the National Environmental Health Association's co-branded software development company.

800.233.9847 | www.decadesoftware.com

DECADE® software company
Trusted to do more.®

JOURNAL OF
Environmental Health
Dedicated to the advancement of the environmental health professional
Volume 77, No. 6 January/February 2015

Editor's Note: This special issue features *Journal* articles that were prepublished online in 2014 and made available to NEHA members through My NEHA and the online Store.

ABOUT THE COVER

Given the popularity of buying vintage toys on the Internet, the authors of this month's cover feature, "Hazardous Metals in Vintage Plastic Toys Measured by a Handheld X-ray Fluorescence Spectrometer," examined over 100 toys from the 1970s and 1980s including Little People by Fisher-Price to determine their heavy metal content. The authors found lead or cadmium in 67% of the toys, often exceeding acceptable limits. The authors' study revealed a potentially unrecognized source of harmful metal exposure for children.

See page 8.

Cover photo © Rob Mattingley | iStockPhoto

ADVERTISERS INDEX

ADVANCEMENT OF THE SCIENCE

ADVANCEMENT OF THE PRACTICE

continued on page 4

continued from page 3

ADVANCEMENT OF THE **PRACTITIONER**

YOUR **ASSOCIATION**

Official Publication

Journal of Environmental Health
(ISSN 0022-0892)

Kristen Ruby-Cisneros, Managing Editor
Elizabeth Donoghue-Armstrong, PhD, Copy Editor
Hughes design|communications, Design/Production
Cognition Studio, Cover Artwork
Soni Fink, Advertising
For advertising call 303.756.9090, ext. 314

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 77, Number 6. 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.proquest.com. 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 managing editor for Instructions for Authors, or visit www.neha.org/JEH.

To submit a manuscript, visit http://jeh.msubmit.net. Direct all questions to Kristen Ruby-Cisneros, managing editor, kruby@neha.org.

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.

Printed on recycled paper.

PRINTED WITH SOY INK

PRESIDENT'S MESSAGE

Carolyn Hester Harvey,
PhD, CIH, RS, DAAS, CHMM

New Year's Resolution: Get to Know Chikungunya

Happy New Year to all of our NEHA family and friends! It is the start of a new year and hopefully a short winter. I hope you had a safe and happy holiday season with family and friends. Winter makes us think of snow skiing, sledding, and ice skating, but it also makes us yearn for spring and warm weather. Winter seems to last forever when you wish for sunshine and warm breezes. Many of you will be vacationing in warmer climates during the winter and early spring. As an environmental health professional, I would like to advise you of a new mosquito-borne viral disease that has been prevalent in the Caribbean islands since late 2013 and has since migrated to the U.S.

Chikungunya is a viral disease that is transmitted to humans by the bites of infected *Aedes aegypti* and *Aedes albopictus* mosquitoes. The virus has an extrinsic incubation period of approximately 10 days in the mosquito vector. Symptoms usually begin 3–7 days after being bitten by an infected mosquito but onset can take up to 12 days. Distinguishing symptoms for this disease are fever and severe joint pain. Other symptoms include muscle pain, headache, nausea, fatigue, and rash. The joint pain is often very debilitating and usually lasts for a few days or may be prolonged to a period of weeks or months. The name "chikungunya" is derived from a word in the Kimakonde language meaning "to become contorted" and describes the stooped appearance of sufferers with joint pain (arthralgia).

The disease shares some clinical signs with dengue and can be misdiagnosed in areas where dengue is common. Treatment is focused on relieving the symptoms as no cure exists for the disease. Doctors advise patients to get plenty of rest, drink sufficient fluids to prevent dehydration, and to take medicinal products such as ibuprofen, naproxen, acetaminophen, or paracetamol to relieve fever and pain.

> *It is important for us to stay abreast of the varying environmental health diseases and challenges affecting our regions and the health of our communities.*

Jamaica Association of Public Health Inspectors

In October I represented NEHA at the Jamaica Association of Public Health Inspectors' (JAPHI) annual educational conference in Runaway Bay, Jamaica. JAPHI is a longstanding NEHA affiliate. The JAPHI conference theme was "Environmental Health Officers: Resolute in Mitigating the Public Health Impacts of Climate Change." The conference also discussed the new appearance of chikungunya, which is climate sensitive. Dr. Henroy Scarlett of the University of the West Indies (UWI) at Mona presented a very compelling case for implementing climate change control processes to reduce the potential occurrence of mosquito-borne and other climate-sensitive diseases. Dr. Scarlett serves as the chairman of a subcommittee on public education and outreach on chikungunya at UWI. This committee educates staff and students as well as residents in communities close to the university about chikungunya.

Chikungunya has greatly impacted the health and well-being of the people of Jamaica. The first confirmed case of chikungunya in Jamaica occurred in July 2014 and since that time the entire country has been affected. The Pan American Health Organization (PAHO) reported in its November 7, 2014, epidemiological update that 70 confirmed cases and 896 suspected cases of the disease had occurred in Jamaica but no deaths. Anecdotal evidence suggests that the number of chikungunya cases on the island could be well in excess of what was officially reported. The Jamaican media has also reported some cases of suspected chikungunya-related deaths. Mr. Steve Morris, president of JAPHI, and I conducted a radio program interview to discuss the problems occurring in Jamaica from this disease and the precautions citizens needed to implement to reduce their exposure.

Occurrence

The disease occurs in Africa, Asia, and the Indian subcontinent. In recent decades, mosquito vectors of chikungunya have spread to Europe and the Americas. Chikungunya was reported for the first time in the Americas on the Caribbean island of St. Martin in December 2013. According to PAHO and the World Health Organization (WHO), as of November 7, 2014, 874,103 suspected cases, 14,703 confirmed cases, 1,966 imported cases, and 153 deaths had been associated with chikungunya in the Americas. Martinique (74) and Guadeloupe (65) account for most of the deaths. For the same period, 11 confirmed and 1,616 suspected cases of the disease were reported in the U.S. Cases of death from chikungunya are very rare and are almost always related to preexisting health problems. Older adults and people with chronic illnesses (such as diabetes, heart disease, hypertension, chronic kidney failure, tuberculosis, and HIV) should undergo medical evaluation and monitoring when they contract the disease.

Protection and Precautions

The proximity of mosquito breeding sites to human habitation is a significant risk factor for chikungunya. Prevention and control relies heavily on reducing the number of natural and artificial water-filled container habitats that support breeding of the mosquitoes. For protection during outbreaks of chikungunya, clothing that minimizes skin exposure to these day-biting vectors is advised. Repellents can be applied to exposed skin or to clothing in strict accordance with product label instructions. Repellents should contain DEET (N, N-diethyl-3-methylbenzamide), IR3535 (3-[N-acetyl-N-butyl]-aminopropionic acid ethyl ester), or icaridin (1-piperidinecarboxylic acid, 2-[2-hydroxyethyl]-1-methylpropylester). For those who sleep during the daytime, particularly young children, the sick, or the elderly, insecticide-treated mosquito nets afford good protection. Mosquito coils or other insecticide vaporizers may also reduce indoor biting.

Basic precautions should be taken by people traveling to risk areas and these include use of repellents, wearing long sleeves and pants, and ensuring rooms are fitted with screens to prevent mosquitoes from entering. This map (www.cdc.gov/chikungunya/geo/index.html) will give you an indication of where in the U.S., the Caribbean, and other countries you could be bitten by mosquitoes carrying the virus.

As environmental health practitioners and advocates of caution whenever we encounter potential vectors, local health and vector control agencies will be working diligently to eradicate these mosquito species and to inform the public about how they may help in this endeavor. We can alleviate potential habitats for mosquitos by removing containers that may have standing water and by supporting the local vector control programs. If you are sick with chikungunya, you can help prevent further spread of the virus by avoiding mosquito bites. NEHA will be posting information on the Web site as the late spring and summer mosquito season gets under way. NEHA's board of directors is working on a position paper, which should be on the NEHA Web site after our spring board meeting (April 10–11, 2015).

Additional Resources

The Centers for Disease Control and Prevention are an excellent resource for information and current information can be found on their dedicated Web site: www.cdc.gov/chikungunya. WHO also has an exceptional site: www.who.int/mediacentre/factsheets/fs327/en/.

I hope this information is helpful to you as environmental health professionals. With the New Year arriving, it is important for us to stay abreast of the varying environmental health diseases and challenges affecting our regions and the health of our communities. If you have any personal experience managing this disease in your community and would like to share your thoughts and expertise, feel free to contact me.

Dr Carolyn Harvey

carolyn.harvey@eku.edu

Hazardous Metals in Vintage Plastic Toys Measured by a Handheld X-ray Fluorescence Spectrometer

Gillian Zaharias Miller, PhD
Ecology Center

Zoe E. Harris
St. Ambrose University

Abstract **Over 100 plastic toys from the 1970s and 1980s, both polyvinyl chloride ("vinyl") and nonvinyl, were analyzed in the study described here using a handheld X-ray fluorescence spectrometer to quantify hazardous metal content. A sampling of recent vinyl toys was also tested. The majority of nonvinyl samples were Fisher Price brand toys. The vinyl toys consisted largely of Barbie dolls and other dolls. Overall, lead or cadmium was found in 67% of vintage plastic toys, frequently at concentrations exceeding current U.S. and European limits. Arsenic was detected at levels of concern in 16% of the samples. In the nonvinyl toys, heavy metal content was found to correlate with certain colors of plastic. The likely sources of the detected metals are discussed. None of the contemporary vinyl toys contained detectable cadmium, lead, or arsenic. Given that vintage toys remain in widespread use by children in homes and other locations, the results illuminate a potential source of heavy metal exposure for children.**

Introduction

Hazardous Metals in Contemporary Toys

Recent years have seen a sharp increase in revelations of so-called toxic toys and other everyday products contaminated with hazardous metals in the U.S. The reports have come from a number of sources: academic research studies, nonprofit centers, and occasionally, news outlets (Gregory & Roe, 2007; Guney & Zagury, 2012; HealthyStuff.org, 2008; Kumar & Pastore, 2007; Pritchard, 2012). Researchers have found handheld X-ray fluorescence (XRF) spectrometers to be convenient and accurate for rapidly testing consumer products (Reames & Charlton, 2013).

Prior to 2009, when the Consumer Product Safety Improvement Act (CPSIA) went into effect, the U.S. had no laws restricting heavy metals in consumer products, including toys. The CPSIA restricted total lead in children's products to 600 ppm in 2009 and reduced the limit to 100 ppm in 2011. (Note that ppm, parts per million, is equivalent to mg/kg.) No mandatory limits exist on cadmium or other heavy metals in toys, although voluntary guidelines borrowed from Europe were adopted.

Table 1 lists current U.S. and EU mandatory limits for five heavy metals in children's toys (Guney & Zagury, 2012). Some European countries have their own restrictions; Denmark's are listed as an example.

Usage of Vintage Toys

An Internet search revealed a robust trade in pre-1990 vintage toys, including toys identical to those tested in our study. Some buyers are collectors; some are parents seeking remembered toys to give to their own children. The market for old toys, together with personal observation, suggests that vintage plastic toys are in widespread use in homes, daycares, church nurseries, and waiting rooms. A search of the academic literature shows a lack of research on old toys. A handheld XRF study of daycare center toys carried out in the Las Vegas area found a high rate of lead- and cadmium-containing toys, both vinyl and nonvinyl, in 10 different child care centers (Greenway & Gerstenberger, 2010). In that study, however, the age and origin of the toys were not known.

Health Risks

The developing brains and bodies of infants and young children are especially vulnerable to toxic exposures. This is because 1) they absorb and retain lead more efficiently than do adults (Ziegler, Edward, Jensen, Mahaffey, & Fomon, 1978); 2) they are exposed to contaminated dust particles by playing close to the floor; 3) they chew on, mouth, and occasionally swallow items; and 4) they handle many toys and frequently put their fingers into their mouths (Guney & Zagury, 2012).

No safe blood level of lead has been established; even very low amounts in a child's body are linked to reduced intelligence (Canfield et al., 2003; Lanphear et al., 2005). The long-term consequences of lead exposure, which affects virtually every organ system

TABLE **1**

Governmental Restrictions on Heavy Metals in Toys

Metal	Limits in the U.S.	Limits in the EU
Cadmium	No mandatory limit*	Migratable cadmium <75 ppm[a] (EU); total cadmium <75 ppm (Denmark)
Lead	Total content <100 ppm	Migratable lead <90 ppm (EU); total lead <100 ppm (Denmark)
Arsenic	No mandatory limit	Migratable arsenic <25 ppm (EU)
Mercury	No mandatory limit	Migratable mercury <60 ppm (EU); total mercury <100 ppm (Denmark)
Barium	No mandatory limit	Migratable barium <1000 ppm (EU)

[a]ppm = parts per million.
*Although no limit is defined for toys, in children's jewelry, cadmium cannot exceed 300 ppm.

TABLE **2**

Examples of Toys Tested in Each Category

1970s–1980s non-PVC[a]	1970s–1980s PVC	2010–2013 PVC
Fisher Price Little People and accessories	Katie Kangaroo by Fisher Price (1976–77)	Animal figures
Fisher Price and Little Tikes stoves and cookware	My Little Pony and accessories	"Rubber" bath ducks
Barbie doll torsos	Barbie and other doll heads and legs	Barbie and other doll heads
Colored foods, brand unknown	American Girl doll (1988)	

[a]PVC = polyvinyl chloride.

in the body, are reviewed in Rosin (2009). Tests of bioavailability of lead and cadmium from toys and jewelry have been reviewed in Gunery and Zagury (2012). Cadmium, while less well studied than lead, appears to impact brain development (Kippler et al., 2012). Cadmium is also known to damage renal function, may contribute to osteoporosis, builds up in the placenta, and may increase cancer risk (Järup & Akesson, 2009).

Mercury, arsenic, and barium are additional chemicals of concern in children's products. Profiles of the toxicological effects of those metals can be found in the Agency for Toxic Substances and Disease Registry (ATSDR, 2011).

One concern with old toys is degradation of the materials. Plastic objects will degrade over time, releasing small plastic particles as well as embedded metals or metal compounds. Thus, vintage toys may pose a greater exposure hazard than new toys.

Methods

A handheld XRF spectrometer, model Niton XL3t-980 GOLDD+, was rented from Thermo Scientific. The XRF analyzer was calibrated by the manufacturer to allow quantitative elemental analysis for several material classes, including plastics, metals, and ceramics. Plastics mode was chosen for all samples in our study. Within plastics mode, the XRF analyzer identifies polyvinyl chloride (PVC) plastic based on chlorine content, but cannot distinguish between other types of plastic. In this article, "PVC" and "vinyl" are used interchangeably.

A calibration check was performed at the beginning and end of every test session and approximately every two hours in between. For plastics mode, the certified calibration standard used was a plastic disc impregnated with ppm levels of multiple metals.

Ninety-one plastic toys purchased in the 1970s and 1980s, 14 toys purchased between 2010 and 2013, and one doll from 2005 were collected from the homes of families in the Midwest. Examples of these toys are given in Table 2.

The toy surfaces were wiped with Kimwipes. The 77 nonvinyl toys were subject to a total of 125 XRF analyses on different solid-color parts. Likewise, the 26 vintage vinyl toys were subject to 61 scans and the 14 contemporary vinyl toys to 24 scans. Most toy parts were tested once, but a few were scanned twice, in some cases days apart, to verify repeatability. Each XRF scan consisted of a 30-second exposure to the X-ray beam while the analyzer collected and averaged spectra multiple times. Error ranges calculated by the XRF instrument for each element concentration are reported here as two standard deviations, 2σ, which is considered the 95% confidence interval (Piorek, 2009).

Toys were held steady in a clamp or placed on a high-density polyethylene block. The polyethylene block was chosen because it contained no elements that would confound the results from the test samples. Care was taken to position toys to avoid any signal from the clamp.

A thickness correction was programmed into the XRF analyzer before scanning toy parts that were thinner than 10 mm. A caliper was used to measure thickness for most samples. A few toy thicknesses were estimated by visual inspection because their shapes prevented caliper use.

Toys with curved surfaces presented a challenge. For all such toys, the flattest possible location was chosen for analysis to minimize air gaps and loss of quantitative accuracy. Also, since the XRF beam window is recessed, spherical surfaces such as the Little People heads could be covered by the window opening without air gaps.

An Omnic Fourier Transform Infrared (FTIR) spectrometer was used in transmission mode to help identify the plastic type of nonvinyl toys. Thin strips of plastic were shaved from four Fisher Price toys of different colors and placed in the path of the infrared beam in air. The resulting spectra were examined after subtracting a background spectrum.

Results and Discussion

Table 3 summarizes the measurements. A majority (69% and 66% of PVC and non-PVC, respectively) of vintage plastic toys

contained either cadmium or lead or occasionally both metals.

The minimum concentrations counted in Table 3 were chosen as follows. 1) Cadmium and lead: readings of 90 ppm would be considered noncompliant (Piorek, 2009), or very close, because the upper error limit is close to the 100 ppm legal limit. 2) Arsenic: only readings above 65 ppm had error ranges of ±20% or less and thus could be considered quantitative (Piorek, 2009). 3) Barium: values >250 ppm showed unambiguous barium peaks in the spectra, whereas lower readings had high error ranges ($2\sigma > 30\%$).

The three toy categories—vintage nonvinyl, vintage vinyl, and recent vinyl—are discussed in separate sections below.

TABLE **3**

Summary of Hazardous Metal Measurements in Three Toy Categories

Measurement	Vintage Non-PVC[a] Toys	Vintage PVC Toys	Recent PVC Toys
# of toys tested	77	26	14
Detectable cadmium or lead	51 (66%)	18 (69%)	0
Lead >90 ppm[b]	26 (34%)	8 (31%)	0
Lead >1000 ppm	18 (23%)	3 (12%)	0
Cadmium >90 ppm	23 (30%)	10 (38%)	0
Cadmium >1000 ppm	9 (12%)	1 (4%)	0
Arsenic >65 ppm	14 (18%)	2 (8%)	0
Mercury >10 ppm	12 (16%)	1 (4%)	0
Barium >250 ppm	17 (22%)	18 (69%)	5 (36%)

[a]PVC = polyvinyl chloride.
[b]ppm = parts per million.

Vintage Nonvinyl Toys

Out of 91 old plastic toys collected for our study, 77 were nonvinyl or, in the case of the Barbie dolls, partly nonvinyl. Barbie dolls were found by XRF to have PVC heads and legs and non-PVC backs or torsos. Twelve doll torsos were therefore included in the nonvinyl toy category. (The heads and legs of the same dolls were included in the vinyl category.)

As described in the Methods section, plastic from four nonvinyl toys (excluding Barbie doll torsos) of different colors were analyzed by FTIR. The resulting spectra from the four samples showed similar spectral profiles. The spectra are consistent with polyethylene or polypropylene that has undergone partial oxidation, forming C=O bonds, as suggested by a peak at 1,739 cm^{-1} (Socrates, 2001). A peak due to vinyl CH_2 groups also appears at 908 cm^{-1}, which is consistent with commercial polyethylene but not polypropylene (Socrates, 2001).

The plastic strips were observed to float in water and to sink in 70% isopropyl alcohol. This places the density of the plastic between 0.88 and 1.0 g/cm^3, which is consistent with polyethylene but not polypropylene. We concluded that the toys (excluding Barbie torsos) are likely made of polyethylene, and that the chemical structure of the polymer has degraded to some degree since manufacture.

The Barbie torso material was not identified other than as a nonvinyl plastic containing no halogens. This plastic was difficult to scrape or shave off and was not analyzed by FTIR or by the density test.

Table 3 shows that 34% of the 77 nonvinyl toys would violate the current U.S. and Denmark limits on lead. Thirty percent would violate the limits on cadmium. Furthermore, 23% of the toys contained more than 10 times the lead limit, and 12% contained more than 10 times the cadmium limit. Of the cadmium- and lead-containing samples, most had one metal or the other, but not both.

Arsenic was unambiguously detected in 18% of nonvinyl toys (Table 3). Barium was measured >250 ppm in 22% of samples. Some of these toys might exceed EU limits for arsenic and barium (Table 1), but direct comparison is not possible because the EU standard is a migration, or soluble, limit and migration of metals from toys was not studied in this work.

Figure 1 shows lead and cadmium content as measured by XRF of individual nonvinyl samples sorted by color. Within each color, the results are shown in order of increasing lead content. Overall, the highest concentrations of both cadmium and lead were found in yellow toy parts. Most of the leaded yellow toys contained anywhere from 10 times to nearly 70 times the current limit of 100 ppm.

Green, orange, and brown nonvinyl samples were similarly likely to contain high lead or cadmium concentrations, including a few >1,000 ppm. Red and peach colors frequently contained lead or cadmium well over 100 ppm. Peach plastic was especially likely to contain excessive cadmium. In white, magenta, turquoise, black, and gray samples, cadmium and lead were either nondetectable or very minimal, although we note that only a small number of samples was available for those colors.

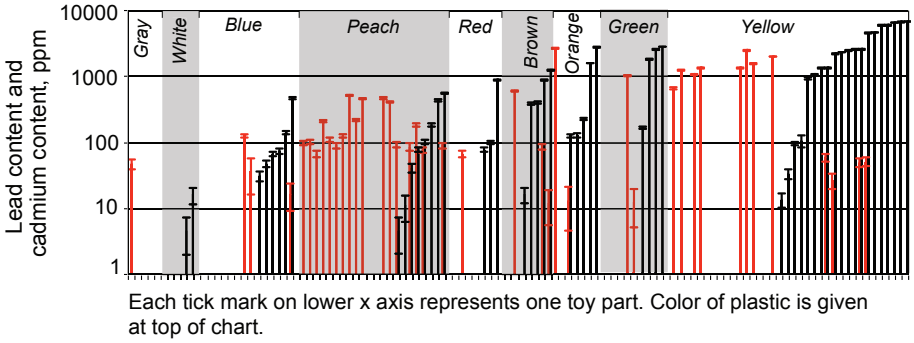
Twelve of the nonvinyl toys (16%) contained mercury below regulatory limits, ranging from 13.6±3.9 ppm to 46.4±5.1 ppm. Ten of these toys were the 10 light peach colored heads of Little People figures. Mercury was not detected in the 12 Barbie torsos of similar color.

All of the 14 toys containing arsenic (Table 3) also contained lead. Not all lead-containing samples contained arsenic, however. Arsenic measurement with XRF requires caution because the arsenic K peak overlaps with the lead L peak. The Niton XRF instrument was calibrated to differentiate between lead and arsenic. Failing to include a thickness correction for a sample under 10 mm, however, increases the chance of incorrect separation of the arsenic and lead peaks. In our study, thickness corrections were used when needed and the calibration checks gave reasonably accurate results for a plastic sample containing known amounts of both arsenic and lead. Hence, we take the arsenic measurements in our study to be real.

Why are hazardous metals present in so many old nonvinyl toys? The metals are almost certainly colorants or pigments. Lead chromate, $PbCrO_4$, also known as chrome yellow, was a standard plastic colorant in the era in which these toys were made. Lead sulfate ($PbSO_4$) and

FIGURE **1**

Lead (Black Bars) and Cadmium (Red Bars) Measured in Nonvinyl Vintage Toys Sorted by Color

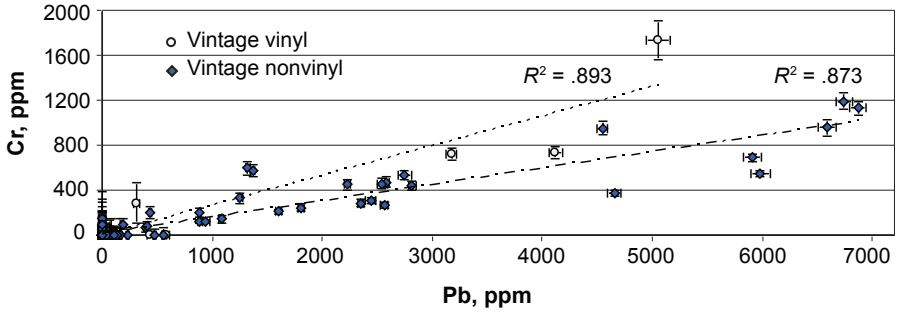


Ppm = parts per million.

Within each color, samples are arranged in order of increasing lead content. Black, magenta, and turquoise toys are not included because they contained no significant lead or cadmium. A log scale is used to display the wide range of measured concentrations. Error bars show ±2σ. Upper and lower error bars are shown for every measurement, but appear as one bar when the gap is small.

FIGURE **2**

Chromium (Cr) Content as a Function of Lead (Pb) Content in Nonvinyl (Shaded Diamonds) and Vinyl (Open Circles) Vintage Samples



Error bars represent ±2σ. Linear regression results are shown. Ppm = parts per million.

lead oxide (PbO) were mixed with the chromate in varying amounts to produce a color palette from light yellow to red (Rangos, 2003).

Similarly, cadmium compounds such as cadmium sulfide and cadmium selenide were—and still are—used to produce yellow and orange hues in plastics (Rangos, 2003; Vonkeman, Thornton, & Makuch, 2001). Mercury-cadmium sulfides were also used to produce colors from orange to maroon (Rangos, 2003).

In the 1980s and early 1990s, European countries restricted the use of these chemicals due to concerns about toxicity and environmental contamination, both during manufacture and disposal. As a result, the usage of lead-, cadmium-, and mercury-based colorants has been greatly reduced, and less toxic substitutes have been developed (Rangos, 2003; Vonkeman et al., 2001).

Although XRF cannot determine the chemical form of the elements in the tested samples, the data do provide evidence suggesting that lead, cadmium, and mercury are pigment constituents. Figure 2 shows measured chromium content as a function of lead content for the complete nonvinyl sample set (all colors). If lead is in the form of lead chromate, chromium content should increase linearly with lead content. Figure 2 shows a roughly linear trend. The ratio of lead to chromium in pure lead chromate would be approximately 4:1 by weight. In our measurements, most samples showed a lead:chromium weight ratio of around four or greater, even as high as 12. Ratios higher than four may reflect the presence of additional lead compounds added for color tuning such as lead oxide and lead sulfate (Rangos, 2003).

The six blue samples with detectable lead did not show detectable chromium. This may be because all but one of the blue leaded samples had lower lead (31±5 to 140±8 ppm), and if chromium is present in those, its concentration is likely below the limit of detection in XRF. Judging from the 2σ values, below 100 ppm the chromium readings cannot be considered quantitative. It is worth noting that all 23 samples containing at least 100 ppm chromium also contained significant lead.

The presence of cadmium did not show a trend with color as clearly as lead did, except for the peach samples (faces and heads of light-skinned Little People as well as Barbie torsos). All 11 of the peach Little People samples contained cadmium ranging from 68±7 to 523±13 ppm. Of the doll torsos, cadmium was found in 7 of the 12, ranging from 85±11 to 611±14 ppm. Since sulfur was not measured in the XRF mode used here, it is not possible to see if cadmium follows sulfur content, which might indicate cadmium sulfide pigments. Selenium was not detected in any samples, ruling out the presence of cadmium selenide.

Cadmium content was linearly correlated with barium content. A linear regression of cadmium versus barium gave a slope of 1.07 with an R^2 value of .93 (graph not shown). This relationship suggests a common source of both cadmium and barium in the majority of cadmium-containing toys. It is possible these toys contain a yellow or orange cadmium-based pigment, plus barium sulfate, which is white and often mixed with other colors to vary the shade.

Vintage Vinyl Toys

Twenty-six toys were vinyl or partially vinyl (e.g., doll heads and legs). Most of the vintage vinyl toys were dolls with peach or tan skin. Of

the cadmium- and lead-containing samples, most had one metal or the other, but not both. Arsenic was clearly detected in two of the 26 toys. Barium was found in 69% (Table 3).

Since lead and cadmium were the most frequent toxic metals found aside from barium (Table 3), we focus on those. In general, both lead and cadmium in various chemical forms may be added to PVC for three purposes: as pigments, as stabilizers against degradation, and, less commonly, as plasticizers. Lead-based stabilizers such as tribasic lead sulfate and lead stearates continue to be widely used in PVC products (Jennings & Starnes, 2005). Cadmium-barium-based stabilizers have also been used.

In the 1970s and 1980s vinyl toys tested, lead and cadmium are mostly likely part of pigment compounds added for color. The evidence is as follows. First, the concentrations of lead and cadmium, while high relative to current acceptable limits in toys, are lower than would be expected for stabilizer compounds. If lead- or cadmium-based stabilizers were present, metal content should be on the order of 1%–3% (Vonkeman et al., 2001). The highest weight concentrations detected in vinyl toys here were ~0.1% cadmium and ~0.5% lead.

Second, the darker colored toys in our sample set had the highest levels of lead or cadmium, consistent with more pigment for a more intense shade. Although the majority of vintage PVC samples were light peach colored, a few were darker: a dark tan Barbie, a brown kangaroo, and a dark brown doll shoe. These contained, respectively, 1077±26 ppm cadmium in the cheek, 4123±57 ppm lead in the body, and 5052±106 ppm lead in the shoe bottom.

As with the nonvinyl toys, leaded vintage PVC toys may contain the pigment lead chromate. Figure 2 shows chromium content in vintage vinyl (open circles) as a function of lead content. The two metals are moderately linearly correlated. No significant correlations were seen between cadmium and barium (ruling out cadmium-barium stabilizers), cadmium and selenium, cadmium and chromium, or lead and barium.

Contemporary Vinyl Toys

As shown in Table 2, of the 14 recent PVC toys tested, none contained detectable cadmium, lead, arsenic, or mercury. Roughly one-third contained clearly detectable barium. The toys were a variety of colors.

Concerns about toxic metals in pigments and PVC stabilizers has spurred manufacturers to find substitutes (Jennings & Starnes, 2005). The sample set of recent PVC toys in our study was small, but the absence of detectable hazardous metals (with the exception of relatively small amounts of barium) likely reflects their overall decrease in toys sold in the U.S.

We caution, however, that hazardous heavy metals have been found in a significant number of new toys as recently as 2008 (HealthyStuff.org, 2008). Also, federal regulators have been criticized for not enforcing existing restrictions (Pritchard, 2012). Since new U.S. legislation took effect in 2009, it is possible that the frequency of contamination in toys has continued to decrease, but a larger sample set of new toys is needed to assess this.

Potential Exposure From Plastic Toys

As noted in the Introduction, solid polymers degrade over time as they are exposed to light, heat, oxidizing agents, and handling. Indeed, the vintage nonvinyl samples in our study are visibly rough and worn away along the edges. FTIR confirmed the presence of oxidized bonds. The heavy-metal pigments discussed above and likely contained in many of the vintage toys are not chemically bound to the polymers. Instead, pigments are tiny particles embedded within the polymer. Toxic particles may therefore be released due to chemical breakdown of plastic toys or by mouthing or handling (Guney & Zagury, 2012).

Limitations

Our study was limited to measuring hazardous metals present in vintage and new toys. Additional research is needed to determine how much heavy metal from a given toy will migrate onto a child's skin or be ingested during mouthing. Future work should therefore include tests that simulate handling and mouthing of the tested toys.

Conclusion

Vintage plastic toys frequently contain toxic heavy metals, particularly lead or cadmium, at concentrations exceeding current restrictions. Pigments appear to be a major source of these metals. Old toys are still in frequent use and thus present an exposure pathway that may be overlooked for children, especially children already burdened with toxic exposures from other sources.

Acknowledgements: The authors wish to thank the St. Ambrose University Summer Research Institute for funding. Special thanks to Dr. Jodi Prosise, Dr. Barret Ferm, and the Department of Chemistry. We received technical assistance from James Collins, Gary McEachern, and Ritch Vernon, all of Thermo Scientific. Finally, we acknowledge assistance from St. Ambrose students Barb Anderson, Kialee Bowles, and Alex Ducray.

Corresponding Author: Gillian Zaharias Miller, Staff Scientist, Ecology Center, 339 East Liberty Street, Ann Arbor, MI 48103.
E-mail: gillian@ecocenter.org.

References

Agency for Toxic Substances and Disease Registry. (2011). *Toxic substances portal: Substances A–Z.* Retrieved from http://www.atsdr.cdc.gov/substances/indexAZ.asp

Canfield, R.L., Henderson, C.R., Jr., Cory-Slechta, D.A., Cox, C., Jusko, T.A., & Lanphear, B.P. (2003). Intellectual impairment in children with blood lead concentrations below 10 µg per deciliter. *New England Journal of Medicine, 348*(16), 1517–1525.

Greenway, J.A., & Gerstenberger, S. (2010). An evaluation of plastic toys for lead contamination in day care centers in the Las Vegas valley. *Bulletin of Environmental Contamination and Toxicology, 85*(4), 363–366.

Gregory, T., & Roe, S. (2007, November 18). Many more toys tainted with lead, inquiry finds. *Chicago Tribune,* 1. Retrieved from http://

References

articles.chicagotribune.com/2007-11-18/news/chi-leadmain-story_1_800-toys-lead-tainted-toys-julie-vallese

Guney, M., & Zagury, G.J. (2012). Heavy metals in toys and low-cost jewelry: Critical review of U.S. and Canadian legislation and recommendations for testing. *Environmental Science & Technology, 46*(8), 4265–4274.

HealthyStuff.org. (2008, December 3). *One in three children's toys tested by HealthyToys.org found to have significant levels of toxic chemicals including lead, flame retardants, and arsenic.* Retrieved from http://www.healthystuff.org/get-stuff.php?report=One+in+Three+Children%27s+Toys+Tested+by+HealthyToys.org+Found+to+have+Significant+Levels+of+Toxic+Chemicals+Including+Lead%2C+Flame+Retardants%2C+and+Arsenic

Järup, L., & Akesson, A. (2009). Current status of cadmium as an environmental health problem. *Toxicology and Applied Pharmacology, 238*(3), 201–208.

Jennings, T.C., & Starnes, W.H., Jr. (2005). PVC stabilizers and lubricants. In C.E. Wilkes, J.W. Summers, C.A. Daniels, M.T. Berard, & H. Verlag (Eds.), *PVC handbook* (pp. 103–104). Munich, Germany: Hanser.

Kippler, M.J., Tofail, F., Hamadani, J.D., Gardner, R.M., Grantham-McGregor, S.M., Bottai, M., & Vahter, M. (2012). Early-life cadmium exposure and child development in 5-year-old girls and boys: A cohort study in rural Bangladesh. *Environmental Health Perspectives, 120*(10), 1462–1468.

Kumar, A., & Pastore, P. (2007). Lead and cadmium in soft plastic toys. *Current Science, 93*(6), 818–822.

Lanphear, B.P., Hornung, R., Khoury, J., Yolton, K., Baghurst, P., Bellinger, D.C., Canfield, R.L., Dietrich, K.N., Bornschein, R., Greene, T., Rothenberg, S.J., Needleman, H.L., Schnaas, L., Wasserman, G., Graziano, J., & Roberts, R. (2005). Low-level environmental lead exposure and children's intellectual function: An international pooled analysis. *Environmental Health Perspectives, 113*(7), 894–899.

Piorek, S. (2009). Consumer goods analysis, appendix B. In *Thermo Scientific, Niton XL3 Resource Guide* (Version 8.0.0). Tewsbury, MA: Thermo Scientific.

Pritchard, J. (2012, October 14). AP impact: Feds muff kid jewelry cadmium crackdown. *Associated Press*. Retrieved from http://bigstory.ap.org/article/ap-impact-feds-muff-kid-jewelry-cadmium-crackdown

Rangos, G. (2003). Inorganic colored pigments. In R.A. Charvat (Ed.), *Coloring of plastics: Fundamentals* (pp. 134–136). New York: Wiley Interscience.

Reames, G., & Charlton, V. (2013). Lead detection in food, medicinal, and ceremonial items using a portable X-ray fluorescence (XRF) instrument. *Journal of Environmental Health, 75*(6), 16–20.

Rosin, A. (2009). The long-term consequences of exposure to lead. *The Israel Medical Association Journal, 11*(11), 689–693.

Socrates, G. (2001). *Infrared and Raman characteristic group frequencies* (3rd ed.). Chichester, UK: Wiley.

Vonkeman, G.H., Thornton, I., & Makuch, Z. (2001). Cadmium. In M.J. Scoulios (Ed.), *Mercury, cadmium, lead: Handbook for sustainable heavy metals policy and regulation* (pp. 206–213). Dordrecht, Netherlands: Kluwer Academic Publishers.

Ziegler, E.E., Edward, B.B., Jensen, R.L., Mahaffey, K.R., & Fomon, S.J. (1978). Absorption and retention of lead by infants. *Pediatric Research, 12*(1), 29–34.

Florida County Health Department, Environmental Health 2006 Survey: Do Rural Counties Know "What to Do" in a Chemical or All-Hazards Event?

Alan Becker, MPH, PhD
Sandra Suther, PhD
Matthew Dutton, PhD
Institute of Public Health
Florida A&M University

Gregory D. Kearney, MPH, DrPH
Department of Public Health
East Carolina University

Xiaohui Xu, MD, PhD
Department of Epidemiology
University of Florida

Abstract **The objective of the study described here was to determine basic plans and collaboration with first responder stakeholders and to identify perceived roles and responsibilities in preparing for and responding to a chemical disaster. A survey was developed and provided to environmental health personnel at county health departments (CHDs) in Florida. Most of the counties had good collaborative relationships with first responder stakeholders. A little more than half of the respondents had access to a resource manual with contact information and had developed and maintained a chemical plan. Rural counties were less likely to know "what to do" or their responsibility in a chemical disaster; however, both rural and nonrural counties were equally likely not to have a written plan. Public health agencies at the local CHD must be the communicators of public health messages in coordination with the incident commander and the state communications office in a chemical disaster, so it is important to strengthen collaboration and cooperation with chemical response stakeholders.**

Introduction

Environmental health administrators from all 67 counties in the state of Florida were asked to respond to a survey about their perceived preparedness and functions in response to a chemical disaster. Questions included in the survey were related to training, resources, contact information, and how they may interact with local, state, and federal stakeholders involved in emergency management, response, and cleanup. The survey was conducted prior to a rural county health department (CHD) exercise related to "what to do and who to contact in a chemical disaster." The development of a flow chart for communications and a contact list with phone numbers was updated as part of this process. Environmental health administrators of each CHD were selected as the sample because environmental health personnel routinely attend local emergency planning committee (LEPC) meetings and work with emergency management officials who are important stakeholders in emergency response. The aims of the exploratory survey were to 1) determine chemical disaster preparedness and response related to planning, resources, contact information, and basic collaboration and coordination with chemical stakeholders; 2) evaluate differences in rural and nonrural CHDs and environmental health's chemical disaster preparedness; and 3) identify the perceived roles and responsibilities of the environmental health administrators. This is the first peer-reviewed publication that includes a survey of environmental health personnel in CHDs addressing these issues related to chemical disaster preparedness.

Background

Most chemical incidents perpetrated by criminals or terrorists involve chemical agents (James Martin Center for Nonproliferation Studies, 2002). Agents of primary interest include blood, nerve, blister/vesicants, choking, and metals. Chemicals of interest are chemicals with properties that cause explosions, gases, inhalation hazards, flammable liquids and solids, oxidizers, and toxic or poisonous products such as organophosphates (Florida Department of Health [FDOH], 2012).

The mechanism of delivery to the target organ is dependent on the route of exposure. The most rapid response to a pollutant is intravenous subsequently followed by inhalation, injection by interperitoneal, subcutaneous, intramuscular, ingestion, or topical chemical exposure (Eaton & Gilbert, 2007). Other important aspects of exposure are the concentration of the chemical and the duration of the exposure (Yu, Tsunoda, & Tsunoda, 2011). The most critical common route of exposure from an occupational or chemical exposure is the respiratory route, but other routes such as oral or dermal have to be considered.

The release of chemicals to the environment with subsequent exposure to humans may occur from various sources. Chemical, biological, radiological, and nuclear emergencies may occur due to occupational exposure, fire, explosion, release of toxicants, and warfare and may be caused by ignorance, negli-

TABLE **1**

Perceived Preparedness and Functions in Response to a Chemical Disaster (*N* = 48)

Close-Ended Questions	Yes # (%)	No # (%)
Q1. Is there a liaison assigned to the local emergency management?	46 (95.8)	2 (4.2)
Q2. Is there a liaison to emergency response?	39 (81.3)	9 (18.8)
Q3. What to do and who to contact?	39 (81.3)	9 (18.8)
Q4. Does environmental health participate in the local emergency planning committee meetings?	40 (83.3)	8 (16.7)
Q5. Do you have a first responder resource manual including contact list?	30 (62.5)	18 (37.5)
Q6. Are there environmental health plans for a chemical disaster/response?	28 (58.3)	20 (41.7)
Q7. Is there a key position responsible for a chemical response?	26 (54.2)	22 (45.8)
Q8. Is another section besides environmental health involved in a chemical event?	25 (52.1)	23 (47.9)

gence, incompetence, accident, or malicious intention (Sharma, 2010). Examples in the chemical industry include accidents or disasters such as explosion of ammonium nitrate; crude sulfate turpentine fire and hydrogen sulfide gas release; flammable hydrocarbons; and a major hydrochloric acid spill that resulted in death, injury, evacuations, or contamination of the environment (Belke, 1997). Catastrophic chemical accidents or disasters in industry are not routine but may be a weekly or monthly occurrence (Belke, 1997). Chemical disasters may also occur in rural areas from rail or other transportation mishaps and subsequent spills so it is important that rural areas prepare for these disasters.

Similar to other states, a mixed profile exists in Florida with funding provided by local fees and state and federal funding. CHDs nationally receive 25% of their funding from local sources (Meyer & Weiselberg, 2009). In southern states CHDs receive about $19.75 per person from federal funding compared to the 2009 national median of $28.92 per person (Robert Wood Johnson Foundation, 2010). Due to the downturn in recent years funding from all sources has decreased.

A CHD mutual aid organization called the Regional Domestic Security Task Force (RDSTF) is divided into seven regions that are located in Ft. Meyers, Jacksonville, Miami, Orlando, Pensacola, Tallahassee, and Tampa Bay and is made up of members such as fire/rescue, emergency management, public health, hospitals, and law enforcement (Florida Department of Law Enforcement, n.d.). RDSTFs provide support to the impacted community by serving as a force multiplier for local agencies and working in conjunction with emergency management professionals (Florida Department of Law Enforcement, n.d.). The goal of RDSTF is to provide a regional response in rural counties. It allows smaller counties to draw resources and capacity from larger metropolitan areas and it also allows these smaller counties to provide assistance to larger metropolitan areas if an event occurs there (Regional Domestic Security Task Force, 2012).

Several organizations (e.g., Centers for Disease Control and Prevention [CDC], 2011a; Council of State and Territorial Epidemiologists [CSTE], 2004; LaTourette, Davis, Howell, Preethi, & Dausey, 2009; U.S. Department of Homeland Security, 2007) have developed protocols, capabilities, and recommendations to address chemical disaster response by public health, CHDs, and environmental health. In addition, the public health emergency response guide provides guidance on developing collaborations with emergency management, emergency medical services, LEPC, first responders, academia, and other pertinent agencies and organizations (CDC, 2011b). An assessment of public health preparedness for chemical emergencies provided by chemical experts in each state reported insufficient planning, resources, and partnerships (CSTE, 2004).

In 2012 the Florida Department of Health (FDOH) approved the Chemical Incident Annex, identifying public health actions such as preparing, responding, and recovering from a chemical emergency, and the authority to activate specialized actions if an individual or cluster of ill persons with similar symptoms requires medical treatment following exposure to priority chemicals. This action may result in FDOH activity related to human health impacts, public health guidance, identifying counter measures for impacted populations, laboratory support, waste disposal, and assisting with air and water sampling activities (FDOH, 2012). This activation provides assistance to CHDs in the event of a chemical disaster.

In 2008–2009 Minnesota distributed a survey to working environmental health professionals statewide through an environmental health organization to determine the preparedness level to respond to an all-hazard incident in their communities (Golob & Murphy, 2009). Several gaps were gathered from the survey including the inability to contribute to an all-hazard response due to lack of awareness of resources, no repository of environmental health emergency preparedness resources, confusion of roles and responsibilities, and lack of time and knowledge (Golob & Murphy, 2009).

Methods

SAS and Excel were used in analyzing the data. A Chi-square statistic was calculated considering variables of rural counties vs. nonrural counties and yes and no responses of the survey. For our study, the census definition of rural is defined as less than 100 persons per square mile.

The survey was validated by a panel of environmental health and preparedness experts for content validity. The survey was delivered as a voluntary online survey with a deadline of 30 days from the initial notification to the survey's population. Environmental health administrators from 67 Florida county health departments were invited to participate via an online server using SharePoint.

The survey addressed eight closed-ended (yes or no) questions (Table 1) related to chemical preparedness/disaster. Survey variables for rural vs. nonrural related to the closed-ended (yes/no) responses (Table 2) were compared to see if a significant difference occurred in rural vs. nonrural responses.

The survey also contained one open-ended question that allowed the CHD environmen-

tal health administrators to list multiple perceived roles and responsibilities in a chemical event. Themes were developed from the open-ended question and categorized based on consensus of the authors. The five major themes were consultation to outside agencies, nonroutine functions, consultation for health-related issues, routine responsibilities, and risk communication (Table 3).

Responses to the closed-ended survey were analyzed for internal consistency using Cronbach's alpha and factor analysis (Table 4).

Results

Forty-eight of the 67 CHD environmental health administrators completed the survey. Fourteen of the 19 counties that did not respond to the survey were rural counties. Survey results showed that the majority of CHD environmental health administrators are interacting with important stakeholders necessary for a chemical response (Table 1). For example, 95.8% responded "yes" when asked if a liaison is assigned to local emergency management, 83.3% were participating in LEPC meetings, and 81.3% had a liaison with emergency response. Eighty-one percent of respondents answered "yes" when asked, "Would you know what to do and who to contact during a chemical disaster?" Only 62.5% of the respondents had access to a resource manual, 58.3% had a chemical plan, and 54.2% had an employee assigned key responsibility for chemical response (Table 1).

The closed ended (yes/no) questions were evaluated comparing rural vs. nonrural counties. Question 3, "Would you know what to do and who to contact during a chemical disaster?" and Question 8, "Is another section besides environmental health involved in a chemical event?" were significant with *p*-values of .0093 and .0038, respectively (Table 2).

Rural counties were less likely than nonrural (63.16%, 93.10%, $p = .0093$) to "know what to do and who to contact" during a chemical disaster. Additionally, rural counties were less likely than nonrural counties to have other sections involved in a chemical event (26.32%, 68.97%, $p = .0038$).

Thirty-seven of the 48 CHD environmental health administrators responded to the open-ended question, "What are roles and responsibilities that you think that environmental health should be doing?" Seven rural and four nonrural counties did not respond to the open-end question. Table 3 presents the percentage of responses from environmental health administrators for each key theme (consultation to outside agencies, nonroutine functions, consultation for health-related issues, routine responsibilities, and risk communication).

TABLE **2**

Rural vs. Nonrural Perceived Preparedness and Functions in Response to a Chemical Disaster

Question	Yes/No	Rural # (%) (*n* = 19)	Nonrural # (%) (*n* = 29)	*p*-Value
Q1. Is there a liaison assigned to the local emergency management?	Yes	19 (100)	27 (93.1)	.2423
	No	0 (0)	2 (6.9)	
Q2. Is there a liaison to emergency response?	Yes	16 (84.21)	23 (79.31)	.6706
	No	3 (15.79)	6 (20.69)	
Q3. What to do and who to contact?	Yes	12 (63.16)	27 (93.10)	.0093*
	No	7 (36.84)	2 (6.90)	
Q4. Does environmental health participate in the local emergency planning committee meeting?	Yes	15 (78.95)	25 (86.21)	.5093
	No	4 (21.05)	4 (13.79)	
Q5. Do you have a first responder resource manual including contact list?	Yes	9 (47.37)	21 (72.41)	.0796
	No	10 (52.37)	8 (27.59)	
Q6. Are there environmental health plans for a chemical disaster/response?	Yes	10 (52.63)	18 (62.07)	.5166
	No	9 (47.47)	11 (39.93)	
Q7. Is there a key position responsible for a chemical response?	Yes	11 (57.89)	15 (51.72)	.6748
	No	8 (42.11)	14 (48.28)	
Q8. Is another section besides environmental health involved in a chemical event?	Yes	5 (26.32)	20 (68.97)	.0038*
	No	14 (73.32)	9 (31.03)	

**p*-Value significant.

"Consultations to outside agencies" were identified in 47.9% of the total responses as responsibilities that CHD environmental health should provide in a supporting role. The outside agencies most likely to request consultation included HAZMAT, fire department, Department of Agriculture and Consumer Services, emergency management, Department of Environmental Protection, and medical staff (Table 3). In addition, 31.3% of CHD environmental health administrators identified various duties that are "nonroutine responsibilities." Some of these nonroutine responsibilities included HAZMAT training, providing lab sample/container, first response, preparedness planning, updating contacts, providing emergency and protective equipment, participating in the incident command system, support shelter for victims, and monitoring the state warning point. "Consultations for health-related issues" were identified in 25.0% of the total responses that included providing information on chemicals, treatment, risk, safe reentry, and symptoms. "Routine environmental health job responsibilities" made up 20.8% of the responses and included water, food safety, sewage, indoor and outdoor air quality, and environmental epidemiology response. Finally, "risk communication" and education to the community accounted for 20.8% of the total responses (Table 3).

Internal consistency was measured using Cronbach's alpha, a measure of how closely related a list of items are as a group. The closer this value is to one, the more consistent a scale or questionnaire. The Cronbach's alpha for this data set was .759, indicating

TABLE **3**

Perceived Roles and Responsibilities in a Chemical Disasters (*N* = 48)

Themes and Examples	# (%)
a. Consultation to outside agencies: HAZMAT, fire department, Department of Agriculture and Consumer Services, Emergency Management, Department of Environmental Protection, and medical staff	23 (47.9)
b. Non-routine functions: HAZMAT training, providing lab sample/container, first response, preparedness planning, updating contacts, providing emergency and protective equipment, participating in the incident command system, support shelter for victims, and monitoring the state warning point	15 (31.3)
c. Consultation for health-related issues: chemical information, treatment, risk, safe reentry, symptoms, and consultation with the department of health central office	12 (25.0)
d. Routine responsibilities: water, food safety, sewage, indoor and outdoor air quality, and environmental epidemiology response	10 (20.8)
e. Risk communications: provides public health information and education to the community	10 (20.8)
f. Did not answer open-ended question: Unsure, none, or question not answered	11 (22.9)

TABLE **4**

Factor Analysis Scores for the Eight-Item Questionnaire

Question	Component 1	Component 2	Component 3
Question 1	-.014	.167	**.887**
Question 2	.361	.144	**.669**
Question 3	**.819**	.276	-.212
Question 4	-.110	**.795**	.193
Question 5	.444	**.638**	.107
Question 6	**.767**	.062	.228
Question 7	**.740**	.042	.358
Question 8	.221	**.728**	.067

Note. Bolded values indicate similarity among answers within respective components.

that this was a strongly consistent scale. Factor analysis with varimax rotation was used to determine how many principal components were present within the scale. Three primary components were identified that explained 67.52% of the variation in the data. The first component appears to relate to a county's preparedness for a chemical accident or all-hazards incident, the second component focuses on how the CHD relates to other county agencies, and the third component relates to whether or not the CHD has a liaison to other agencies (Table 4). From the results of this analysis, we can see that questions 3, 6, and 7 were answered in similar ways by the respondents; questions 4, 5, and 8 were answered in similar ways; and questions 1 and 2 were answered in similar ways. These analyses show a consistent and reliable scale while identifying interesting themes within the data.

Discussion

CHDs have not always been the lead on chemical preparedness/response practices at the local level and may not have developed or identified their role. This may be due to inadequate preparedness funding, budget restraints, staffing shortages, and competing public health responsibilities (Hyde, Kim, Martinez, Clark, & Hacker, 2006). The National Association of County and City Health Officials (NACCHO, 2013) reported that 71% of the CHDs in Florida reported loss of staff versus 36% nationally; 57% cut at least one program versus 49% nationally; 72% reported a lower budget than the previous year versus 27% nationally; and 61% expected a lower budget next year versus 31% nationally. It is important for CHDs to identify what basic preparedness/response to engage in because of recent CHD personnel reductions.

Significant differences occurred in rural counties that did not know "what to do or who to contact" in response to a chemical disaster. The majority (81.3%) of CHD environmental health administrators responded that they would, yet only 58.3% of all CHD environmental health departments have a plan. The rural counties were less likely to know "what to do and who to contact" and were also less likely to have another section besides environmental health involved in chemical response than nonrural counties. The tabletop exercise identified important aspects of who needed to be contacted and when. The safety net of the RDSTF should not preclude a rural or nonrural CHD having a plan and developing a procedure.

Our survey results have findings similar to the Minnesota survey. Several gaps were gathered from the Minnesota survey including the inability to contribute to an all-hazard response due to lack of awareness of resources, no repository of environmental health emergency preparedness resources, confusion of roles and responsibilities, and lack of time and knowledge (Golob & Murphy, 2009). The results of our study demonstrate the continued and similar weaknesses in all-hazards response and for chemical response. The RDSTF provides resources, manpower, and training to ensure that these gaps are addressed.

Risk communication and community education were the most frequent perceived responsibilities chosen by CHD environmental health administrators. It is the CHDs mission to ensure the safety and welfare of the residents so it is important to develop roles and responsibilities in preparation for disasters (Sharma, 2010). The CHDs communicate updates to the public, policy makers, internal/external response partners, and the media through coordination with the state health office (FDOH, 2012). A multidisciplinary team controls the critical information and it is maintained in compliance with the National Incident Management System. This information is disseminated to the public through

state and county public information officers (Domestic Security Oversight Council, 2011).

Protocol and training are needed to identify and provide chemical consultation, agency consultation, public health consultation, and consultation on health-related issues. Both clinical and environmental toxicology with environmental epidemiology expertise would be beneficial in identifying expected health effects of the chemicals, environmental health impacts, and the frequency and type of illness (Jeffery, Misra, & Viswanathan, 2002). Scientific support from universities, poison control centers, and federal and state environmental agencies related to medical, environmental health and impact, and risk assessment toxicology related to high-risk industries should be developed and expanded (Schwenk, Kluge, & Jaroni, 2005). Nonroutine responsibilities should be practiced through tabletop exercises.

Limitations

Questions may have been misinterpreted by the survey respondents and may have included capacity of the entire CHD in some instances and environmental health in others. Another limitation is the use of a convenience sample, which can lead to the underrepresentation or overrepresentation of particular groups within the sample (Creswell, 2014). The majority of nonresponses were from rural counties, potentially affecting the responses and results. Generalizability of findings beyond the study is limited due to the use of a convenience sample and small size for both the quantitative and qualitative portions of the survey.

Conclusion

Evidence exists that both rural and nonrural counties are engaging with stakeholders such as emergency management, emergency first responders, and LEPC. A new process may be needed in both rural and nonrural CHDs to develop plans and a first response resource manual with important contact information for all agencies including HAZMAT, fire department, Department of Agriculture and Consumer Services, emergency Management, Department of Environmental Protection, and medical staff.

It is also important to consider the rural CHDs' limited resources to develop a basic template for what rural CHDs should be prepared to do during a disaster. Additional resources are needed from the federal government or state government to support rural CHDs' preparedness as well as the development of a report card to ensure rural CHDs have the capacity to carry out rudimentary public health functions. In Florida a popular saying goes, "It is local, stupid." Anything developed has to come from the local community to improve and establish consistency in protocols, procedures, and planning at both rural and nonrural CHDs.

Acknowledgements: The authors would like to thank the Florida A&M online public health students in Topics in Public Health Class Fall 2012 for their critique of this article and valuable input. Data were presented at the 73rd NEHA Annual Educational Conference & Exhibition in Atlanta, Georgia, in 2009.

Corresponding Author: Sandra Suther, Associate Professor, Florida A&M University, Institute of Public Health, Tallahassee, FL 32307. E-mail: sandra.suther@famu.edu.

References

Belke, J. (1997). *Recurring causes of recent chemical accidents*. Washington, DC: U.S. Environmental Protection Agency, Chemical Emergency Preparedness and Prevention Office. Retrieved from http://pscfiles.tamu.edu/safety-alert/recurring-causes-of-recent-chemical-accidents.pdf

Centers for Disease Control and Prevention. (2011a). *Public health preparedness capabilities: National standards for state and local planning*. Retrieved from http://www.cdc.gov/phpr/capabilities/DSLR_capabilities_July.pdf

Centers for Disease Control and Prevention. (2011b). *Public health emergency response guide for state, local, and tribal public health directors*. Retrieved from http://www.bt.cdc.gov/planning/responseguide.asp

Council of State and Territorial Epidemiologists. (2004). *A national assessment of the status of planning for public health preparedness for chemical and radiological contaminating terrorism: CSTE's findings and recommendations*. Retrieved from http://www.cste2.org/webpdfs/ChemRad.pdf

Creswell, J.W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Thousand Oaks, CA: Sage.

Domestic Security Oversight Council. (2011). *Florida domestic security strategic plan 2012–2014*. Retrieved from http://www.fdle.state.fl.us/Content/getdoc/13b174e9-e137-41b0-98fc-09b846bc8cdb/StrategicPlanandFundingStrategyOctober2001.aspx

Eaton, D.L., & Gilbert, S.G. (2007). Principles of toxicology. In C.D. Klaassen (Ed.), *Cassarett & Doull's toxicology* (7th ed., p. 18). New York: McGraw Hill.

Florida Department of Health. (2012). *Chemical incident annex to the emergency operations plan*. Retrieved from http://www.floridahealth.gov/programs-and-services/emergency-preparedness-and-response/preparedness-planning/_documents/FDOH_EOP_Chemical_Annex.pdf

Florida Department of Law Enforcement. (n.d.). *Regional domestic security task force*. Retrieved from http://www.fdle.state.fl.us/content/getdoc/48f59c85-35bf-453f-a806-bda267c91439/Domestic-Security-Homepage.aspx

Golob, B.R., & Murphy, T.J. (2009). *Assessing and promoting environmental health preparedness in Minnesota*. Retrieved from http://www.cdc.gov/nceh/ehs/topics/EmergencyPreparedness.htm

Hyde, J., Kim, B., Martinez, L.S., Clark, M., & Hacker, K. (2006). Better prepared but spread too thin: The impact of emergency pre-

References

paredness funding on local public health. *Disaster Management & Response, 4*(4), 106–113.

James Martin Center for Nonproliferation Studies. (2002). *The Monterey WMD terrorism database page*. Retrieved from http://cns.miis.edu/reports/cbrn2k1.htm

Jeffery, F.N., Misra, V., & Viswanathan, P.N. (2002). Convergence of clinical toxicology and epidemiology in relation to health effects of chemicals. *Environmental Toxicology and Pharmacology, 12*(3), 169–179.

LaTourette, T., Davis, L., Howell, D.R., Preethi, S.R., & Dausey, D.J. (2009). *Public health preparedness and response to chemical and radiological incidents*. Retrieved from http://www.rand.org/pubs/technical_reports/TR719.html

Meyer, J., & Weiselberg, L. (2009). *County and city health departments: The need for sustainable funding and the potential effect of reform on their operations*. Retrieved from http://healthyamericans.org/assets/files/HMA.pdf

National Association of County and City Health Officials. (2013). *Local health department job losses and program cuts: State-level tables from the 2013 profile study*. Retrieved from http://www.naccho.org/topics/infrastructure/lhdbudget/upload/State-Tables-Brief-8-13-13-2.pdf

Regional Domestic Security Task Force. (2012). *About RDSTF*. Retrieved from http://www.tbrpc.org/rdstf

Robert Wood Johnson Foundation. (2010). *Shortchanging America's health. A state-by-state look at how public health dollars are spent and key state health effects*. Retrieved from http://www.rwjf.org/content/dam/web-assets/2010/03/shortchanging-america-s-health

Schwenk, M., Kluge, S., & Jaroni, H. (2005). Toxicological aspects of preparedness and aftercare for chemical incidents. *Toxicology, 214*(3), 232–248.

Sharma, R.K. (2010). Chemical, biological, radiological and nuclear disasters: Pitfalls and perils. *Journal of Pharmacy & BioAllied Sciences, 2*(3), 155–156.

U.S. Department of Homeland Security. (2007). *Target capabilities list: A companion to the national preparedness guidelines*. Retrieved from http://www.fema.gov/pdf/government/training/tcl.pdf

Yu, M., Tsunoda, H., & Tsunoda, M. (2011). Environmental toxicology: Factors affecting xenobiotic action. In *Environmental toxicology: Biological and health effects of pollutants* (3rd ed., pp. 73–74). New York: CRC Press.

SPECIAL REPORT

Bisphenol A: A Threat to Human Health?

Seema Srivastava, PhD
Priya Gupta, MSc
Anil Chandolia, MSc
Imtiyaz Alam, MSc
Department of Zoology
University of Rajasthan

Abstract **All of us now carry in our bodily tissues a virtual stew of heavy metals and hundreds of synthetic chemicals: persistent ones, which can have a "half-life" in the body of several years; and nonpersistent compounds, which may pass through the body in a matter of hours. Bisphenol A (BPA) is a nonpersistent compound that can alter the reproductive system of laboratory animals even at extremely low exposure levels. This is relevant because BPA is chronically present in our environment with the potential for constant exposure, making it functionally equivalent to a persistent compound. In this review the authors emphasize particular outcomes that occur in response to the relevant dose of BPA exposure that causes developmental effects on reproductive systems, brain and metabolic processes, and the male germ line. At a specific dose level, BPA exposure also shows oxidative toxicity and carcinogenic effects.**

Introduction

Bisphenol A (BPA) is an anthropogenic chemical made up of two phenolic rings and joined by a bridging group formed by the reaction of phenol with acetone (Figure 1). Solid at ambient temperatures, usually as a white powder or flake, BPA is used as the building block for polycarbonate plastic and epoxy resins, mainly in dental sealants, eyeglasses, food containers, infant bottles, reusable water bottles, medical devices, compact discs, epoxy-phenolic resins in the surface coating of drinking water storage tanks, photographic film, and in polycarbonate for water pipes, which means that BPA is almost everywhere around us in the form of our daily usable goods. As a component of polycarbonate plastic, over six billion pounds of BPA are produced each year (Welshons, Nagel, & vom Saal, 2006).

BPA acts as an endocrine disruptor that mimics the structure and function of the 17-β estradiol hormone and has the ability to bind with estrogen receptors. A 2008 report by the National Toxicology Program cited the adverse effects of BPA on fetuses, infants, and children. In 2010 the Food and Drug Administration banned the use of BPA in baby bottles. In September 2010 Canada's environmental science department declared BPA to be a "toxic substance." The presence of BPA in the environment can cause serious health problems, although opinions vary on this point. Studies on BPA have shown the increased susceptibility to cancerous changes (Jenkins et al., 2009), effects on fertility and reproductive tract (Al-Hiyasat, Darmani, & Elbetieha, 2002), oxidative toxicity (Kabuto, Amakawa, & Shishibori, 2004), neurotoxic effects (Le, Carlson, Chua, & Belcher, 2008), genotoxic effects (Karim & Husain, 2010; Naik & Vijayalaxmi, 2009), and other health problems (Fernandez et al., 2007).

Exposure Assessment

Exposure is predominantly oral. BPA molecules are bound by an ester bond, which is disrupted by heat or acidic or basic conditions and releases BPA into food or beverages in contact with the plastics (European Commission, 2008). The highest estimated BPA dietary exposures were for infants 0–6 months of age who were exclusively fed with canned liquid infant formula using polycarbonate bottles. In this case, sources of BPA exposure include migration from both the formula packaging and the polycarbonate bottle.

Infants who were either fed with formula from nonpolycarbonate bottles or exclusively breastfed had substantially lower estimated BPA exposures compared with those exclusively fed with infant formula using polycarbonate bottles. Once solid foods are introduced, an infant's exposure to BPA decreases relative to body weight (World Health Organization, 2010). BPA exposure from nonfood sources (e.g., thermal paper, medical equipment) is generally lower than that from food sources. The dietary exposure estimates for four population groups are summarized in Table 1. From this exposure estimate experts conclude that food is by far the major contributor of overall exposure to BPA for most population groups.

BPA and Human Health

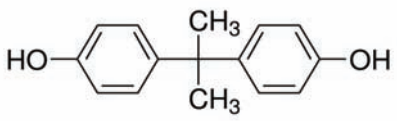
Any acute or chronic changes are the result of slow and long-term exposure of BPA. Although BPA affects humans differently under various doses, we have considered the following criteria as major effects of long-term exposure.

Reproductive System

We discuss here the effects of BPA on male and female fertility. Numerous environmental toxicants adversely affect spermatogenesis in rodents and humans, which can lead to low sperm count, abnormal sperm morphology, and poor semen quality in males (Al-Hiyasat et al., 2002) along with chromosomal abnormalities, fetal loss, endometriosis, menstruation irregularities, spontaneous abortion,

FIGURE **1**

Biphenyl A: 2, 2,-bis (4-hydroxyphenyl) Propane



and reduced fertility in females (Sharara, Seifer, & Flaws, 1998). BPA is a toxicant in a group that includes other chemicals such as chlorinated hydrocarbons, pesticides, glycol ether, phthalates, and heavy metals.

BPA has been considered a weak estrogen because of its low potency compared with estradiol in assays involving nuclear receptors (Blair et al., 2001; Thomas & Dong, 2006). Low levels of BPA, however, act additively with xenoestrogen and natural estrogens (Silva, Rajapakse, & Kortenkamp, 2002; Soto, Chung, & Sonnenschein, 1994; Soto, Fernandez, Luizzi, Oles Karasko, & Sonnenschein, 1997; Tollefesen, 2002). Several studies have pointed out that rodents exposed to BPA during the prenatal or perinatal period show a large variety of adverse reproductive outcomes, including decreased epididymal weight and increased sloughing from the seminiferous epithelium (Richter et al., 2007; Salian, Doshi, & Vanage 2009a, 2009b; vom Saal et al., 1998) and increased prostate weight (Nagel et al., 1997).

Regarding prepubertal or pubertal exposures, rodent studies have shown decrement in epididymal sperm counts after BPA exposure (Herath et al., 2004). During adult exposure, changes in sperm morphology such as abnormalities in the acrosomal cap, vesicle, and deformed nuclei were found in Wistar and Swiss rats at 20 µg/kg day (Chitra, Latchoumycandane, & Mathur, 2003).

Prepubertal or pubertal and adult exposures show a decrease in plasma concentrations of testosterone levels (Herath et al., 2004; Takao et al., 1999) Luteinizing hormone (LH) levels were increased in BPA-treated male rats, which shows that BPA causes hormonal imbalances (Tohei, Suda, Taya, Hashimoto, & Kogo, 2001). BPA may also have antiandrogenic activity, for example at a wide range of concentration. That is,

TABLE **1**

Sources of Exposure in Population and Its Dietary Estimates

Population	Source of Exposure	Dietary Exposure Estimate (µg/kg body weight per day)	
		Mean	95th Percentile
Infants 0–6 months	Exclusively breastfed	0.3	1.3
	Polycarbonate bottles and formula[a] (powder/liquid)	2.0–2.4	2.7–4.5
	Formula, no polycarbonate bottles[a] (powder/liquid)	0.01–0.5	0.1–1.9
Infants 6–36 months	Breastfed and solid food (best case-worst case)[b]	0.1	0.3–0.6[c]
	Polycarbonate bottles and formula[a] and solid food (best case-worst case)[b]	0.5–0.6	1.6–3.0[c]
	Formula only, no polycarbonate bottles[a] and solid food (best case-worst case)[b]	0.01–0.1	0.1–1.5[c]
Children 3+ years	Fruits, desserts, vegetables, meat, soups, seafood, carbonated drinks (best case-worst case)[b]	0.2–0.7	0.5–1.9[c]
Adults	Fruits, vegetables, grains, meat, soups, seafood, desserts, carbonated drinks, tea, coffee, alcoholic beverages (best case-worst case)[b]	0.4–1.4	1.0–4.2[c]

[a]Assumes formula only, no breast milk.

[b]Worst case is assuming the daily consumption of 100% packaged food and beverages, and the best case is assuming the daily consumption of 25% packaged food and beverages.

[c]Because of the use of the budget method model, maximum consumption is reported in these upper range of exposure estimates.

2–400 mg/kg/day of gestation was found with significantly lower regulated steroidogenic acute regulatory protein, which is a nuclear transporter protein critical for steroid biosynthesis in steroid-producing organs such as testes, ovaries, and adrenal glands in fetal rats (Manna, Dyson, & Stocco, 2009).

BPA causes infertility or subfertility when postnatal exposure occurs at oral dosing of rats with 50 mg/kg/day by disrupting the blood-testis barrier (Li, Mruk, Lee, & Cheng, 2009), which is a hormone-dependent structure also essential for germ cell development; without proper functioning, germ cells do not develop into mature sperm. Prolonged disruption causes infertility (Bonde et al., 2010; Delbès, Hales, & Robaire, 2010). Neonatal exposure of BPA doses at 10 g/kg/day impairs fertility by protuberating Sertoli cell junctional protein (adhesion, gap, and tight junction) that leads to impaired spermatogenesis (Salian et al., 2009a).

BPA causes significant disruption of the alignment of chromosomes and aneuploidy observed in the developing oocyte in females, which is also a cause of spontaneous abortion in humans (Hunt et al., 2003). With this finding it was predicted that an increase in mortality of embryos would occur at a maternal dose of 25 µg/kg/day (Al-Hiyasat, Darmani, & Elbetieha, 2004). Implantation of embryos is not affected at low BPA maternal doses (as low as 10 µg/kg/day), and is significantly decreased only at a maternal dose of approximately 70 mg/kg/day, which is just above the low-dose range (Berger, Hancock, & deCatanzaro, 2007). In one study, BPA-exposed females delivered a significantly smaller number of pups and animals due to development of polycystic ovarian syndrome (Fernandez, Bourguignon, Lux-Lantos, & Libertun, 2010).

Neonatal exposure to BPA was associated with altered gene expression and hormone responsiveness in uterine stroma in adulthood, which could contribute to impaired fertility (Varayoud, Ramos, Bosquiazzo, Muñoz De Toro, & Luque, 2008). Other effects, however, such as effects on sex hormone levels during pregnancy or oocyte quality, could also contribute to reduced fertility. Indeed, oocytes are one of the longest-lived nonregenerating cells in the body and are subject to a lifetime of environmental exposures that are difficult to quantify (Crain et al., 2008). Vascular endothelial growth factor (VEGF) plays a role in

the regulation of uterine microvascular permeability and angiogenesis in the implantation process (Ferrara, Gerber, & LeCouter, 2003; Halder et al., 2000). Postnatal exposure of BPA at a dose of 0.05 mg/kg/day disturbed VEGF expression due to a change in endocrine pathways and impaired the implantation process, so negative effects on fertility occurred in adult rats (Bosquiazzo et al., 2010).

Developmental Effects

Over the last several decades, hundreds of experimental studies have been conducted, mostly with rats and mice, on the potential reproductive and developmental toxicity of BPA. To make these effects relevant to human health, researchers considered a specific dose of BPA exposure that is relevant to human exposure levels, i.e., a dose resulting in serum levels close to those observed in human serum (below 1 mg/kg/day). The reproductive and developmental effects from low-dose exposure caused permanent changes to the genital tract (Markey, Wadia, Rubin, Sonnenschein, & Soto, 2005), lower body weight, increase of anogenital distance in both genders (Honma et al., 2002), and disruption of ovarian development (Adewale, Jefferson, Newbold, & Patisaul, 2009).

Immune System

BPA has been reported to modulate immune function at doses between 2.5 and 30 µg/kg/day (Sawai, Anderson, & Walser-Kuntz, 2003; Yoshino et al., 2003), including patterns of cytokine and antibody production, response to infection, and autoimmune disease progression. T-helper lymphocytes are a source of cytokine families that stimulate inflammatory responses and resistance to intracellular infections (Th1 cytokines), or that shift the response to antibody production, resistance to extracellular organisms, and allergy (Th2 cytokines). BPA may enhance or shift the pattern of cytokine production following antigen stimulation. Skewing of the Th1/Th2 cytokine profile by endocrine-disrupting compounds has been associated with allergy and asthma (Chalubinski & Kowalski, 2006). Exposure to BPA has also been associated with modulation of innate immune system cell function, for example in the administration of 5 mg/kg/day subcutaneously to adult BALB/c mice for 5 days (Sugita-Konishi et al., 2003).

The effects of BPA exposure on the immune system may be critically dependent on the timing of exposure. Estrogen receptor expression by lymphocytes is dependent upon the age and strain of the animal; in addition, recent evidence suggests the spleen undergoes significant molecular remodeling during puberty, resulting in both age and gender-dependent differences in immune gene expression (Lamason et al., 2006). Nevertheless, studies conducted by Yoshino and co-authors (2003) indicate similar dose-associated, gender-independent immune system effects in eight-week-old offspring of BPA-exposed dams and animals exposed as adults. These results suggest quantitative, rather than qualitative, differences in lifestage-dependent immune system sensitivity to BPA.

Neurobehavioral, Neurotoxic, and Neuroendocrine Effects

BPA-induced changes in function of the hypothalamus pituitary-gonad axis have been observed in both males and females. Effects on LH, prolactin, and brain aromatase activity in males, and disruption of LH and estrous cyclicity resulting in elongated estrous phase in females (Rubin, Murray, Bamassa, King, & Soto, 2001) have been observed on weaning mice. Low-dose exposures of BPA during development have persistent effects on brain structure, function, and behavior in rats and mice (Richer et al., 2007). The European Union report (European Commission, 2008) included a review of all studies on the effects on neurological development following prenatal and perinatal exposure to BPA. The neurotoxicity endpoints were evaluated as locomotory and exploratory activity; cognitive, emotional, social, sexual, and maternal behavior; behavior response to pharmacological challenge; brain morphology; immunohistochemistry; and receptor/gene expression. For a better understanding of the potential neurotoxicity risk of BPA, BPA should be studied in terms of validity and reliability of the test systems and for their relevance for effects on the behavior and cognitive development of humans and relevant exposure and exposure routes.

Metabolic Effects

BPA can contribute to the onset of metabolic diseases (e.g., obesity and diabetes mellitus), which may indirectly affect male fertility. Administration of BPA (i.e., 10 µg/kg/day for two days) stimulated insulin production by pancreatic β cells in adult mice. Adults with the highest levels of circulating BPA were more than twice as likely to develop diabetes as those with lower levels of BPA (Alonso-Magdalena, Ropero, Soriano, Quesada, & Nadal, 2010; Alonso-Magdalena, Quesada, & Nadal, 2011). BPA is lipophilic, and it can accumulate in fat stores to increase the number and size of adipocytes, thereby resulting in weight gain. Adipocytes also express endrogen receptors to which BPA binds (Pedersen et al., 2001). Obesity itself is a risk factor for diabetes, cancer, infertility, and a host of other diseases, which have also been linked to environmental toxicant exposure.

Genotoxicity

Genotoxic studies of BPA were realized using in vitro and in vivo evaluations with controversial results. Bucher (2010) reported that BPA is not a mutagen in in vitro tests, nor does it induce cell transformation. BPA has been shown to affect chromosomal structure in in vitro studies, but no evidence exists for in vivo studies. In vivo genotoxic potential of BPA was studied by Naik and Vijayalaxmi (2009) in mouse bone marrow cells using cytogenetical assays, as chromosomal aberrations, micronucleus test, and c-mitotic effects. They applied single oral doses of 10, 50, and 100 mg/kg and repeated oral doses of 10 mg/kg for five days. Their investigation revealed that although BPA failed to induce conventional chromosomal aberrations and micronuclei, its genotoxic effects were manifested in the form of achromatic lesions and c-mitotic effects in bone marrow cells of Swiss albino mice. Later they studied genotoxic effects of BPA and octylphenol (OP) in rats using comet assay. They observed significant differences in animals that received BPA 250 mg/kg/day and OP 250 mg/kg/day compared with the control group. Oral administration of BPA and OP may posses a genotoxic risk in rats at high doses of tested chemicals and may not be so critical in low doses (Ulutas et al., 2011). Furthermore, a need exists for studies to explore mechanisms of the genotoxic potential of BPA in vivo.

Oxidative Toxicity

Several studies reported the occurrence of oxidative toxicity after BPA exposure in rats and mice (Chitra, Rao, & Mathur, 2003;

Gong & Han, 2006). It was suggested that BPA caused tissue injury in the liver, kidney, brain, and other organs by the formation of reactive oxygen species (Bindhumol, Chitra, & Mathur, 2003; Kabuto et al., 2004). Moreover, the study of Bindhumol and co-authors (2003) revealed that low doses of BPA generate reactive oxygen species by decreasing the activities of antioxidant enzymes and increasing lipid peroxidation thereby causing oxidative stress in liver of rats. Vitamin E (α-tocopherol), a powerful lipophilic antioxidant (Yoganathan, Eskild, & Hansson, 1989), has also been shown to suppress lipid peroxidation in testicular microsomes and mitochondria (Gavazza & Catala, 2006; Lucesoli & Fraga, 1999) and to reverse the detrimental effects of oxidative stress mediated by exposure to such factors as polychlorinated biphenyls and cyclophosphamide (Senthil et al., 2004). Short-term BPA exposure may partly inhibit the reproductive function in adolescent male mice with certain stimulating effects on antioxidant ability, and supplementation of vitamin E during BPA exposure may have certain protective effects on reproductive inhibition caused by it (Fang, Zhou, Zhong, Gao, & Tan, 2013).

Carcinogenicity

BPA exposure during the perinatal period has been reported to alter both prostate and mammary gland development in ways that may render these organs more susceptible to the development of neoplasia or preneoplastic conditions.

Prostate Gland

Prenatal exposure to BPA may affect the development of prostate cancer in later life. Maternal oral dose of 10 µg BPA/kg/day of gestation stimulated an increase in the number of primary prostatic ducts as well as proliferation of basal cells (the progenitor cells thought to be responsible for the development of prostate cancer) in the dorsolateral region, but not in ventral primary ducts as seen in male CD1 mouse fetuses (Timms et al., 2005). Interestingly, the similar dose of BPA administered via injection to neonatal rats resulted in 100% of the subsequent adult males exhibiting prostate intraepithelial neoplasia lesions, which are pretumorous prostate cancer lesions (Ho, Tang, Belmonte de Frausto, & Prins, 2006). In another study prenatal exposure at dose 25 µg/kg/day in Wistar rats caused cell proliferation in ventral ducts (Ramos et al., 2001). This finding is different from those reported by Timms and co-authors (1999) in which male Sprague Dawley rats exposed to the highest natural serum level of E2 (17-β estradiol) showed enlargement of the dorsolateral prostrate but not the ventral prostrate.

Mammary Gland

Terminal end buds of the mammary gland are particularly sensitive to carcinogenic events (Russo & Russo, 1996). It has been speculated that BPA exerts several estrogenic effects on the rodent mammary gland (Richter et al., 2007). This may be an indirect response to the modulation of the timing of puberty because early commencement of puberty can affect the development of the mammary gland through premature exposure to ovarian hormones, such as estrogen and progesterone, both of which affect growth and development (Medina, 2005). In the mammary gland, fetal exposure of female CD1 mice to BPA causes differences in ductal invasion as well the number of ducts and terminal end and alveolar buds in adults (Markey, Luque, Munoz De Toro, Sonnenschein, & Soto, 2001; Munoz De Toro et al., 2005). Fetal exposures also increased ductal area and ductal extension in (embryonic day 18) female mammary glands in the same strain of mice (Vandenberg et al., 2007) whereas in Sprague-Dawley and Wistar rats, BPA led to an increase in susceptibility to carcinogen-induced mammary tumors, although no spontaneous tumors were observed (Betancourt, Eltoum, Desmond, Russo, & Lamartiniere, 2010; Murray, Maffini, Ucci, Sonnenschein, & Soto, 2007) Hence, their increase following BPA exposure suggests that these mice may be at increased risk for mammary tumor genesis. Supporting this postulate, intraductal mammary epithelial hyperplasias have been observed in CD1 mice exposed to BPA during fetal life or prenatally (Vandenberg et al., 2008). BPA may increase mammary tumor genesis through at least two mechanisms: molecular alteration of fetal glands without associated morphological changes and direct promotion of estrogen-dependent tumor cell growth. Both results indicate that exposure to BPA during various biological states increases the risk of developing mammary cancer in mice (Lozada & Keri, 2011).

Conclusion

Data demonstrate that BPA functions as a xenoestrogen (synthetic estrogen) and changes the expression of the endocrine receptor by binding with them. Prenatal and neonatal periods are critical because during these time frames BPA exposure affects many tissue, organ, and biological pathways that compromise testicular function and semen quality directly or indirectly, thereby leading to subfertility or infertility. It appears to be species and strain specific in terms of sensitivity of particular outcomes. Extensive evidence exists that BPA affects developmental changes in the brain, behavior, and signaling systems. Results from studies may reflect that the estrogenic effect of BPA could be related to an inhibitory effect on testicular steroid genesis and spermatogenesis. Although no evidence indicates that oral ingestion of BPA by humans at exposure levels typical of its presence in the environment has adverse effects, blood BPA levels in pregnant mothers and their fetuses are of concern. BPA exposure at the workplace as seen in a cohort study also gives evidence that it has an adverse effect on male sexual dysfunction and shows a dose-response relationship of BPA exposure.

This finding not only has public health implications for male fertility, but possibly for other health outcomes as well, since male sexual function may be a more sensitive and easily measured end point that provides early signals about the adverse BPA effects on other endpoints that are more difficult to study. Associations between BPA exposure and measures of reproductive function in fertile men, however, were small and of uncertain clinical significance. Vertical transmissions of BPA exposure at different dose levels need to be confirmed by additional studies. Nevertheless, given the extensive use of BPA in consumer products to which humans are chronically exposed, these findings increase the need to examine the health effects of BPA in both occupationally and environmentally exposed populations at the relevant dose level.

Corresponding Author: Seema Srivastava, Associate Professor, Department of Zoology, University of Rajasthan, Jaipur-302004, Rajasthan, India. E-mail: drseemaa07@gmail.com.

References on page 24

References *continued from page 23*

Adewale, H.B., Jefferson, W.N., Newbold, R.R., & Patisaul, H.B. (2009). Neonatal bisphenol A exposure alters rat reproductive development and ovarian morphology without impairing activation of gonadotropin releasing hormone neurons. *Biology of Reproduction*, *81*(4), 690–699.

Al-Hiyasat, A.S., Darmani, H., & Elbetieha, A.M. (2002). Effects of bisphenol A on adult male mouse fertility. *European Journal of Oral Sciences*, *110*(2), 163–167.

Al-Hiyasat, A.S., Darmani, H., & Elbetieha, A.M. (2004). Leached components from dental composites and their effects on fertility of female mice. *European Journal of Oral Science*, *112*(3), 267–272.

Alonso-Magdalena, P., Quesada, I., & Nadal, A. (2011). Endocrine disruptors in the etiology of type 2 diabetes mellitus. *Nature Reviews—Endocrinology, 7*(6), 347–353.

Alonso-Magdalena, P., Ropero, A.B., Soriano, S., Quesada, I., & Nadal, A. (2010). Bisphenol A: A new diabetogenic factor? *Hormones (Athens)*, *9*(2), 118–126.

Berger, R.G., Hancock, T., & deCatanzaro, D. (2007). Influence of oral and subcutaneous bisphenol A on intrauterine implantation of fertilized ova in inseminated female mice. *Reproductive Toxicology*, *23*(2), 138–144.

Betancourt, A.M., Eltoum, I.A., Desmond, R.A., Russo, J., & Lamartiniere, C.A. (2010). In utero exposure to bisphenol A shifts the window of susceptibility for mammary carcinogenesis in the rat. *Environmental Health Perspectives*, *118*(11), 1614–1619.

Bindhumol, V., Chitra, K.C., & Mathur, P.P. (2003). Bisphenol A induces reactive oxygen species generation in the liver of male rats. *Toxicology*, *188*(2–3), 117–124.

Blair, R.M., Fang, H., Branham, W.S., Hass, B.S., Dial, S.L., & Moland, C.L. (2001). The estrogen receptor relative binding affinities of 188 natural and xenochemicals: Structural diversity of ligands. *Toxicological Science*, *54*(1), 138–153.

Bonde, J.P. (2010). Male reproductive organs are at risk from environmental hazards. *Asian Journal of Andrology*, *12*(2), 152–156.

Bosquiazzo, V.L., Varayoud, J., Muñoz de Toro, M., Luque, E.H., & Ramos, J.G. (2010). Effects of neonatal exposure to bisphenol A on steroid regulation of vascular endothelial growth factor expression and endothelial cell proliferation in the adult rat uterus. *Biology of Reproduction*, *82*(1), 86–95.

Bucher, J.R. (2010, November). *Background paper on genotoxicity of bisphenol A*. Paper presented at the FAO/WHO Expert Meeting on Bisphenol A (BPA), Ottawa, Canada.

Chalubinski, M., & Kowalski, M.L. (2006). Endocrine disruptors—potential modulators of the immune system and allergic response. *Allergy*, *61*(11), 1326–1335.

Chitra, K.C., Latchoumycandane, C., & Mathur, P.P. (2003). Induction of oxidative stress by bisphenol A in the epididymal sperm of rats. *Toxicology*, *185*(1–2), 119–127.

Chitra, K.C., Rao, K.R., & Mathur, P. (2003). Effect of bisphenol A and co-administration of bisphenol A and vitamin C on epididymis of adult rats: A histopathological and biochemical study. *Asian Journal of Andrology*, *5*(3), 203–208.

Crain, D.A., Janssen, S.J., Edwards, T.M., Heindel, J., Ho, S.M., Hunt, P., Iguchi, T., Juul, A., McLachlan, J.A., Schwartz, J., Skakkebaek, N., Soto, A.M., Swan, S., Walker, C., Woodruff, T.K., Woodruff, T.J., Giudice, L.C., & Guillette, L.J., Jr. (2008). Female reproductive disorders: The roles of endocrine-disrupting compounds and developmental timing. *Fertility and Sterility*, *90*(4), 911–940.

Delbès, G., Hales, B.F., & Robaire, B. (2010). Toxicants and human sperm chromatin integrity. *Molecular Human Reproduction*, *16*(1), 14–22.

European Commission. (2008). *European Union risk assessment report: Bisphenol A*. Retrieved from http://echa.europa.eu/documents/10162/d1d9e186-4385-4595-b6cb-5a1a7a160f07

Fang, Y., Zhou, Y., Zhong, Y., Gao, X., & Tan, T. (2013). Effect of vitamin E on reproductive functions and antioxidant activity of adolescent male mice exposed to bisphenol A [Article in Chinese]. *Journal of Hygiene Research*, *42*(1), 18–22.

Fernandez, M.F., Arrebola, J.P., Taoufiki, J., Navalon, A., Ballesteros, O., Pulgar, R., Vilchez, J.L., & Olea, N. (2007). Bisphenol A and chlorinated derivatives in adipose tissue of women. *Reproductive Toxicology*, *24*(2), 259–264.

Fernandez, M., Bourguignon, N., Lux-Lantos, V., & Libertun, C. (2010). Neonatal exposure to bisphenol A and reproductive and endocrine alterations resembling the polycystic ovarian syndrome in adult rats. *Environmental Health Perspectives*, *118*(9), 1217–1222.

Ferrara, N., Gerber, H.P., & LeCouter, J. (2003). The biology of VEGF and its receptors. *Nature Medicine*, *9*(6), 669–676.

Gavazza, M.B., & Catala, A. (2006). The effect of alpha-tocopherol on lipid peroxidation of microsomes and mitochondria from rat testis. *Prostaglandins, Leukotrienes, and Essential Fatty Acids*, *74*(4), 247–254.

Gong, Y., & Han, X.D. (2006). Nonylphenol-induced oxidative stress and cytotoxicity in testicular sertoli cells. *Reproductive Toxicology*, *22*(4), 623–630.

Halder, J.B., Zhao, X., Soker, S., Paria, B.C., Klagsbrun, M., & Das, S.K. (2000). Different expression of VEGF isoforms and VEGF specific receptor neuropilin-1 in the mouse uterus suggests a role for VEGF in vascular permeability and angiogenesis during implantation. *Genesis*, *26*(3), 213–224.

Herath, C.B., Jin,W., Watanabe, G., Arai, K., Suzuki, A.K., & Taya, K. (2004). Adverse effects of environmental toxicants, octylphenol and bisphenol A, on male reproductive functions in pubertal rats. *Endocrinology*, *25*(2), 163–172.

Ho, S.M., Tang, W.Y., Belmonte de Frausto, J., & Prins, G.S. (2006). Developmental exposure to estradiol and bisphenol A increases susceptibility to prostate carcinogenesis and epigenetically regulates phosphodiesterase type 4 variant 4. *Cancer Research*, *66*(11), 5624–5632.

References

Honma, S., Suzuki, A., Buchanan, D.L., Katsu, Y., Watanabe, H., & Iguchi, T. (2002). Low dose effect of in utero exposure to bisphenol A and diethylstilbestrol on female mouse reproduction. *Reproductive Toxicology*, *16*(2), 117–122.

Hunt, P.A., Koehler, K.E., Susiarjo, M., Hodges, C.A., Hagan, A., Voigt, R.C., Thomas, S., Thomas, B.F., & Hassold, T.J. (2003). Bisphenol A causes meiotic aneuploidy in the female mouse. *Current Biology*, *13*(7), 546–553.

Jenkins, S., Raghuraman, N., Eltoum, I., Carpenter, M., Russo, J., & Lamartinere, C. (2009). Oral exposure to bisphenol A increase dimethylbenzanthracene-induced mammary cancer in rats. *Environmental Health Perspectives*, *117*(6), 910–915.

Kabuto, H., Amakawa, M., & Shishibori, T. (2004). Exposure to bisphenol A during embryonic fetal life and infancy increases oxidative injury and causes underdevelopment of the brain and testis in mice. *Life Sciences*, *74*(24), 2931–2940.

Karim, Z., & Husain, Q. (2010). Application of fly ash adsorbed peroxidase for the removal of bisphenol A in batch process and continuous reactor: Assessment of genotoxicity of its product. *Food and Chemical Toxicology*, *48*(12), 3385–3390.

Lamason, R., Zhao, P., Rawat, R., Davis, A., Hall, J., Chae, J., Agarwal, R., Cohen, P., Rosen, A., Hoffman, E.P., & Nagaraju, K. (2006). Sexual dimorphism in immune response genes as a function of puberty. *BioMedCentral Immunology*, *7*, 1472.

Le, H.H., Carlson, E.M., Chua, J.P., & Belcher, S.M. (2008). Bisphenol A is released from polycarbonate drinking bottles and mimics the neurotoxic actions of estrogen in developing cerebellar neurons. *Toxicology Letters, 176*(2), 149–156.

Li, M.W., Mruk, D.D., Lee, W.M., & Cheng, C.Y. (2009). Disruption of the blood-testis barrier integrity by bisphenol A in vitro: Is this a suitable model for studying blood-testis barrier dynamics? *International Journal of Biochemistry and Cell Biology*, *41*(11), 2302–2314.

Lozada, K.W., & Keri, R.A. (2011). Bisphenol A increases mammary cancer risk in two distinct mouse models of breast cancer. *Biology of Reproduction*, *85*(3), 490–497.

Lucesoli, F., & Fraga, C.G. (1999). Oxidative stress in testes of rats subjected to chronic iron intoxication alpha-tocopherol supplementation. *Toxicology*, *132*(2–3), 179–186.

Manna, P.R., Dyson, M.T., & Stocco, D.M. (2009). Regulation of the steroidogenic acute regulatory protein gene expression: Present and future perspectives. *Molecular Human Reproduction*, *15*(6), 321–333.

Markey, C.M., Luque, E.H., Muñoz De Toro, M., Sonnenschein, C., & Soto, A.M. (2001). In utero exposure to biphenyl A alters the development and tissue organization of the mouse mammary gland. *Biology of Reproduction*, *65*(4), 1215–1223.

Markey, C.M., Wadia, P.R., Rubin, B.S., Sonnenschein, C., & Soto, A.M. (2005). Long-term effects of fetal exposure to low doses of the xenoestrogen bisphenol A in the female mouse genital tract. *Biology of Reproduction*, *72*(6), 1344–1351.

Medina, D. (2005). Mammary developmental fate and breast cancer risk. *Endocrinology-Related Cancer*, *12*(3), 483–495.

Muñoz De Toro, M., Markey, C.M., Wadia, P.R., Luque, E.H., Rubin, B.S., Sonnenschein, C., & Soto, A.M. (2005). Perinatal exposure to bisphenol A alters peripubertal mammary gland development in mice. *Endocrinology*, *146*(9), 4138–4147.

Murray, T.J., Maffini, M.V., Ucci, A.A., Sonnenschein, C., & Soto, A.M. (2007). Induction of mammary gland ductal hyperplasias and carcinoma in situ following fetal bisphenol A exposure. *Reproductive Toxicology*, *23*(3), 383–390.

Nagel, S.C., vom Saal, F.S., Thayer, K.A., Dhar, M.G., Boechler, M., & Welshons, W.V. (1997). Relative binding affinity-serum modified access (RBA-SMA) assay predicts the relative in vivo bioactivity of the xenoestrogens bisphenol A and octylphenol. *Environmental Health Perspectives*, *105*(1), 70–76.

Naik, P., & Vijayalaxmi, K.K. (2009). Cytogenetic evaluation for genotoxicity of bisphenol A in bone marrow cells of Swiss albino mice. *Mutation Research*, *676*(1–2), 106–112.

Pedersen, S.B., Bruun, J.M., Hube, F., Kristensen, K., Hauner, H., & Richelsen, B. (2001). Demonstration of estrogen receptor subtypes α and β in human adipose tissue: Influences of adipose cell differentiation and fat depot localization. *Molecular Cell Endocrinology*, *182*(1), 27–37.

Ramos, J.G., Varayoud, J., Sonnenschein, C., Soto, A.M., Muñoz De Toro, M., & Luque, E.H. (2007). Prenatal exposure to low doses of bisphenol A alters the periductal stroma and glandular cell function in the rat ventral prostate. *Biology of Reproduction, 65*(4), 1271–1277.

Richter, C.A., Birnbaum, L.S., Farabollini, F., Newbold, R.R., Rubin, B.S., Talsness, C.E., Vandenbergh, J.G., Walser-Kuntz, D.R., & vom Saal, F.S. (2007). In vivo effects of bisphenol A in laboratory rodent studies. *Reproductive Toxicology*, *24*(2), 199–224.

Rubin, B.S., Murray, M.K., Bamassa, D.A., King, J.C., & Soto, A.M. (2001). Perinatal exposure to low doses of bisphenol A affects body weight, patterns of estrous cyclicity, and plasma LH levels. *Environmental Health Perspectives*, *109*(7), 675–680.

Russo, I.H., & Russo, J. (1996). Mammary gland neoplasia in long-term rodent studies. *Environmental Health Perspectives*, *104*(9), 938–967.

Salian, S., Doshi, T., & Vanage, G. (2009a). Neonatal exposure of male rats to bisphenol A impairs fertility and expression of sertoli cell junctional proteins in the testis. *Toxicology*, *265*(1–2), 56–67.

Salian, S., Doshi, T., & Vanage, G. (2009b). Perinatal exposure of rats to bisphenol A affects the fertility of male offspring. *Life Science*, *85*(21–22), 742–752.

continued on page 26

References *continued from page 25*

Sawai, C., Anderson, K., & Walser-Kuntz, D. (2003). Effect of bisphenol A on murine immune function: Modification of interferon-γ, IgG2a, and disease symptoms in NZB × NZW F1 mice. *Environmental Health Perspectives, 111*(16), 1883–1887.

Senthil kumar, J., Banudevi, S., Sharmila, M., Murugesan, P., Srinivasan, N., Balasubramanian, K., Aruldhas, M.M., & Arunakaran, J. (2004). Effects of vitamin C and E on PCB (Aroclor 1254) induced oxidative stress, androgen binding protein and lactate in rat Sertoli cells. *Reproductive Toxicology, 19*(2), 201–208.

Sharara, F.I., Seifer, D.B., & Flaws, J.A. (1998). Environmental toxicants and female reproduction. *Fertility and Sterility*, *70*(4), 613–622.

Silva, E., Rajapakse, N., & Kortenkamp, A. (2002). Something from "nothing"—eight weak estrogenic chemicals combined at concentrations below NOECs produce significant mixture effects. *Environmental Science and Technology*, *36*(8), 1751–1756.

Soto, A.M., Chung, K.L., & Sonnenschein, C. (1994). The pesticides endosulfan, toxaphene, and dieldrin have estrogenic effects on human estrogen sensitive cells. *Environmental Health Perspectives*, *102*(4), 380–383.

Soto, A.M., Fernandez, M.F., Luizzi, M.F., Oles Karasko, A.S., & Sonnenschein, C. (1997). Developing a marker of exposure to xenoestrogen mixtures in human serum. *Environmental Health Perspectives*, *105*(Suppl. 3), 647–654.

Sugita-Konishi, Y., Shimura, S., Nishikawa, T., Sunaga, F., Naito, H., & Suzuki, Y. (2003). Effect of bisphenol A on nonspecific immunodefenses against nonpathogenic *E. coli*. *Toxicology Letters*, *136*(3), 217–227.

Takao, T., Nanamiya, W., Nagano, I., Asaba, K., Kawabata, K., & Hashimoto, K. (1999). Exposure with the environmental estrogen bisphenol A disrupts the male reproductive tract in young mice. *Life Science*, *65*(22), 2351–2357.

Thomas, P., & Dong, J. (2006). Binding and activation of the seven-transmembrane estrogen receptor GPR30 by environmental estrogens: A potential novel mechanism of endocrine disruption. *Journal of Steroid Biochemistry and Molecular Biology*, *102*(1–5), 175–179.

Timms, B.G., Howdeshell, K.L., Barton, L., Bradley, S., Richter, C.A., & vom Saal, F.S. (2005). Estrogenic chemicals in plastic and oral contraceptives disrupt development of the mouse prostate and urethra. *Proceedings of the National Academy of Sciences of the USA*, *102*(19), 7014–7019.

Timms, B.G., Petersen, S.L., & vom Saal, F.S. (1999). Prostate gland growth during development is stimulated in both male and female rat fetuses by intrauterine proximity to female fetuses. *Journal of Urology*, *161*(5), 1694–1701.

Tohei, A., Suda, S., Taya, K., Hashimoto, T., & Kogo, H. (2001). Bisphenol A inhibits testicular functions and increases luteinizing hormone secretion in adult male rats. *Experimental Biology and Medicine*, *226*(3), 216–221.

Tollefsen, K.E. (2002). Interaction of estrogen mimics, singly and in combination, with plasma sex steroid-binding proteins in rainbow trout (*Oncorhynchus mykiss*). *Aquatic Toxicology*, *56*(3), 215–225.

Ulutas, O.K., Yildiz, N., Durmaz, E., Ahbab, M.A., Barlas, N., & Çok, I. (2011). An in vivo assessment of the genotoxic potential of bisphenol A and 4-tert-octylphenol in rats. *Archives of Toxicology*, *85*(8), 995–1000.

Vandenberg, L.N., Maffini, M.V., Schaeberle, C.M., Ucci, A.A., Sonnenschein, C., Rubin, B.S., & Soto, A.M. (2008). Perinatal exposure to the xenoestrogen bisphenol-A induces mammary intraductal hyperplasias in adult CD1 mice. *Reproductive Toxicology*, *26*(3–4), 210–219.

Vandenberg, L.N., Maffini, M.V., Wadia, P.R., Sonnenschein, C., Rubin, B.S., & Soto, A.M. (2007). Exposure to environmentally relevant doses of the xenoestrogen bisphenol-A alters development of the fetal mouse mammary gland. *Endocrinology*, *148*(1), 116–127.

Varayoud, J., Ramos, J.G., Bosquiazzo, V.L., Muñoz De Toro, M., & Luque, E.H. (2008). Developmental exposure to bisphenol A impairs the uterine response to ovarian steroids in the adult. *Endocrinology*, *149*(11), 5848–5860.

vom Saal, F.S., Cooke, P.S., Buchanan, D.L., Palanza, P., Thayer, K.A., & Nagel, S.C., Parmigiani, S., & Welshons, W.V. (1998). A physiologically based approach to the study of bisphenol A and other estrogenic chemicals on the size of reproductive organs, daily sperm production, and behavior. *Toxicology and Industrial Health*, *14*(1–2), 239–260.

Welshons, W.V., Nagel, S.C., & vom Saal, F.S. (2006). Large effects from small exposures. Endocrine mechanisms mediating effects of bisphenol A at levels of human exposure. *Endocrinology*, *147*(6 Suppl.), 56–69.

World Health Organization. (2010). *Toxicological and health aspects of bisphenol A* (Report of Joint Food and Agricultural Organization/World Health Organization Expert Meeting). Retrieved from http://whqlibdoc.who.int/publications/2011/97892141564274_eng.pdf

Yoganathan, T., Eskild, W., & Hansson, V. (1989). Investigation of detoxification capacity of rat testicular germ cells and Sertoli cells. *Free Radical Biology and Medicine*, *7*(4), 355–359.

Yoshino, S., Yamaki, K., Yanagisawa, R., Takano, H., Hayashi, H., & Mori, Y. (2003). Effects of bisphenol A on antigen-specific antibody production, proliferative responses of lymphoid cells, and TH1 and TH2 immune responses in mice. *British Journal of Pharmacology*, *138*(7), 1271–1276.

INTERNATIONAL PERSPECTIVES

Prepublished online January/February 2014, National Environmental Health Association.

Comparative Study of Heavy Metals in "Soil-Wheat" Systems Between Sewage-Irrigated Areas and Clean-Water-Irrigated Areas in Suburban Beijing

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 25 countries worldwide, are addressed. Our goal is to raise diverse issues of interest to all our readers, irrespective of origin.*

Ye Zhao, PhD
Sha-sha Han, MS
State Key Laboratory of Water Environment Simulation
School of Environment, Beijing

Zhi-fan Chen, PhD
College of Environment and Planning
Henan University

Jing Liu, MS
Hong-xia Hu, MS
State Key Laboratory of Water Environment Simulation
School of Environment, Beijing

Abstract **After years of irrigating farmland with wastewater, concern is increasing about health risks from heavy metals contaminating wheat grown in sewage-irrigated soils in suburban areas of Beijing, China. The study discussed in this article aimed to compare the characteristics of heavy metal distribution in a sewage-irrigated "soil-wheat" system with those from a clean-water-irrigated area by collecting and analyzing samples from both areas. The results indicated that the average concentrations of copper, chromium, lead, and zinc in sewage-irrigated soil were higher than the values in the clean-water-irrigated region. Irrigation with wastewater could lead to increased bioconcentration factors. Therefore, issues of food contamination caused by sewage irrigation deserve more attention.**

Introduction

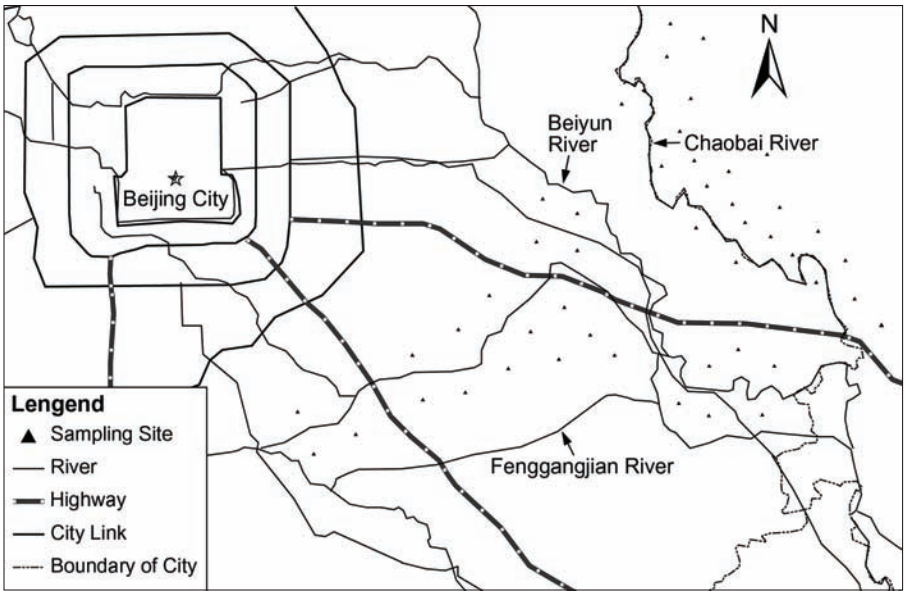
Using urban sewage that has been primarily treated to irrigate farmland is an effective method to address the water shortage problem in agriculture, improve soil fertility, and dispose of municipal wastewater (Wang & Zhou, 2004; Zhu, 2001). Experimental research on sewage irrigation has been performed in China since 1957, and the research has shown that people who consume crops irrigated with sewage effluent have a greater potential for contracting infectious diseases (Bouwer, 2000; O'Hara & Rubin, 2005). Research has also shown that if untreated sewage were regularly used for irrigation, heavy metal elements in the wastewater would accumulate in the soil and lead to heavy metal pollution (Ahmad, Hayat, & Pichtel, 2005; Solís et al., 2005; van der Perk, 2006). Once the heavy metal content exceeds a certain threshold, these metals enter into the crops through a process known as enrichment; this process subsequently reduces the crop yield and quality and harms human health (Li et al., 2010).

Heavy metals can enter the human body in three main ways: respiration, dermal exposure, and dietary intake. Compared with respiration and dermal exposure, dietary intake is the most common method because diets are often large and complex and because of the varying heavy metal content in food (Grasmück & Scholz, 2005; Järup, 2003). Of those food items containing heavy metals, cereals have been paid little attention even though cereals are consumed almost daily around the world (Chary, Kamala, & Raj, 2008; Nadal, Schuhmacher, & Domingo, 2004). Thus, performing risk assessments of grain crops has a practical significance.

The farmland near the river in Beijing's eastern suburbs has been irrigated by wastewater for more than 50 years. The accumulation and distribution of heavy metals in the soil have become controversial social issues (Yang, Chen, et al., 2005). Based on earlier studies from scholars abroad and at home, our study focused on determining and ana-

FIGURE **1**

Sampling Sites and Geographical Map of Study Area



lyzing concentrations of copper, chromium, lead, and zinc in soil and wheat seeds through field investigations and sample analysis in a sewage-irrigated area and a clean-water-irrigated area located in a suburb of Beijing. Twenty-four regions with wheat production in sewage-irrigated areas and 24 regions in clean-water-irrigated areas were selected, and soil and wheat samples were collected. Inductively coupled plasma-atomic emission spectroscopy (ICP-AES), which is a rapid, convenient, and precise technique (Wang, Ma, & Itoh, 2005), was used to determine the concentration of heavy metals (copper, chromium, lead, and zinc) in the soil and wheat samples. Our goal was to provide information about soil pollution control and recovery as well as food health risk analysis.

Materials and Methods

Study Sites

The study area is located at the junction of the Tongzhou District in Beijing and Xianghe County in Hebei Province. The site is in a warm, temperate continental climate zone with an average annual temperature of 10.5°C. The annual precipitation, which is concentrated in summer and fall, is approximately 620 mm. On the surface of the field, one can find tawny or yellowish-brown sandy loam and silty clay loam carried by the Chaobai River and developing loamy aquatic soil, sandy aquatic soil, and sticky aquatic soil. The background values for all of those soils are relatively uniform (Environmental Monitoring Station, 1990; State Environmental Protection Administration of China, 1994).

In terms of water sources, our research area included parallel regions of the Lianghui River, the Fenggangjian River, and the Beiyun River. The quality of the surface water is significantly different in the regions corresponding to each of these rivers. Areas along the Chaobai River, together with the north plain, have good water quality, while the Beiyun River has poor water quality due to large deposits of sewage from downtown Beijing. The Fenggangjian River's water quality is the worst of the three rivers, primarily because it was originally an artificial river built to receive waste.

As shown in Figure 1, the Fenggangjian River and the western side of the Beiyun River are sewage-irrigated areas; mixed-irrigated areas fall between the Beiyun River and the Chaobai River; and the northeastern coast of the Chaobai River is a clean-water-irrigated area. The study area is dominated by irrigation agriculture, with crops of winter wheat, summer maize, cotton, and vegetables. In our study, "soil-wheat" systems in sewage-irrigated areas and clean-water-irrigated areas were the main focus.

Sample Collection and Handling

A field investigation of the study area was conducted using remote sensing images and topographic maps (Rejith, Jeeva, Vijith, Sowmya, & Hatha, 2009). Soil samples were collected in 2010 from a concentrated farming region away from the highway. Twenty-four of the selected sample regions were located in sewage-irrigated areas along the Fenggangjian River and the Beiyun River, and 24 of the sample regions were located in clean-water-irrigated areas northeast of the Chaobai River. In each sample region, topsoil (0–20 cm) was collected using the plumb point method. Each sample point is shown in Figure 1. Wheat samples were collected from the 48 selected wheat areas, with 24 from sewage-irrigated areas and 24 from clean-water-irrigated areas. Six wheat plants were randomly selected in each area from which to obtain wheat seeds.

All soil samples were air dried, ground, and passed through a 0.149-mm mesh (100 mesh) sieve in a timely manner in the laboratory before the samples were measured and analyzed. Those samples were then sealed in Kraft paper envelopes until analysis. After the wheat seed samples were dried and decorticated indoors, the wheat grains were subjected to an ultrasonic cleaning; then they were washed with deionized water three times, roasted in an oven at 80°C to a constant weight, and smashed after cooling down. The smashed samples were preserved in Kraft paper bags for further analysis.

Sample Determination and Analysis

Potentiometric technique was used to determine the soil pH by a pH meter. The potassium dichromate oxidation method was used to determine the content of the organic matter in the soil. Quantitative potassium dichromate-sulfuric acid solution was added to oxidize the organic carbon in the soil under heat. The remaining potassium dichromate was titrated with ferrous sulfate standard solution. Meanwhile, silica was subjected to the same steps to be used as an experimental blank for comparison. The organic matter in the soil could be calculated from the differ-

TABLE **1**

Basic Characteristics and Concentrations of Heavy Metals in Sewage-Irrigated Topsoil in Suburban Beijing (mg/kg)

Element	Range	Mean	*SD*	National Secondary Standard	Soil Background Value in Beijing	Concentration in 1985	Ratio of Exceeding Standard Value
Copper	13.31–60.04	26.51	10.34	100	23.6	10.07	0
Chromium	64.55–166.83	101.29	22.05	300	68.1	52.66	0
Lead	19.9–42.83	28.04	5.98	300	25.4	13	0
Zinc	61.59–142.52	85.59	18.74	250	102.6	42.32	0

ence in the mass of the oxidant before and after oxidation.

A 0.10-g sample of dried soil that was filtered through 100 mesh was weighed precisely. This sample was subsequently digested according to the USEPA-3050B acid digestion recommendations from the U.S. Environmental Protection Agency (U.S. EPA, 1996). Eventually, the volume of the soil solution was adjusted to a certain value (10 mL). In addition to preparing the sample plant solutions, 0.20 g of a wheat test sample were accurately weighed and put into a polytetrafluoroethylene crucible; then 3 mL of nitric acid and 1 mL of perchloric acid were added successively. After adding acid, crucibles were placed into cans, which were sealed to prevent volatilization and placed into an oven at 150°C for four hours. Again, 1 mL of nitric acid was added, and the volume was adjusted to 10 mL with deionized water. The quantitative analyses of the heavy metals (copper, chromium, lead, and zinc) in the solutions were performed using ICP-AES.

All the sample determinations were performed in triplicate to minimize the risk of error, and the arithmetic mean value was the final result. The blank reagent and standard reference soil and plant materials (from the National Research Center for Standards in China) were included in each sample batch to verify the accuracy and precision of the digestion procedure and subsequent analyses.

TABLE **2**

Basic Characteristics and Concentrations of Heavy Metals in Clean-Water-Irrigated Topsoil in Suburban Beijing (mg/kg)

Element	Range	Mean	*SD*	National Secondary Standard	Ratio of Exceeding Standard Value
Copper	13.54–48.12	25.66	5.97	100	0
Chromium	55.89–138.82	78.5	12.04	300	0
Lead	15.85–27.85	23.34	2.66	300	0
Zinc	41.63–98.39	72.29	10.31	250	0

Results and Discussion

Physicochemical Properties of Soils

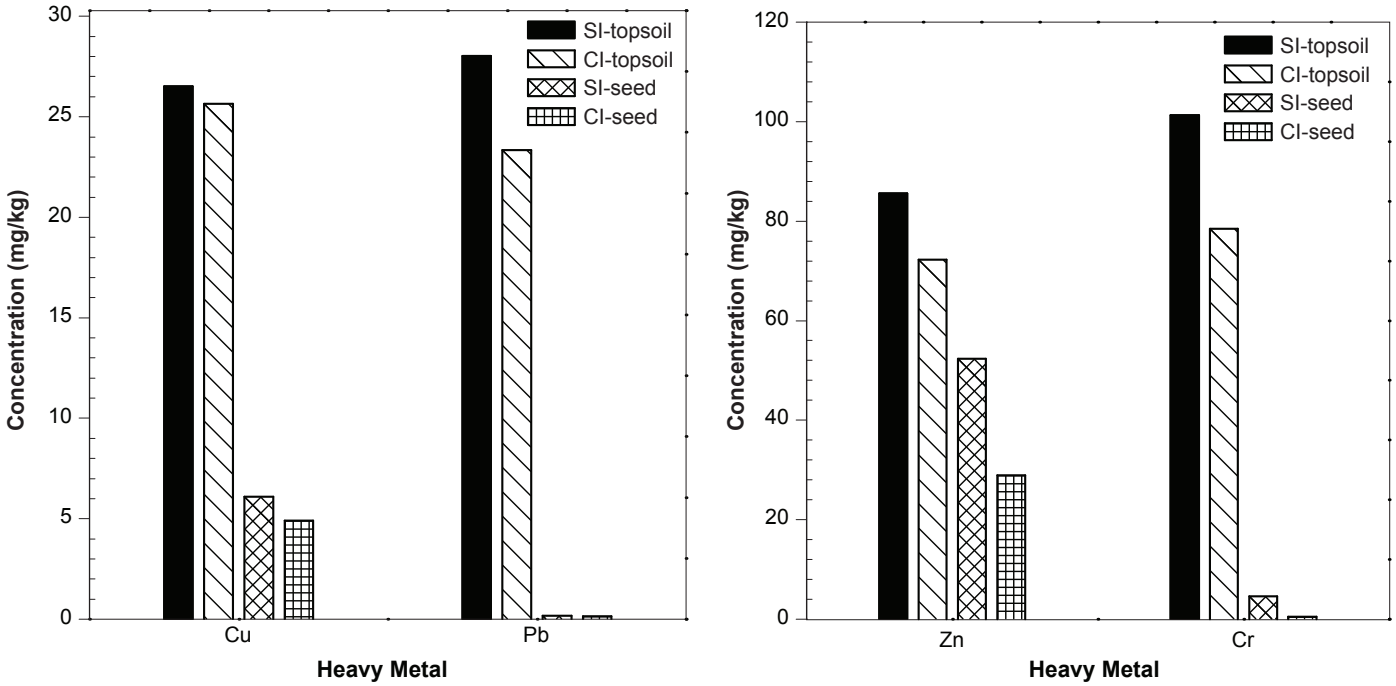
Our results revealed that the mean pH value (water-soil ratio is 5:1) of the topsoil in sewage-irrigated soils was 8.30 with a standard deviation of approximately 4%. The mean pH value of the topsoil in clean-water-irrigated soils was 7.30 with a standard deviation of approximately 7%. The mean value of the organic matter mass ratio in sewage-irrigated soils was 1.590 g/kg and the standard deviation was approximately 43%. In clean-water-irrigated soils, the value was 1.40 g/kg and the standard deviation was approximately 34%. In sewage-irrigated soils, a decrease in the pH of 1.00 was accompanied by an increase in the organic matter of 13.57% compared to clean-water-irrigated soils, which suggested that the soil properties were significantly affected by sewage irrigation.

Heavy Metal Concentrations in Soils

The data for four heavy metals found in sewage-irrigated soils are presented in Table 1, and the data for four heavy metals found in clean-water-irrigated soils are shown in Table 2. The average mass ratio of chromium in the topsoil of the sewage-irrigated area was obviously higher than the background value (57.3–73.9 mg/kg) (Environmental Monitoring Station, 1990; State Environmental Protection Administration of China, 1994); this value was also remarkably higher than the global background value (55.0 mg/kg) in soils that were developed from loess and silt sediment (Kabata-Pendias, 1985). Nearly 15 of the 24 sampling points in the sewage-irrigated areas had a mass ratio of chromium in the topsoil that exceeded 75.0 mg/kg. The mass ratio of copper was found to be equivalent to the background value of copper (20.7–27.3 mg/kg) in the study area and to the global background value (25.0 mg/kg) in soils developed from loess and silt sediment. Seven out of the 24 sampling points in the sewage-irrigated areas, however, had a mass ratio of copper in the topsoil that exceeded 27.5 mg/kg. The average mass ratio of zinc in the topsoil of the sewage-irrigated areas was remarkably higher than the global background value (58.5 mg/

FIGURE **2**

Comparisons of Four Heavy Metals Between Sewage-Irrigated "Soil-Wheat" System and Clean-Water-Irrigated "Soil-Wheat" System



Cu = copper; Pb = lead; Zn = zinc; Cr = chromium; SI-topsoil = sewage-irrigated topsoil; CI-topsoil = clean-water-irrigated topsoil; SI-seed = sewage-irrigated seed; CI-seed = clean-water-irrigated seed.

kg) in soils developed from loess and silt sediment (Kabata-Pendias, 1985). Nearly 20 of the 24 sampling points in the sewage-irrigated areas had a mass ratio of zinc in the topsoil that exceeded 88.5 mg/kg.

All of the results were in agreement with the heavy metal contents in the soils from the Liangfeng-irrigated area that were measured by Yang, Zheng, and co-authors (2005). Further statistical analysis showed that the organic matter content in the soil had a significant positive correlation with the heavy metal concentrations of chromium, copper, and zinc ($p < .05$). This result may be attributable to the adsorption of heavy metals onto organic matter, with most of the heavy metals being delivered to the soil through sewage irrigation.

Figure 2 also clearly shows that the average concentrations of copper, chromium, lead, and zinc in the sewage-irrigated soil were higher than the background values of the soil in clean-water-irrigated regions; the concentration of chromium showed the biggest difference between sewage-irrigated soils and clean-water-irrigated soils, and copper showed the smallest difference. In the sewage-irrigated soils, the average concentrations of copper, chromium, lead, and zinc exceeded those of the clean-water-irrigated areas by 1.03-, 1.29-, 1.20-, and 1.18-fold, respectively, indicating the accumulation of these heavy metals in the soil of the sewage-irrigated fields. Furthermore, the concentrations of copper, chromium, lead, and zinc in the sewage-irrigated fields can be ranked as follows: chromium (101.29 mg/kg) > zinc (85.59 mg/kg) > lead (28.04 mg/kg) > copper (26.51 mg/kg). Compared with the values measured in 1985, a large accumulation of heavy metals occurred in sewage-irrigated fields. But when compared with the national secondary standard values, the concentrations of heavy metals were all under the minimal threshold value, indicating that the study area can temporarily guarantee agricultural production and human health.

The concentrations of copper, chromium, lead, and zinc in the clean-water-irrigated fields can be ranked in a similar order: chromium (78.5 mg/kg) > zinc (72.29 mg/kg) > copper (25.66 mg/kg) > lead (23.34 mg/kg).

The results indicated that sewage irrigation has increased the concentration of heavy metals in the soil, especially the concentrations of lead and zinc. Similar results were found in previous studies (Khan, Cao, Zheng, Huang, & Zhu, 2008; Liu, Zhao, Ouyang, Soderlund, & Liu, 2005). The distribution of metals in the farmland at each site was primarily affected by the location of the farmland and the duration of irrigation time. Farmland close to the main channel that was irrigated with sewage for many years showed a higher level of contamination. This observation indicates that continuous sewage irrigation may result in heavy metal contamination in the soil.

TABLE **3**

Concentration of Heavy Metals in the Wheat Seed of Sewage-Irrigated Areas (mg/kg)

Element	Range	Mean	*SD*	National Secondary Standard	Concentration in 1985	Bioconcentration Coefficient	Ratio of Exceeding Standard Value
Copper	4.21–12.34	6.09	1.57	10	6.3	0.23	0.04
Chromium	0.22–8.95	4.62	2.08	1	0.147	0.046	0.93
Lead	0–0.63	0.17	0.21	0.2	0.046	0.006	0.37
Zinc	30.70–95.72	52.38	13.05	50	17.7	0.61	0.52

TABLE **4**

Concentration of Heavy Metals in the Wheat Seed of Clean-Water-Irrigated Areas (mg/kg)

Element	Range	Mean	*SD*	National Secondary Standard	Bioconcentration Coefficient	Ratio of Exceeding Standard Value
Copper	2.6–8.56	4.91	1.69	10	0.19	0
Chromium	0.12–0.95	0.48	0.25	1	0.006	0
Lead	0.09–0.31	0.16	0.06	0.2	0.006	0.12
Zinc	17.03–47.03	28.88	9.24	50	0.4	0

Heavy Metal Concentrations of the Wheat Samples

As indicated in Table 3, the concentrations of zinc and copper in the dry matter of wheat seeds grown in sewage-irrigated soil were highest among the four heavy metals. Correlation analysis revealed that the zinc concentration in the wheat seeds was significantly correlated with that of the soil in which the wheat seeds were grown ($p < .05$). Chromium and lead are unnecessary elements for growth in plants and were absorbed primarily through passive absorption. The data in Table 3 show that the concentration of lead ranged between 0 and 0.63 mg/kg. The mean value was 0.17 mg/kg, which is below the tolerance limit for Chinese standards. The mean concentration of chromium in wheat seeds was 4.62 mg/kg, which is 4.6 times higher than the tolerance limit for Chinese standards. The proportion of samples that exceeded this tolerance limit was as high as 93%; thus, chromium contamination of wheat seeds demands increased attention.

Large variations were apparent between sewage-irrigated and clean-water-irrigated regions (Figure 2). The average concentrations of copper, chromium, and zinc in seeds from sewage-irrigated soil were higher than those from clean-water-irrigated areas by 1.24-, 9.63-, and 1.81-fold, respectively, while the concentrations of lead in the two types of seeds were almost equal. Combined with the data presented above, this result indicates that the concentrations of some heavy metals exceeded the national secondary standard; thus, continuous sewage irrigation can cause heavy metal contamination in the edible seeds of crops grown in this soil.

In addition, analysis of variance revealed that the concentrations of chromium and lead were not distributed uniformly throughout the studied areas. On the one hand, heavy metals in the soil originally demonstrated some spatial differences. On the other hand, however, factories and an airport were near the study area, which would have affected the concentrations of heavy metals. Therefore, it is necessary to pay attention to uncertainty in this study region.

Heavy Metal Transfer From Soil to Edible Seeds

The bioconcentration coefficient (BCF) of a heavy metal in the soil can be used to measure how difficult it is for that heavy metal to be absorbed by plants from the soil. In terms of agriculture, the absorbed dose (concentration) of the edible portion of a food crop (kernel) is generally used as an assessment of a heavy metal's effectiveness. The computational formula used is as follows:

$$\mathbf{BCF}^{Wheat}_{heavymetal} = \mathbf{C}^{seed}_{heavymetal} / \mathbf{C}^{soil}_{heavymetal}$$

$\mathbf{C}^{seed}_{heavymetal}$ is the concentration of heavy metals in the wheat kernel and $\mathbf{C}^{soil}_{heavymetal}$ is the concentration of heavy metals in the soil. The BCFs of seeds collected from sewage-irrigated soil and clean-water-irrigated soil are shown in Table 3 and Table 4, respectively.

The BCF trend of the seeds grown in sewage-irrigated soil was as follows: zinc (0.61) > copper (0.23) > chromium (0.046) > lead (0.006). The higher BCF values for zinc and copper might be correlated with the physiological characteristics of the plants and the heavy metals. When comparing the BCFs of sewage-irrigated seeds with those of clean-water-irrigated seeds, it is clear that irrigation with sewage could lead to increased BCF values in the seeds. Among the heavy metals, the BCFs of zinc and copper were 1.53- and 1.21-fold higher, respectively.

Conclusion

The average concentrations of copper, chromium, lead, and zinc in the sewage-irrigated soil were higher than the concentrations in the clean-water-irrigated soil, indicating the accumulation of these heavy metals in the soil. Compared with the national secondary standard, however, the concentrations of heavy metals were all under a certain value. Therefore, the study area can temporarily guarantee agricultural production and human health, but if sewage irrigation continues, the risk for heavy metal contamination in the soil will significantly increase in the future.

In "soil-wheat" systems in sewage-irrigated areas, the average concentrations of copper, chromium, and zinc in seeds mean that crops grown in sewage-irrigated soil were contaminated with heavy metals, some of which exceeded the permissible limits. Also, irrigation with wastewater can lead to increased BCF values. Therefore, issues of food contamination attributable to sewage irrigation with regard to the quality of agricultural products and human health deserve more attention.

Aside from wheat, many other foods are possible avenues for human ingestion of heavy metals. No other foods or intake methods besides wheat were considered in our study. Thus, further research into heavy metal health risks attributable to other foods (e.g., vegetables, meats, eggs, milk, and so on), drinking water, breathing outdoors, and contact with the outside world should be conducted to determine the ratios of influence from various sources and provide a theoretical basis for public health.

Acknowledgements: This work was financially supported by the Ministry of Land and Resources' Special Funds for Scientific Research on Public Benefit (No. 201011006-1) and the National Key Basic Research and Development (973) Program of China (Grant No. 2007CB407302). We are grateful to Dr. Ke Sun for her comments. In addition, we thank the participating institutes, as well as the anonymous reviewers for their kind and helpful comments regarding the manuscript.

Corresponding Author: Ye Zhao, Professor, School of Environment, Beijing Normal University, Beijing, 100875, China. E-mail: zhaoye@bnu.edu.cn.

References

Ahmad, I., Hayat, S., & Pichtel, J. (2005). *Heavy metal contamination of soil problems and remedies* (pp. 212–226). Enfield, NH: Science Publishers.

Bouwer, H. (2000). Groundwater problems caused by irrigation with sewage effluent. *Journal of Environmental Health*, *63*(3), 17–20.

Chary, N.S., Kamala, C.T., & Raj, D.S.S. (2008). Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. *Ecotoxicology and Environmental Safety, 69*(3), 513–524.

Environmental Monitoring Station. (1990). *Background value of soil elements in China*, (pp. 330–382) [In Chinese]. Beijing: Chinese Environmental Science Press.

Grasmück, D., & Scholz, R.W. (2005). Risk perception of heavy metal soil contamination by high-exposed and low-exposed inhabitants: The role of knowledge and emotional concerns. *Risk Analysis, 25*(3), 611–622.

Järup, L. (2003). Hazards of heavy metal contamination. *British Medical Bulletin, 68*, 167–182.

Kabata-Pendias, A. (1985). *Trace elements in soils and plants* (pp. 1–20). Boca Raton, FL: CRC Press.

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

Li, Q.S., Cai, S.S., Mo, C.H., Chu, B., Peng, L.H., & Yang, F.B. (2010). Toxic effects of heavy metals and their accumulation in vegetables grown in a saline soil. *Ecotoxicology and Environmental Safety, 73*(1), 84–88.

Liu, W.H., Zhao, J.Z., Ouyang, Z.Y., Soderlund, L., & Liu, G.H. (2005). Impacts of sewage irrigation on heavy metal distribution and contamination in Beijing, China. *Environment International, 31*(6), 805–812.

Nadal, M., Schuhmacher, M., & Domingo, J.L. (2004). Metal pollution of soils and vegetation in an area with petrochemical industry. *Science of the Total Environment*, 321(1–3), 59–69.

O'Hara, R.E., & Rubin, R. (2005). Reducing bioaerosol dispersion from wastewater treatment and its land applications: A review and analysis. *Journal of Environmental Health*, *68*(2), 24–29.

Rejith, P.G., Jeeva, S.P., Vijith, H., Sowmya, M., & Hatha, A.A.M. (2009). Determination of groundwater quality index of a highland village of Kerala (India) using geographical information system. *Journal of Environmental Health*, *71*(10), 51–58.

Solís, C., Andrade, E., Mireles, A., Reyes-Solís, I.E., García-Calderón, N., Lagunas-Solar, M.C., Piña, C.U., & Flocchini, R.G. (2005). Distribution of heavy metals in plants cultivated with wastewater irrigated soils during different periods of time. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, 241*(1–4), 351–355.

State Environmental Protection Administration of China. (1994). *Background value of soil environment in People's Republic of China* (pp. 26–71) [In Chinese]. Beijing: Chinese Environmental Science Press.

U.S. Environmental Protection Agency. (1996). *USEPA-3050B acid digestion of sediments sludge and soils.* Retrieved from http://www.epa.gov/osw/hazard/testmethods/sw846/pdfs/3050b.pdf

van der Perk, M. (2006). *Soil and water contamination: From molecular to catchment scale* (pp. 125–128). London: Taylor & Francis Group.

Wang, X., & Zhou, Q.X. (2004). Ecological process, effect and remediation of soil heavy metal contamination [Article in Chinese]. *Ecology Science, 23*(3), 278–281.

continued on page 34

References *continued from page 33*

Wang, X.P., Ma, Y.J., & Itoh, M. (2005). Analysis of 23 mineral elements in tea samples collected from China and Japan by using ICP-AES and ICP-MS combined with a closed decomposition [Article in Chinese]. *Spectroscopy and Spectral Analysis*, *25*(10), 1703–1707.

Yang, J., Chen, T.B., Zheng, Y.M., Luo, J.F., Liu, H.L., Wu, W.Y., & Chen Y.C. (2005). Dynamic of heavy metals in wheat grains collected from the Liangfeng irrigated area, Beijing and a discussion of availability and human health risks [Article in Chinese]. *Acta Scientiae Circumstantiae*, *25*(12), 1661–1668.

Yang, J., Zheng, Y.M., Chen, T.B., Huang, Z.C., Luo, J.F., Liu, H.L., Wu, W.Y., & Chen, Y.C. (2005). Accumulation and temporal variation of heavy metals in the soils from the Liangfeng irrigated area, Beijing city [Article in Chinese]. *Acta Scientiae Circumstantiae*, *25*(9), 1175–1181.

Zhu, G.Z. (2001). Pollution of heavy metals on soils in east-south area of Beijing and its remediation [Article in Chinese]. *Environment Protection of Agriculture, 20*(3),164–166.

INTERNATIONAL PERSPECTIVES

Prepublished online March 2014,
National Environmental Health Association.

A Study of the Antimicrobial Resistance and Transfer of Resistance Among Organisms Isolated From Lettuce (*Lactuca sativa*) Leaves in Three Localities in Southwest Nigeria

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 25 countries worldwide, are addressed. Our goal is to raise diverse issues of interest to all our readers, irrespective of origin.*

Oluwatoyin A. Igbeneghu, PhD
Adebayo Lamikanra, PhD
Department of Pharmaceutics
Obafemi Awolowo University

Abstract **The bacterial flora of lettuce from western Nigeria were investigated for their identity, antimicrobial resistance, and ability to transfer such resistance to other organisms. The isolated contaminants were mostly Gram-negative organisms of the Enterobacteriaceae family, which included *Enterobacter* species and *E. coli*. The organisms were resistant to a wide range of antimicrobials and they exhibited multiple antimicrobial resistance phenotypes. Common resistance phenotypes observed included those to beta lactam antibiotics, trimethoprim, and streptomycin. A majority of the isolates had minimum inhibitory concentration of trimethoprim over 1,000 mg/L and they were shown to possess the ability to transfer their resistance to a plasmidless *E. coli* strain. The results of the authors' study underscore the contributory role of lettuce in the dissemination of antimicrobial resistance in the Nigerian community.**

Introduction

Vegetables are an important component of many diets in all parts of the world. Among other things, they are a good source of vitamins, minerals, and fiber (Ejoh, Nkonga, Gouado, & Moses, 2007; Rickman, Barrett, & Bruhn, 2007a, 2007b). In Nigeria, a wide range of vegetables is consumed regularly; most of the vegetables are subjected to high cooking temperatures and are therefore unlikely to be sources of foodborne microbial infections. A few vegetables, however, are eaten raw as components of salads, coleslaw, and other meals. This is not a common practice as it is restricted mainly to the western-oriented elites in Nigerian society. The number of such people is increasing and may become quite considerable in the near future.

The processing of lettuce for salads includes washing, rinsing, blanching, and shredding. Unprocessed lettuce is a product that is exposed to a range of conditions that are likely to increase its potential for microbial contamination. The cultivation of lettuce in water-logged areas, the use of animal manure to increase yield, and even the handling by the farmers create avenues for the contamination of the vegetables by bacteria, whether pathogenic or not. The practice on the part of the consumer of not using prepared salads immediately but leaving them at ambient temperatures and at high humidity could aid the proliferation of contaminants. More importantly this practice could increase the risk of transfer of antimicrobial resistance among contaminants and to gastrointestinal commensals and pathogens when eaten. Large quantities of salads and coleslaw are consumed in large social gatherings such as weddings and funerals. Such salad preparations are also not consumed immediately after preparation and any microbial contaminants are able to proliferate before the salads are eaten, thus enhancing their capacity for infection.

The important role of vegetables such as spinach, lettuce, and tomatoes in outbreaks of foodborne infections from *Shigella*, *E. coli*, and *Salmonella* is of interest not only in countries such as the U.S. but also in Nigeria. This is because of the long distance distribution of these particular vegetables. In Nigeria, lettuce is cultivated on a commercial scale in Jos, Plateau State. From Jos, harvested lettuce is distributed to many parts of the country where consumers are located. This kind of elaborate distribution system makes it possible for vegetables from one source to be consumed over a wide area. In the U.S., the Food and Drug Administration identified 18 outbreaks of *E. coli* O157:H7 (usually of bovine origin) associated with fresh or fresh-cut lettuce resulting in 409 illnesses and two deaths in less than two decades (Centers for Disease Control and Prevention [CDC], 2001a, 2001b). In 2003, an outbreak of salmonellosis in the United Kingdom was attributed to salad vegetables from retail establishments (Sagoo, Little, Ward, Gillespie, & Mitchell, 2003). In 2008, another *E. coli* O157:H7 lettuce outbreak was reported in

the U.S. in Michigan, Illinois, New York, Oregon, and Ohio and spread to Ontario, Canada (eFoodAlert.com, 2008). In early 2011, a new enterovirulent *E. coli* O104:H4 was identified as the cause of an outbreak in Germany. This strain has now been documented in 11 European countries (Bielaszewska et al., 2011; Pennington, 2011). Outbreaks of pathogenic organisms associated with lettuce, spinach, and tomatoes continue to occur and those associated with *E. coli* and *Salmonella* species are the most common (CDC, 2012). Although the episodes of food poisoning from consumption of vegetables have not been reported in developing countries such as Nigeria, the presence of organisms exhibiting not only resistance to antibiotics but also the ability to transfer such resistance to other organisms is a possibility; however, it is unlikely to be of concern to consumers. Thus, consumers will probably continue to buy and eat these kinds of vegetables without any fear of infection or acquisition of antibiotic-resistant organisms.

The aim of our study was to determine the presence of organisms in lettuce and the ability of such organisms to transfer this resistance to other organisms, some of which may be pathogenic to humans. It is expected that the findings from our study will lead to the identification of one more possible reservoir of resistance and factors responsible for the high incidence of antibiotic resistance in our environment (Okeke & Sosa, 2003).

Materials and Methods

Materials

One hundred twenty-five different samples of fresh lettuce were purchased from markets located in Ile-Ife (n = 50), Ilorin (n = 50), and Lagos (n = 25), all located in the western part of Nigeria. They were packed in sterile plastic bags to prevent contamination after purchase. The samples were transferred to the laboratory and tested immediately. The leaves were identified and authenticated as *Lactuca sativa* at the Department of Botany, Obafemi Awolowo University, Ile-Ife.

Bacteriological Procedures

Isolation and Identification of Bacterial Contaminants

Bacterial contaminants on the samples were isolated using the method of Österblad and co-authors (1999) with modifications in the quantity of each sample from which contaminants were isolated as well as the medium of dispersion of contaminants for isolation. Each sample of lettuce was aseptically chopped into fine pieces using a sterile knife. Five-gram portions of each sample were aseptically weighed and transferred into 100 mL of sterile water in a conical flask and the mixture was shaken thoroughly with a spin mixer to disperse any contaminants in the water. One-half mL of a 1-in-100 dilution of the water in which each lettuce sample was suspended was plated out on the surface of over-dried nutrient agar plates. The plates were incubated at 98.6ºF (37ºC) for 24 hours and the different colonies arising from each sample after incubation were transferred onto fresh plates and later subcultured onto MacConkey agar. All plates were incubated at 98.6ºF (37ºC) for 24 hours after which the isolates were then taken through a set of standard biochemical tests and identified to the species level based on the interpretation of results of the biochemical tests (Farmer, 1999). The identity of each isolate was confirmed using API 20E. All isolates were stored on nutrient agar stabs and in nutrient broth containing 16% glycerol stored in the refrigerator and deep freezer, respectively. They were subcultured on nutrient agar or nutrient broth when required for further testing.

Antibiotic Susceptibility Tests

The susceptibility of the isolates to antibiotics was determined using the disc diffusion method approved by the Clinical Laboratory Standards Institute (2006). Two to three distinct colonies of each test organism taken from a nutrient agar culture were inoculated into 10 mL of sterile water using a sterile loop. The suspension was thoroughly mixed with a spin mixer and adjusted to 0.5 McFarland standard. The resulting suspension was applied to the surface of over-dried Mueller-Hinton agar and spread evenly with a sterile cotton-tipped applicator. The inoculated plates were incubated at 98.6ºF (37ºC) for 20 minutes for acclimatization and growth of the inoculum. Antibiotic discs were then lightly but firmly pressed onto the surface of the plates using a sterile forcep and placed equidistant to each other. The plates were refrigerated after application of the discs at 39.2ºF (4ºC) for 30 minutes to ensure adequate diffusion of antibiotics. *E. coli* (American Type Culture Collection [ATCC] 25922) was used as the control organism. All plates were incubated at 98.6ºF (37ºC) for 18 hours. The diameters of inhibition zones were measured in millimeters and interpreted in accordance with the manufacturer's recommendations. The antibiotic tested included ampicillin (10 µg), ciprofloxacin (5 µg), chloramphenicol (30 µg), trimethoprim (5 µg), cephalothin (30 µg), streptomycin (10 µg), nalidixic acid (30 µg), and tetracycline (30 µg). Others were augmentin (30 µg), cloxacillin (30 µg), gentamicin (10 µg), ofloxacin (5 µg), erythromycin (30 µg), ceftriazone (30 µg), ceftazidin (30 µg), and cefuroxime (30 µg). The organisms were categorized as resistant or susceptible based on the antibiotic disc manufacturer's recommendation.

Minimum Inhibitory Concentration (MICs) Determination

MICs to trimethoprim were determined by the agar dilution method described by the Clinical Laboratory Standards Institute (2006). Duplicate plates of Mueller-Hinton agar containing 0, 4, 8, 16, 32, 64, 125, 250, 500, and 1,000 g/L of trimethoprim as the lactate were inoculated with dilutions of 18-hour nutrient broth cultures of each of trimethoprim-resistant isolates containing about 2 x 10^5 CFUs/mL using a multipoint inoculator. Results were taken after 48 hours' incubation at 98.6ºF (37ºC). *E. coli* ATCC 25922 was used as a control. The lowest concentration of trimethoprim-inhibiting growth in both replicates was taken as the MIC.

Resistance Transfer by Transconjugation

The ability of the organisms to transfer their resistance was determined using transconjugation experiments following the method of Sundström and co-authors (1987). Nalidixic-acid-resistant mutant of *E. coli* ATCC 25922 was used as the competent recipient. *E. coli* ATCC 25922 and each isolate that was resistant to trimethoprim (donor) was inoculated into 2-mL tubes of Mueller-Hinton broth and incubated for 18 hours at 98.6ºF (37ºC). At the end of this incubation, 0.2 mL each of the donor and recipient were mixed together on the surface of over-dried Mueller-Hinton agar. The conjugation mixtures were then incubated at 98.6ºF (37ºC) for 24 hours. Growth from each donor-recipient mixture was harvested

and suspended in 3 mL of normal sterile saline. Transconjugants were selected by transferring the 2–3 loopfuls of the suspension onto overdried Mueller-Hinton agar plates containing nalidixic acid (40 mg/L) with either tetracycline (40 mg/L) as hydrochloride, streptomycin (40 mg/L), trimethoprim (10 mg/L), or chloramphenicol (40 mg/L). The plates were incubated and observed after 48 hours.

Results

A total of 554 bacterial isolates were recovered from the 125 samples of lettuce tested in our study. The recovered organisms included 77 Gram-positive bacilli, 140 Gram-positive cocci, and 337 Gram-negative bacilli. The contaminants were organisms of the genera *Citrobacter, Enterobacter, Escherichia, Klebsiella, Pantoea, Pseudomonas, Serratia, Proteus, Bacillus*, and *Staphylococcus*. The number of contaminants ranged between three and seven bacteria species per sample with *Enterobacter* being the most common Gram-negative contaminant of the samples (Table 1).

TABLE **1**

Organisms Recovered From Contaminated Lettuce Samples

Organism	# of Isolates Recovered/# of Samples Contaminated				% of Samples Contaminated
	Ile-Ife *n* = 50	Ilorin *n* = 50	Lagos *n* = 25	Total *N* = 125	
Staphylococcus spp.	93/45	34/29	13/9	140/83	66.4
Bacillus spp. (*cereus, sphaericus, subtilis*)	22/22	31/31	24/20	77/73	58.4
Enterobacter spp. (*aerogenes, cloacae*)	44/35	61/43	22/13	127/91	72.8
Proteus spp. (*mirabilis, vulgaris*)	51/28	42/32	18/14	111/74	59.2
Pantoea agglomerans	11/11	11/11	9/9	31/31	24.8
Klebsiella pneumoniae	8/8	1/1	5/5	14/14	1.2
Pseudomonas spp.	6/6	20/15	10/5	36/26	20.8
E. coli	3/3	4/4	2/2	9/8	7.2
Citrobacter spp.	1/1	3/3	1/1	5/5	4.0
Serratia liquifaciens	1/1	1/1	2/2	4/4	3.2

The isolates were found to be resistant to a wide range of antibiotics including the beta lactam antibiotics, aminoglycoside, chloramphenicol, trimethoprim, and tetracycline. Resistance to ampicillin, amoxicillin, augmentin, and trimethoprim was found in over 70% of the contaminants. Resistance to the quinolones was very low as resistance to nalidixic acid was found in 13.5% of the contaminants. Very few (2.8% each) of the isolates were found resistant to the fluoroquinolones, ciprofloxacin, and ofloxacin. Resistance to the aminoglycosides was found among about half of the recovered isolates (Figure 1). Multiple resistance patterns were displayed by the isolates with resistance to 2–3 of the antibiotics. The most common pattern was resistance to five antibiotics. Most of the contaminants (58%) had an MIC of trimethoprim above 1,000 mg/L while 42% had an MIC of trimethoprim between 31.25 and 500 mg/L as shown in Table 2. The ability of the resistant Enterobacteriaceae to transfer their resistances was demonstrated and results of the transconjugation experiment are shown in Table 3.

Discussion

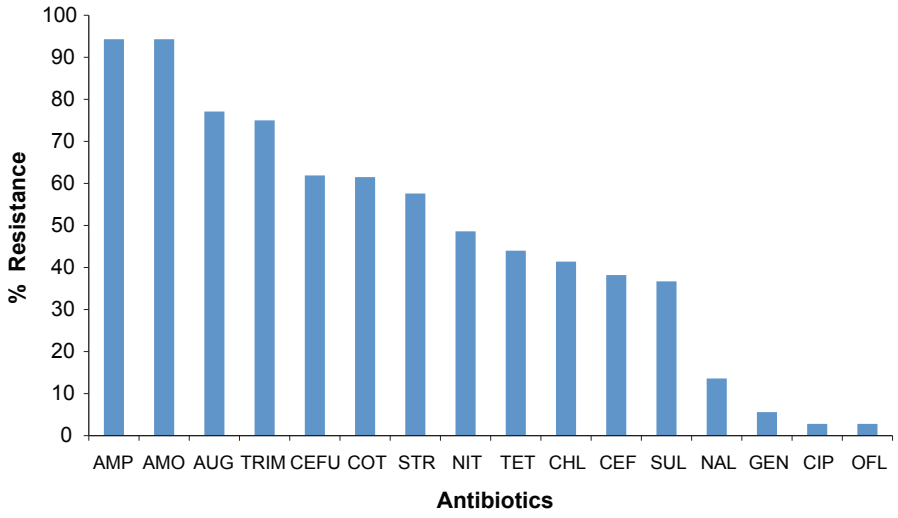
Lettuce has been shown to be a reservoir of microorganisms (Szabo, Scurrah, & Burrows, 2000), which are consumed along with the lettuce by people who eat raw lettuce in salads and coleslaw. Our study has shown that the contaminants of lettuce in Nigeria are mostly Gram-negative organisms, which belong to the family Enterobacteriaceae. These are organisms that are capable of surviving in the human intestine and when pathogenic are able to cause many infections of the gastrointestinal tract. They are likely to have been introduced onto the lettuce leaves right from the cultivation on the farm from either the water used in irrigation, manure from animals or human waste, or from the soil (Beuchat, 2002; Johannessen, Loncarevic, & Kruse, 2002). Of significance is the presence of *E. coli* in about 7% of the samples, indicating the presence of recent fecal contamination (Edberg, Rice, Karlin, & Allen, 2000) of the lettuce samples. This could either be of animal or human origin or both. This suggests that lettuce farmers use water of poor quality for irrigation and washing of harvested lettuce. The discharge of sewage and contaminated industrial waste into streams and rivers, which are the sources of water for irrigation and washing used by vegetable farmers, contributes to the deterioration of the quality of water for agriculture in the developing countries (Olayinka, 2004; Rajaram & Das, 2008).

It is possible that isolated cases of diarrhea associated with the consumption of lettuce contaminated by pathogenic strains of *E. coli* have occurred in Nigeria but this has not been reported or documented. Most outbreaks in the U.S. and United Kingdom were linked with *E. coli* O157:H7, but a new strain was recently implicated in the 2011 German outbreak. This new strain was found to exhibit some of the worst overlap features of the enterovirulent *E. coli* strains. Such features include the production of Shiga toxins peculiar to enterohemorrhagic *E. coli* and the ability to persist by attaching well to the gastrointestinal cells, a characteristic of the enteroaggregative *E. coli* (Bielaszewska et al., 2011; Pennington, 2011). The greater proportion of organisms isolated in our study were commensals and are probably nonpathogenic when ingested. They could be opportunistic pathogens, however, in immunocompromised persons.

More importantly, their presence is significant from the point of view of antibiotic resistance. The isolates were found to be resistant to a wide range of antibiotics including the beta lactam antibiotics, chloramphenicol, trimethoprim, and tetracycline. The resistance rates were particularly high to ampicillin, augmentin, and trimethoprim but low to quinolones. Resistance to chloramphenicol

FIGURE **1**

Antibiotic Resistance Profile of Isolates Recovered From Lettuce



AMP = ampicillin; AMO = amoxicillin; AUG = augmentin; TRIM = trimethoprim; CEFU = cefuroxime; COT = cotrimoxazole; STR = streptomycin; NIT = nitrofurantoin; TET = tetracycline; CHL = chloramphenicol; CEF = ceftazidin; SUL = sulphonamide; NAL = nalidixic acid; GEN = gentamicin; CIP = ciprofloxacin; OFL = ofloxacin.

TABLE **2**

Minimum Inhibitory Concentration of Trimethoprim Against Contaminants From Lettuce Samples

Trimethoprim Concentration (mg/L)	% Inhibited
>1000	58
≥500	8
≥125	22
≥62.5	8
≥31.25	4

TABLE **3**

Rate of Resistance Transfer Among Contaminants Recovered From Lettuce Samples

Resistance	Rate of Transfer (%)
Streptomycin	83
Trimethoprim	70
Tetracycline	69
Chloramphenicol	0

was found among about half of the recovered isolates. In Nigeria, quinolones have not been used as much as the other classes of antibiotics and are thus not likely to have exerted as much selective pressure on resistant organisms in the environment as the older antibiotics. The beta lactam antibiotics, tetracycline and trimethoprim (a component of cotrimoxazole), by contrast, have been used extensively and inappropriately for the prophylaxis and treatment of all sorts of infections in humans. This contributes to the high resistance among commensal Enterobacteriaceae from humans in Nigeria (Okeke, Lamikanra, & Edelman, 1999).

The indiscriminate use of antibiotics in animals as prophylaxis against infections and as growth promoters to boost production has also been reported to lead to the selection of resistant strains (Mathew, Cissell, & Liamthong, 2007). The use of animal manure containing resistant organisms by vegetable farmers will lead to the cross transfer of resistant strains via the soil to vegetables. These strains are ingested along with raw vegetables by humans and get into the sewage via defecation. The inadequate treatment of sewage leads to the discharge of the organisms into the streams and rivers used by vegetable farmers. The use of water contaminated by human or animal fecal matter for irrigation and washing of vegetables therefore results in the contamination of the vegetables with enteric organisms carrying similar resistances as in the humans or animals. Considering the resistance patterns of the organisms isolated from the lettuce samples in our study, it is apparent that any opportunistic infection arising from the strains may require the use of the newer and probably more expensive antimicrobial agents. Measures must therefore be put in place to control the use of antibiotics in agriculture. Similar to our study, most strains of *E. coli* responsible for the German outbreak were resistant to multiple antibiotics that included the aminoglycosides, macrolides, and beta lactams (Davis, 2012).

On mating these isolates with a plasmidless nalidixic-acid-resistant strain of *E. coli* that was sensitive to other antibiotics, the rate of resistance transfer was between 69% and 83% for tetracycline, trimethoprim, and streptomycin. This shows that not only do these organisms carry resistance plasmids, they have the ability to transfer these plasmids and thus their resistance to other organisms whether pathogenic or not. Other recipients could be organisms present in other food items or in the gastrointestinal tract. The ability of these isolates to transfer their plasmids suggests that they can also serve as recipients of plasmids that may carry not only resistance genes but also virulence genes that can further be transferred to other previously harmless organisms. This could lead to the emergence of new pathogens.

Conclusion

The results of our study show that the high level of resistance in this environment may not only be due to the abuse or indiscriminate use of antibiotics in humans but also to the presence of resistant organisms in the food eaten by people in this environment. Lettuce leaves have been shown to be carriers of antibiotic-resistant microorganisms and may contribute to the high level of resistance in the Nigerian

environment. It is therefore very important to put in place some measures to control the microbial contamination of food, especially those eaten without any processing methods that can kill contaminants. Strict adherence to good cultivation practices and sanitation will be required in the production or preparation of raw vegetables for human consumption. Important control measures include the use of potable or biologically treated water for irrigation and washing of harvested vegetables especially those eaten raw. Consumers should be advised to wash and disinfect all vegetables before consumption while the practice of storing vegetable salads at ambient temperatures should be discouraged.

Corresponding Author: Oluwatoyin A. Igbeneghu, Department of Pharmaceutics, Obafemi Awolowo University, Ile-Ife, Nigeria. E-mail: oaigbene@oauife.edu.ng.

References

Beuchat, L.R. (2002). Ecological factors influencing survival and growth of human pathogens on raw fruits and vegetables. *Microbes and Infection, 4*(4), 413–423.

Bielaszewska, M., Mellmann, A., Zhang, W., Köck, R., Fruth, A., Bauwens, A., Peters, G., & Karch, H. (2011). Characterisation of the *Escherichia coli* strain associated with an outbreak of haemolytic uraemic syndrome in Germany, 2011: A microbiological study. *Lancet Infectious Diseases, 11*(9), 671–676.

Centers for Disease Control and Prevention. (2001a). Preliminary FoodNet data on the incidence of foodborne illnesses—selected sites, United States, 2000. *Morbidity and Mortality Weekly Report, 50*(13), 241–246.

Centers for Disease Control and Prevention. (2001b). *Surveillance for outbreaks of* Escherichia coli *O157:H7 infection. Summary of 1999 data. Report from the National Center for Infectious Diseases, Division of Bacterial and Mycotic Diseases to CSTE*. Atlanta, GA: Author.

Centers for Disease Control and Prevention. (2012). *Multistate foodborne outbreaks*. Retrieved from http://www.cdc.gov/foodsafety/outbreaks/multistate-outbreaks/outbreaks-list.html

Clinical and Laboratory Standards Institute. (2006). *Performance standards for antimicrobial disk susceptibility tests, document M2–A9, approved standard* (9th ed.). Wayne, PA: Author.

Davis, C.P. (2012). *A new EEC group?* (Update on the *E. coli* 0104:H4 outbreak in Germany). Retrieved from http://www.medicinenet.com/enterovirulent_e_coli_eec/page4.htm

Edberg, S.C., Rice, E.W., Karlin, R.J., & Allen, M.J. (2000). *Escherichia coli*: The best biological drinking water indicator for public health protection. *Symposium Series of the Society for Applied Microbiology, 29*, 106S–116S.

eFoodAlert.com. (2008). *Latest lettuce outbreak sprouts wings—enters Canada*. Retrieved from http://efoodalert.blogspot.com/2008/10/latest-lettuce-outbreak-sprouts-wings.html

Ejoh, R.A., Nkonga, D.V., Gouado, I., & Moses, M.C. (2007). Nutritional components of some nonconventional leafy vegetables consumed in Cameroon. *Pakistan Journal of Nutrition*, *6*(6), 712–717.

Farmer, J.J. (1999). Enterobacteriaceae: Introduction and identification. In P.R. Murray, E.J. Baron, M.A. Pfaller, F.C. Tenover, & R.H. Yolken (Eds.), *Manual of clinical microbiology* (pp. 442–458). Washington, DC: American Society for Microbiology Press.

Johannessen, G., Loncarevic, S., & Kruse, H. (2002). Bacteriological analysis of fresh produce in Norway. *International Journal of Food Microbiology, 77*(3), 199–204.

Mathew, A.G., Cissell, R., & Liamthong, S. (2007). Antibiotic resistance in bacteria associated with food animals: A United States perspective of livestock production. *Foodborne Pathogens and Disease, 4*(2), 115–133.

Okeke, I.N., Lamikanra, A., & Edelman, R. (1999). Socioeconomic and behavioral factors leading to acquired bacterial resistance to antibiotics in developing countries. *Emerging Infectious Diseases, 5*(1), 18–27.

Okeke, I.N., & Sosa, A. (2003). Antibiotic resistance in Africa—discerning the enemy and plotting a defense. *Africa Health*, *3*, 10–15.

Olayinka, K.O. (2004). Studies on industrial pollution in Nigeria: The effect of textile effluents on the quality of groundwater in some parts of Lagos. *Nigerian Journal of Health and Biomedical Sciences, 3*(1), 44–50.

Österblad, M., Pensala, O., Peterzéns, M., Heleniusc, H., & Huovinen, P. (1999). Antimicrobial susceptibility of Enterobacteriaceae isolated from vegetables. *The Journal of Antimicrobial Chemotherapy*, *43*(4), 503–509.

Pennington, H. (2011). *Escherichia coli* O104, Germany 2011. *Lancet Infectious Diseases*, *11*(9), 652–653.

Rajaram, T., & Das, A. (2008). Water pollution by industrial effluents in India: Discharge scenarios and case for participatory ecosystem specific local regulation. *Futures, 40*(1), 56–69.

Rickman, J.C., Barrett, D.M., & Bruhn, C.M. (2007a). Nutritional comparison of fresh, frozen, and canned fruits and vegetables. Part 1: Vitamins C and B, and phenolic compounds. *Journal of the Science of Food and Agriculture, 87*(6), 930–944.

Rickman, J.C., Barrett, D.M., & Bruhn, C.M. (2007b). Nutritional comparison of fresh, frozen, and canned fruits and vegetables II: Vitamin A and carotenoids, vitamin E, minerals, and fiber. *Journal of the Science of Food and Agriculture, 87*(7), 1185–1196.

Sagoo, S.K., Little, C.L., Ward, L., Gillespie, I.A., & Mitchell, R.T. (2003). Microbiological study of ready-to-eat salad vegetables from retail establishments uncovers a national outbreak of salmonellosis. *Journal of Food Protection, 66*(3), 403–409.

Sundström, L., Vinayagamoorthy, T., & Sköld, O. (1987). Novel type of plasmid-borne resistance to trimethoprim. *Antimicrobial Agents and Chemotherapy, 31*(1), 60–66.

Szabo, E.A., Scurrah, K.J., & Burrows, J.M. (2000). Survey for psychrotrophic bacterial pathogens in minimally processed lettuce. *Letters in Applied Microbiology, 30*(6), 456–460.

INTERNATIONAL PERSPECTIVES

Prepublished online April 2014,
National Environmental Health Association.

A Study on Exposure to Cyanide Among a Community Living Near a Gold Mine in Malaysia

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 25 countries worldwide, are addressed. Our goal is to raise diverse issues of interest to all our readers, irrespective of origin.*

Noor Artika Hassan, MS
Department of Community Medicine
International Islamic University Malaysia

Mazrura Sahani, MPH, MD, PhD
Environmental Health and Industrial Safety Program
National University of Malaysia

Rozita Hod, MPH, MD
Department of Community Health
National University of Malaysia

Noral' Asyikin Yahya, MPath, MD
Institute for Medical Research Malaysia

Abstract **Cyanidation in gold extraction has detrimental impacts on the ecosystem and the population in surrounding areas. The research described in this article aimed to assess the health effects of environmental exposure to cyanide in a community near a gold mining area in Malaysia. A total of 255 members of the exposed community and 117 members of the control community answered questionnaires on their exposure to a gold mine and health outcomes. Urine samples were collected for biomarker assessment (i.e., urinary thiocyanate). The authors found that the mean level of urinary thiocyanate was significantly higher among the exposed community (0.30 ± 0.26 mg/dL) than the control community (0.24 ± 0.23 mg/dL) (p = .0021). The exposed community had a significantly higher prevalence of headaches (prevalence odds ratio [p*OR*] = 2.6, p = .001), dizziness (p*OR* = 3.7, p < .001), skin irritation (p*OR* = 2.1, p = .040), and eye irritation (p*OR* = 5.1, p = .004). No association occurred between dietary exposure and urinary biomarkers. Smokers living near a gold mine had a higher urinary thiocyanate level (0.56 mg/dL) than smokers in the control community (0.49 mg/dL).**

Introduction

Malaysia is well endowed with natural mineral resources. One of the minerals that captivates people is gold. Gold mining in Malaysia began in the 18th century (Metcalfe, 1990). Gold production in this Southeast Asian country increased substantially from 2,489 kg in 2008 to 2,794 kg in 2009 from five gold mines in Pahang, Kelantan, and Johor (Tse, 2010).

Shaft mining was previously used to extract gold (Metcalfe, 1990). During ancient times, large pieces of gold could be extracted with relatively primitive methods and tools, with minimal disturbance to the environment (Müezzinog'lu, 2003). Today, however, cyanidation methods, also known as carbon in leach, have been used extensively in gold extraction, and these methods have a detrimental impact on the ecosystem. The cyanidation method is a simple, straightforward, and popular method for low-grade gold ore processing. Very dilute solutions of sodium cyanide (NaCN) are used in gold mining operations, typically in the range of 0.01% to 0.05% cyanide (100 to 500 parts per million [ppm]) for the process of leaching (Logsdon, Hagelstein, & Mudder, 1999). A stable gold-cyanide complex is then formed once the cyanide dissolves the gold from the ore (International Cyanide Management Code [ICMC], 2010).

Despite its popularity, the sodium cyanide method or cyanidation is highly controversial due to its toxicity. It can cause adverse effects on the ecosystem and the population living around the mining area (Moran, 2004). Although free cyanide breaks down rapidly when exposed to sunlight, the less toxic products, such as cyanates and thiocyanates, may persist in the environment for many years. Due to its toxic impact, cyanidation has been banned in the Czech Republic and in the state of Montana, while Turkey and Greece have been discouraging its use and other U.S. states are considering restricting its use (Haiduc, 2005; Müezzinog'lu, 2003; O'Reilly, Dicinoski, Miura, & Haddad, 2003).

Exposure to cyanide causes several side effects. The effects of acute cyanide exposure are dominated by central nervous system and cardiovascular disturbances (Agency for Toxic Substances and Disease Registry [ATSDR], 2011). Typical signs of acute cyanide poisoning include tachypnea, headaches, vertigo, lack of motor coordination, weak pulse, cardiac arrhythmias, vomiting, stupor, convulsions, and coma (Ballantyne, 1983; Johnson

& Mellors, 1988; Way, 1984). Pathological findings may include tracheal congestion with hemorrhage, cerebral and pulmonary edema, gastric erosions, and petechiae of the brain meninges and pericardium (Way, 1984).

The effects of chronic cyanide exposure are confusion, hallucination, hypo- or hyperthyroidism, abdominal pain, thyroid enlargement, and slurred speech. Baskin and co-authors (2009) stated that chronic cyanide exposure may lead to a kinetic rigid syndrome, tremors, pathological reflexes, disorders of sensitivity, intellectual deficits, and significant neurological morbidity arising from the apoptotic demise of neurons of the basal ganglia and sensory-motor cortex. El Ghawabi and co-authors (1975) found that hemoglobin and lymphocyte counts were higher among exposed workers.

In Malaysia, limited published research exists on the health impacts of cyanidation on communities near gold mining operations. Therefore, our study was conducted in a community living near a gold mine to assess the effects of low-dose exposure to cyanide via gold mining through residents' urinary thiocyanate levels and self-reported symptoms. The level of urinary thiocyanate can be influenced by the distance from the gold mine and can also be affected by other factors such as smoking (Hernán, Olek, & Ascherio, 2001; Scherer, 2006) and food (ATSDR, 2006; Logsdon et al., 1999).

Our study had three major aims: 1) to compare the urinary thiocyanate levels of the exposed and the control communities; 2) to compare the prevalence of cyanide exposure symptoms of the exposed and the control communities; and 3) to provide additional information on lifestyle factors that have been associated with urinary thiocyanate levels such as demographic factors, dietary exposure, and smoking.

Methods

Our cross-sectional study was conducted on the east coast of Peninsular Malaysia. The study area was selected to address community concerns about the impact of gold mining activities on residents' health. It covered 372 adults, aged 18 to 70 years old, who were randomly recruited from two communities. The first community was within a 5 km radius from a gold mine; it included 255 respondents and was classified as the exposed community. The control community was comprised of 117 respondents who were living farther away. The location of the control community was 13.6 km from a gold mine, which was more than 5 km beyond the buffer zone. The members of both communities have similar ethnicities, including Malay, Chinese, and Indian. Both locations are rural areas.

The study protocol was reviewed and approved prior to its implementation by the ethics committee of the Universiti Kebangsaan Malaysia Medical Center. The respondents gave their written consent before participating in our study.

Survey

A survey was conducted among the communities in February 2011 using a modified and validated guided questionnaire (Veiga & Baker, 2004). The questionnaire was translated into Malay and obtained information on demographic characteristics, medical history, cigarette consumption, working exposure, food and water sources, and self-reported symptoms that could be associated with mining activities. Respondents were asked about their sources of water, vegetables, fruits, beef, chicken, duck, and pork to investigate the possibility of cyanide being transmitted through dietary intake. In addition, an open-ended questionnaire was used to obtain information on the intake of food such as almonds, millet sprouts, lima beans, soy, spinach, bamboo shoots, and cassava roots, as these foods contain a relatively low amount of cyanide. Those who had consumed foods that may contain cyanide were categorized as "yes," and those who had not were categorized as "no." Symptoms referred to the abnormal signs or indicators experienced by the community in the two weeks prior to the survey. The symptoms were also categorized as "yes" and "no."

The questionnaire was pretested on 25 respondents from the exposed area who were later excluded from the actual research. To check the internal consistency of the data, Cronbach's alpha values were calculated for the data on food source (.80) and symptoms (.76).

Urine Sample Analysis

Spot urine samples were collected to measure the urinary thiocyanate levels by using the thiocyanate picrate kit method (Haque & Bradbury, 1999). The samples were collected in 30-mL polyethylene containers, kept below 4°C in small cool boxes, and were transported to the Universiti Kebangsaan Malaysia laboratory and stored at -20°C. Using a micropipette, 1.0 mL of urine was placed in a flat-bottomed vial. Then, 0.1 mL of 1 mol/L sulfuric acid (H_2SO_4) and 0.1 mL of 0.13 mol/L potassium permanganate ($KMnO_4$) were added. A 30 x 10 mm picrate paper, attached to a 50 x 10 mm plastic strip with hobby glue, was added to the vial. Another sample was prepared in the same manner without urine to serve as a blank. As a control, a 21-mm Whatman filter paper previously loaded with 10 ppm of thiocyanate was added in a vial, followed by acid, permanganate, and a picrate paper. All the vials were closed and left at room temperature (20°C to 37°C) overnight. Within the next 16 to 24 hours, the vials were opened and the colors of the papers were matched with the color chart, with the blank corresponding to zero and the control corresponding to 10 ppm. To obtain more accurate results, the plastic strip was removed from the picrate paper, which was immersed in 5 mL of distilled water for about 30 minutes. The absorbance of the solution was measured at 510 nm using a Secomam Prim spectrophotometer against the blank yellow solution. The thiocyanate content in ppm was calculated using the following equations:

Thiocyanate content (ppm) =
78 x absorbance

Thiocyanate content in µmol/L =
thiocyanate content (ppm) x 17.2

Power Calculation

The sample size calculation for our cross-sectional study was performed using Power and Sample Size software. The formula for cross-sectional studies with a dichotomous outcome was used and results were analyzed through an uncorrected Chi-square test. Using $\alpha = .05$ (i.e., 5%) and $\beta = .20$ (i.e., 20%), the sample size of the study should be 257 respondents from the exposed community and 257 from the control group. Only 255 respondents from the exposed community and 117 respondents from the control group participated, however, which translates to a response rate of 99% and about 50%, respectively.

Statistical Analysis

Data were analyzed using SPSS for Windows v. 18. Descriptive analysis was used to describe the demographic data. Bivariate analysis and Student's *t*-test were used to compare qualitative dichotomous and continuous data; the Chi-square test was used to test the relationship between two qualitative variables; and analysis of variance was used to compare qualitative polynomial and continuous data. Multiple linear regression was used to assess the association between the urine thiocyanate level and the exposure to gold mine activities, taking into account smoking, dietary exposure, and demographic characteristics.

Results

Sociodemographic characteristics of the study population are presented in Table 1. No significant differences were observed between the two groups in terms of gender, race, education, income, smoking status, and age. The exposed community had a significantly higher proportion of married participants than the control community.

The exposed community had significantly higher urinary thiocyanate levels than the control community. In the exposed community, 15% (34 persons) had higher urinary thiocyanate levels than the guideline value, whereas about 9% (10 persons) of the control community exceeded the guideline value of 0.50 mg/dL (Chandra, Singh, Debnath, Tripathy, & Khanam, 2008). When the 34 participants from the exposed community with urinary thiocyanate levels above the guideline value were stratified by their distance from a gold mine, 16 of them were found living within a 1 km radius while 8 and 10 of them were found living within a 2–3 km radius and a 4–5 km radius, respectively.

Comparing the urinary thiocyanate levels by sociodemographic characteristics (Table 2), males registered a higher mean than females ($p < .001$) and smokers had a higher mean than nonsmokers ($p < .001$). Race, gender, and age did not indicate any significant differences (Tables 2 and 3).

Our study also determined the prevalence of cyanidation symptoms (Table 4). Out of 19 symptoms, eight symptoms had prevalence above 10% in the exposed community, while only three symptoms had prevalence above 10% in the control community. Significant differences occurred between the two communities in four symptoms: headaches ($p = .001$), dizziness ($p < .001$), skin irritation ($p = .04$), and eye irritation ($p = .004$). The prevalence odds ratios (p*OR*) were 2.6, 3.8, 2.2, and 5.1 for headaches, dizziness, skin irritation, and eye irritation, respectively.

When we examined the associations of exposure to a gold mine and other important factors such as smoking, dietary exposure, and age with a urinary biomarker using multivariate analysis, we found that the association between exposure to a gold mine and smoking was significant ($p < .05$). A significant linear relationship also existed between exposure to a gold mine and the urinary thiocyanate level ($p < .05$). Exposure refers to the housing distance from a gold mine. The community near

TABLE **1**

Sociodemographic and Exposure Characteristics of the Participants (*N* = 372)

Variables	Data	Exposed *n* = 255 (%)	Control *n* = 117 (%)	*p*-Value
Gender	Male	104 (40.8)	52 (44.4)	
	Female	151 (59.2)	65 (55.6)	
Race	Bumiputra	152 (59.6)	78 (66.7)	
	Non-Bumiputra	103 (40.4)	39 (33.3)	
Marital status	Married	227 (91.9)	93 (80.9)	
	Unmarried	20 (8.1)	22 (19.1)	
Education	Low	60 (24.3)	38 (33)	
	High	187 (75.7)	77 (67)	
Income	Low	184 (76.3)	91 (81.3)	
	High	57 (23.7)	21 (18.8)	
Smoking status	Yes	46 (18.5)	22 (19.47)	
	No	202 (81.45)	91 (80.53)	
Age (in years), mean±*SD*		47.71±13.83	45.57±15.42	
Urinary thiocyanate (mg/dL)		0.30±0.26[a]	0.24±0.23[b]	.021*

[a]*n* = 228.
[b]*n* = 114.
*Significant at $p < .05$. Urinary thiocyanate = Student's *t*-test.

TABLE **2**

Urinary Thiocyanate (mg/dL) Based on Demographic Characteristics and Smoking Status

Variables	Data	#	Mean±*SD*	*t*	*p*-Value[a]
Gender	Male	140	0.37±0.33	5.78	<.001*
	Female	201	0.21±0.16		
Race	Bumiputra	213	0.28±0.25	-0.24	.810
	Non-Bumiputra	128	0.28±0.26		
Marital status	Married	295	0.27±0.25	1.91	.063
	Unmarried	36	0.37±0.31		
Smoking status	Yes	64	0.55±0.39	6.85	<.001*
	No	266	0.21±0.15		

[a]Student's *t*-test.
*Significant at $p < .05$.

TABLE **3**

Correlation Between Age and Urinary Thiocyanate Level

Variable	*r*	*p*-Value
Age[a]	-.07	.199

[a]Pearson correlation.

TABLE **4**

Prevalence of Acute Cyanidation Symptoms[a]

Symptoms	Data	Exposed *n* = 249 (%)	Unexposed *n* = 115 (%)	p*OR*[b]	95% *CI*[b]	*p*-Value
Headache	Yes	84 (33.7)	19 (16.5)	2.6	1.47–4.49	.001*
	No	165 (66.3)	96 (83.5)			
Dizziness	Yes	76 (30.5)	12 (10.4)	3.8	1.96–7.27	<.001*
	No	173 (69.5)	103 (89.6)			
Fatigue	Yes	42 (16.9)	12 (10.4)	1.74	0.88–3.45	.10
	No	207 (83.1)	103 (89.6)			
Skin irritation	Yes	39 (15.7)	9 (7.8)	2.2	1.02–4.68	.040*
	No	210 (84.3)	106 (92.2)			
Throat irritation	Yes	33 (13.3)	10 (8.7)	1.61	0.76–3.38	.21
	No	216 (86.7)	105 (91.3)			
Eye irritation	Yes	30 (12)	3 (2.6)	5.1	1.53–17.12	.004*
	No	219 (88)	112 (97.4)			

[a]Chi-square test.
[b]p*OR* = prevalence odds ratio; *CI* = confidence interval.
*Significant at $p < .05$.

the gold mine had a urinary thiocyanate level of 0.07 mg/dL (95% confidence interval [*CI*] = 0.02, 0.11). A significant linear relationship also existed between smoking and the urinary thiocyanate level ($p < .001$). Smokers had a higher urinary thiocyanate level at 0.32 mg/dL (95% *CI* = 0.28, 0.40). With the two significant variables, the model explains 30% of the variation in the urinary thiocyanate level of the study sample ($R^2 = .30$). The results show that both factors independently contributed to the urinary thiocyanate level. Dietary exposure and age did not show any correlation with the urinary thiocyanate level.

The model equation for the prediction study is as follows:

Urinary thiocyanate (mg/dL) = 0.17 + (0.32 x smoking) + (0.07 x exposure)

Smokers who lived within a 5 km radius from a gold mine were predicted to have a urinary thiocyanate level of 0.56 mg/dL. Smokers from the control area were expected to have a lower reading of 0.49 mg/dL. If the respondents were nonsmokers who lived near a gold mine, the expected reading was 0.24 mg/dL; nonsmokers who lived far from a gold mine were expected to have a reading of 0.17 mg/dL.

Discussion

Results show that the mean level of urinary thiocyanate in the exposed community was significantly higher than that of the control community. Fifteen percent of the exposed community and 9% of the control community had urinary thiocyanate levels exceeding the guideline level of 0.50 mg/dL (Chandra et al., 2008). Although the mean level of urinary thiocyanate was higher in the exposed community, both communities were still within the acceptable range as the readings were below 0.50 mg/dL.

Information regarding urinary thiocyanate levels in mining communities worldwide is limited. One of the major strengths of our study is that it fills this research gap and provides baseline information on the urinary thiocyanate levels of a community living near a gold mine in Malaysia. Most articles on this topic do not mention the level of thiocyanate in urine (ICMC, 2010). An exception is a similar survey conducted by the National Institute for Occupational Safety and Health (NIOSH, 1988) among workers at the Summitville Consolidated Mining Company, Inc., in Del Norte, Colorado. That survey was conducted in response to an incident that occurred on October 1, 1987, where employees experienced dryness of the mouth, numbness of the fingers and ears, headaches, dizziness, difficulty moving, and unconsciousness. They also reported noticing the odor of almonds. After three weeks, NIOSH monitored the workers and found that the highest level of urinary thiocyanate was 2.05 mg/dL.

Our study found four symptoms that significantly differed between the exposed community and the control community ($p < .05$): headaches, dizziness, skin irritation, and eye irritation. These are all common symptoms of communities staying near a gold mine. This has been proven by a study conducted by the Cordillera Peoples Alliance (2007) in a community in Mankayan, Philippines; a study by Adei and co-authors (2010) in Ghana; and a study by Oosthuizen and co-authors (2010) in South Africa.

Among the exposed and control communities in our study, headaches had the highest prevalence of all the symptoms. The community living within a 5 km radius from a gold mine was three times more likely to have headaches compared to the control group. This prevalence is still lower than that of the study conducted by Oosthuizen and co-authors (2010) in South Africa, where 50% of the respondents complained of having headaches. A study by Silbergeld and co-authors (2002) among gold miners in Pará, Brazil, also had a higher prevalence of headaches (41%) than our study.

Another symptom with a high prevalence in both communities was dizziness. The community living near a gold mine was four times more likely to experience dizziness than the control community. Although many studies have been conducted on dizziness experienced by communities near a gold mine (Adei et al., 2010; Cordillera Peoples Alliance, 2007; Oosthuizen et al., 2010), those studies did not report the specific prevalence of the symptom. An exception is the study conducted by Tomicic and co-authors (2011) among the family members of gold miners, which reported that 54% of the 93 respondents experienced dizziness. In that same study, 38% of 779 gold miners claimed they suffered from dizziness due to gold mining activities.

Eye irritation had the highest odds ratio among all the symptoms. The community living near a gold mine was five times more likely to experience eye irritation than the control community. Mayan and co-authors (2005) conducted a study among a community living near an abandoned mine and reported that the prevalence of eye irritation was 24% in the exposed community and 12% in the control community. In their study, the exposed community was six times more likely to experience eye irritation compared to the control community. This is similar to the odds ratio for eye irritation (5.53) in our study.

Skin irritation is a common symptom of low cyanide exposure. Results show that the community living near a gold mine was twice as likely to experience skin irritation compared to the control community. This result is supported by the study of Adei and co-authors (2010) in a community living near a gold mine in Ntotroso, Ghana, which reported that 42% of the respondents had skin problems. This is higher than the prevalence of skin problems (16%) among the exposed community in our study.

These four symptoms are common symptoms of cyanide exposure. Inhabitants within the concession of Bogoso Gold Limited (Obiri, Dodoo, Okai-Sam, Essumang, & Adjorlolo-Gasokpoh, 2006), which reported 11 cyanide spillages between 1989 and 2004, experienced all these symptoms. Cyanide toxicity results from the inhibition of cytochrome oxidase, thereby limiting the absorption of oxygen at the cellular level (Stanton, Colbert, & Trenholme, 1986). Its outward acute effects resemble those of acute hypoxia. Therefore, headaches and dizziness are the common effects of cyanide intoxication.

TABLE **5**

Factors Associated With the Urinary Thiocyanate Level

Variables	Multiple Linear Regression[a]			
	B[b]	(95% *CI*[c])	*t*	*p*-Value
Smoking	0.32	-0.38, -0.25	-9.32	<.001*
Exposure to a gold mine[d]	0.07	-0.11, -0.01	-2.64	.009*
Gender	0.02	-0.08, 0.26	-0.99	.32
Food sources	0.01	-0.62, 0.31	-0.67	.51

[a] $R^2 = 0.3$.
[b] B = unstandardized coefficient.
[c] CI = confidence interval.
[d] Exposure to a gold mine refers to distance from a gold mine.
*Significant at $p < .05$.

Lifestyle factors also influenced the results of our study. Smoking status and gender were associated with urinary thiocyanate levels. Urinary thiocyanate results showed that an association existed between smoking status and urinary thiocyanate levels in both the exposed and control communities. The mean levels for smokers in the exposed and control communities were 0.55 ± 0.39 mg/dL and 0.21 ± 0.15 mg/dL, respectively. The mean level for smokers in the exposed community was higher than the recommended guideline for normal people (0.50 mg/dL), while that of the control community was still within normal range.

A study conducted by Case (2006) had similar results. The levels of thiocyanate among smokers and nonsmokers were 0.74 mg/dL and 0.14 mg/dL, respectively. The result for smokers was higher in Case's study compared to the result of our study (0.58 mg/dL). For nonsmokers, the mean level in our study was higher than that of Case, with levels of 0.24 ± 0.15 mg/dL and 0.14 mg/dL, respectively. Another study that supported these findings was by Buratti and co-authors (1997). The urinary thiocyanate median value of nonsmokers in their study was 0.10 mg/dL, which was significantly different from that of the smokers (0.40 mg/dL, $p < .001$). Results of our study show that males have a higher urinary thiocyanate level than females due to their smoking habit. Out of 64 smokers, 55 were male.

Cyanide can be found in over 2,000 plant species, including fruits and vegetables that contain cyanogenic glycosides, which can release cyanide on hydrolysis when ingested. Among them are cassava (tapioca, manioc) and sorghum, which are the staple food of hundreds of millions of people in many tropical countries (World Health Organization, 2004). Most cyanide poisoning cases through food occurred in countries with cassava as their staple food, such as Nigeria and Malawi (Chiwona-Karltun, Tylleskär, Mkumbira, Gebre-Medhin, & Rosling, 2000; Kendirim, Chukwu, & Achinewhu, 1995). In our study, however, food was not associated with the urinary thiocyanate level. Although the exposed community ate cabbage and mustard, no significant differences occurred between the urinary thiocyanate level of the exposed and control communities.

Table 5 shows the multiple linear regression results for smoking. Results show that smoking is not a confounder in our study. Both smoking and exposure to a gold mine contributed independently to the urinary thiocyanate level ($p < .05$). The prediction model shows that smokers and exposure to a gold mine produced additive effects. Smokers who live near a gold mine are expected to have a higher level of urinary thiocyanate (0.56 mg/dL) than smokers living in the control area (0.49 mg/dL). The expected level is 0.24 mg/dL for nonsmokers living near a gold mine, and 0.17 mg/dL for nonsmokers living in the control area. Gender and dietary factors are not associated with the urinary thiocyanate level.

Limitations of our study include its cross-sectional design, self-reporting bias, and the nonspecific nature of cyanidation symptoms. Also, no environmental monitoring data exist

to support the findings due to unavailability of suitable equipment in the university. In the future, a cohort study is recommended instead of a cross-sectional study to determine the cause-effect relationship between exposure to cyanide and health. Ambient air concentration of cyanide also should be taken to support the findings.

Conclusion

Our study found that the community living near a gold mine had a higher exposure to cyanide than the control community. This finding is based on their experience of symptoms and their urinary thiocyanate level. Smoking and exposure to a gold mine produced additive effects, with the urinary thiocyanate level higher among smokers living near a gold mine than among nonsmokers living in the control area.

Acknowledgements: The authors would like to acknowledge the staff of Universiti Kebangsaan Malaysia (UKM), the Ministry of Health, Institute for Medical Research, and International Islamic University Malaysia. This research obtained financial support from UKM and approval from the ethics committee of Universiti Kebangsaan Malaysia Medical Center, with the project code FF-141-2011 and UKM-NN-03-FRGS 0041-2010.

Corresponding Author: Mazrura Sahani, Environmental Health and Industrial Safety Program, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Jalan Raja Muda Abdul Aziz, 50300 Kuala Lumpur, Malaysia. E-mail: mazrura@gmail.com.

References

Adei, D., Addei, I., & Kwadjosse, H.A. (2011). A study of the effects of mining activities on the health status of people: A case study. *Research Journal of Applied Sciences, Engineering and Technology*, *3*(2), 99–104.

Agency for Toxic Substances and Disease Registry. (2011). *Toxicological profile for cyanide*. Retrieved from http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=72&tid=19

Ballantyne, B. (1983). Acute systemic toxicity of cyanides by topical application to the eye. *Cutaneous and Ocular Toxicology*, *2*(2–3), 119–129.

Baskin, S.I., Kelly, J.B., Maliner, B.I., Rockwood, G.A., & Zoltani, C.K. (2009). Cyanide poisoning. In S.D. Tuorinsky (Ed.), *Medical aspects of chemical and biological warfare, textbook of military medicine* (Vol. 2, pp. 371–397). Washington, DC: Borden Institute, Walter Reed Army Medical Center.

Buratti, M., Xaiz, D., Caravelliand, G., & Colombi, A. (1997). Validation of urinary thiocyanate as a biomarker of tobacco smoking. *Biomarkers*, *2*(2), 81–85.

Case, B.W. (2006). *A comparison of the accuracy of measurement of urine thiocyanate by spectrometry and ion chromatography in a population without known exposure to cyanide*. Unpublished doctoral dissertation, University of Cincinnati, Ohio.

Chandra, A.K., Singh, L.H., Debnath, A., Tripathy, S., & Khanam, J. (2008). Dietary supplies of iodine and thiocyanate in the etiology of endemic goiter in Imphal East district of Manipur, North East India. *Indian Journal of Medical Research*, *128*(5), 601–605.

Chiwona-Karltun, L., Tylleskär, T., Mkumbira, J., Gebre-Medhin, M., & Rosling, H. (2000). Low dietary cyanogen exposure from frequent consumption of potentially toxic cassava in Malawi. *International Journal of Food Sciences and Nutrition, 51*(1), 33–43.

Cordillera Peoples Alliance. (2007). *Case study on the impacts of mining and dams on the environment and indigenous peoples in Benguet, Cordillera, Philippines*. Khabarovsk, Russia: United Nations Department of Economic and Social Affairs.

El Ghawabi, S.H., Gaafar, M.A., El-Sharati, A.A., Ahmed, S.H., Malash, K.K., & Fares, R. (1975). Chronic cyanide exposure: A clinical, radioisotope, and laboratory study. *British Journal of Industrial Medicine*, *32*(3), 215–219.

Haiduc, I. (2005). Environmental hazards of chemical processes involved in the extraction of gold from mineral ores. *British Library Journal*, *56*(2), 200–205.

Haque, M.R., & Bradbury, J.H. (1999). Simple method for determination of thiocyanate in urine. *Clinical Chemistry, 45*(9), 1459–1464.

Hernán, M.A., Olek, M.J., & Ascherio, A. (2001). Cigarette smoking and incidence of multiple sclerosis. *American Journal of Epidemiology, 154*(1), 69–74.

International Cyanide Management Code. (2010). *Use of cyanide in the gold industry.* Washington, DC: Author.

Johnson, R.P., & Mellors, J.W. (1988). Arteriolization of venous blood gases: A clue to the diagnosis of cyanide poisoning. *The Journal of Emergency Medicine, 6*(5), 401–404.

Kendirim, O.C., Chukwu, O.A., & Achinewhu, S.C. (1995). Effect of traditional processing of cassava on the cyanide content of gari and cassava flour. *Plant Food for Human Nutrition*, *48*(4), 335–339.

Logsdon, M.J., Hagelstein, K., & Mudder, T.I. (1999). *The management of cyanide in gold extraction*. London: International Council on Mining & Metals. Retrieved from http://www.icmm.com/page/1616/the-management-of-cyanide-in-gold-extraction

Mayan, O.N., Gomes, M.J., Henriques, A., Silva, S., & Begonha, A. (2005). Health survey among people living near an abandoned mine. A case study: Jales Mine, Portugal. *Environmental Monitoring and Assessment*, *123*(1–3), 31–40.

Metcalfe, I. (1990). Lower and Middle Triassic conodonts from the Jerus Limestone, Pahang, Peninsular Malaysia. *Journal of Southeast Asian Earth Sciences, 4*(2), 141–146.

Moran, R. (2004). Cyanide uncertainties: Observations on the chemistry, toxicity, and analysis of cyanide in mining-related waters. *Mineral Policy Center Issue paper 1*. Retrieved from

continued on page 48

References *continued from page 47*

http://www.earthworksaction.org/files/publications/morancyanidepaper.pdf

Müezzinog'lu, A. (2003). A review of environmental considerations on gold mining and production. *Critical Reviews in Environmental Science and Technology, 33*(1), 45–71.

National Institute for Occupational Safety and Health. (1988). *Health hazard evaluation report: Summitville Consolidated Mining Company, Inc*. Retrieved from http://www.cdc.gov/niosh/hhe/reports/pdfs/1988-0022-1926.pdf

Obiri, S., Dodoo, D.K., Okai-Sam, F., Essumang, D.K., & Adjorlolo-Gasokpoh, A. (2006). Cancer and noncancer human health risk from eating cassava grown in some mining communities in Ghana. *Environmental Monitoring and Assessment, 118*(1–3), 37–49.

Oosthuizen, M.A., John, J., & Somerset, V. (2010). Mercury exposure in a low-income community in South Africa. *South African Medical Journal*, *100*(6), 366–371.

O'Reilly, J.W., Dicinoski, G.W., Miura, Y., & Haddad, P.R. (2003). Separation of thiosulfate and the polythionates in gold thiosulfate leach solutions by capillary electrophoresis. *Electrophoresis, 24*(12–13), 2228–2234.

Scherer, G. (2006). Carboxyhemoglobin and thiocyanate as biomarkers of exposure to carbon monoxide and hydrogen cyanide in tobacco smoke. *Experimental and Toxicologic Pathology, 58*(2–3), 101–124.

Silbergeld, E.K., Nash, D., Trevant, C., Strickland, G.T., de Souza, M., & da Silva, R.S. (2002). Mercury exposure and malaria prevalence among gold miners in Pará, Brazil. *Revista da Sociedade Brasileira de Medicina Tropicale*, *35*(5), 421–429.

Stanton, M.D., Colbert, T.A., & Trenholme, R.B. (1986). *National Park Service environmental handbook for cyanide leaching projects*. Denver, CO: The Division.

Tomicic, C., Vernez, D., Belem, T., & Berode, M. (2011). Human mercury exposure associated with small-scale gold mining in Burkina Faso. *International Archives of Occupational and Environmental Health*, *84*(5), 539–546.

Tse, P.K. (2010). The mineral industry of Malaysia. In *2008 minerals yearbook: Malaysia*. Retrieved from http://minerals.usgs.gov/minerals/pubs/country/2008/myb3-2008-my.pdf

Veiga, M., & Baker, R. (2004). *Protocols for environmental and health assessment of mercury released by artisanal and small-scale gold miners*. Vienna, Austria: United Nations Industrial Development Organization.

Way, J.L. (1984). Cyanide intoxication and its mechanism of antagonism. *Annual Review of Pharmacology and Toxicology, 24*, 451–481.

World Health Organization. (2004). *Hydrogen cyanide and cyanides: Human health aspects*. Retrieved from http://www.who.int/ipcs/publications/cicad/en/cicad61.pdf

INTERNATIONAL PERSPECTIVES

Prepublished online May 2014,
National Environmental Health Association.

Hand Washing Among Palestinians in the West Bank and Gaza Strip: Attitudes and Practices

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 25 countries worldwide, are addressed. Our goal is to raise diverse issues of interest to all our readers, irrespective of origin.*

Issam A. Al-Khatib
Institute of Environmental and Water Studies
Birzeit University

Lara W. Abusara, MSc
Yazan M. Odeh
Sbeih A. Sbeih
Institute of Community and Public Health
Birzeit University

May A. Massoud
Department of Environmental Health
American University of Beirut

Abstract **Regular and proper hand washing is a low-cost and effective intervention to prevent the spread of infectious diseases. The authors' study aimed to assess the socioeconomic and demographic characteristics associated with attitudes and practices of hand washing before eating in the West Bank and Gaza Strip. It also assessed parents' participation in the personal hygiene of their children. Results revealed that almost all participants believed that it is always necessary to wash one's hands before eating. Females had higher rates than males for washing hands before eating as well as for helping with child hygiene. Not surprisingly, a positive relationship existed between educational level and attitudes and practice of washing hands before eating. The authors recommend that governments, ministries, and different nongovernmental organizations have an active role in developing and implementing programs in order to improve the health of their communities. Such programs should be conducted in all localities and at all levels including homes, schools, and public domains.**

Introduction

Our health is greatly affected by environmental risk factors such as sanitation and hygiene, which includes hands washing (Prüss, Kay, Fewtrell, & Bartram, 2002). Hands need to be washed regularly especially before preparing or eating food; after being around sick people; before and after treating a cut or wound; after cleaning up a child who has used the toilet; after using the toilet; after touching an animal, animal feed, or animal waste; and after cleaning or touching garbage (Centers for Disease Control and Prevention [CDC], 2012). According to the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC), the right way to clean hands is to use soap and clean running water; rub hands together; and make sure to clean the backs of the hands, between fingers, and under the nails. Washing hands with soap and water is the best way to get rid of germs. If soap and water are not available, however, an alcohol-based rub can be used. Although this method will reduce a number of germs, it does not eliminate all the different types (CDC, 2012; World Health Organization [WHO], 2012).

WHO estimates that about 10% of the global burden of disease today could be prevented and controlled by improving the water supply, sanitation, hygiene, and management of water resources (Prüss-Üstün, Bos, Gore, & Bartram, 2008). One of the key United Nations Millennium Development Goals is a 66% reduction in mortality rates in children under five years by 2015 (Fewtrell et al., 2005). Half of all child deaths each year are attributed to diarrhea and acute respiratory infections; both are transmitted from person to person during everyday interaction, through skin contact and contamination of the environment (Curtis, Danquah, & Aunger, 2009). Therefore, hand washing with soap is considered to be one of the most important interventions to prevent and control these infections (Bhojani, D'Costa, & Gupta, 2008; Curtis et al., 2003; Curtis et al., 2009; Curtis et al., 2011; Hass & Larson, 2007). Lack of hygiene and access to safe water or adequate sanitation is among the underlying and structural causes of maternal and child mortality (UNICEF, 2008). In Palestine (the West Bank and Gaza Strip), respiratory infections and diarrheal diseases are major causes of child morbidity and mortality primarily as a result of poor sanitary and environmental conditions (Rionda & Clements, 2000).

Several meta-analysis studies reported that hand washing or hand washing with soap resulted in a significant reduction in the risk of diarrhea (Curtis & Cairncross, 2003; Fewtrell et al., 2005), and that interventions to promote hand washing might save millions of lives (Curtis & Cairncross, 2003). In an intervention study that took place in Karachi, Pakistan, results revealed that households that received free soap and hand

TABLE **1**

Percentage Frequency Distribution of the Sample According to the Household Variables

Variable	%
Age	
18–24	18.9
25–34	31.9
35–44	22.9
45–54	15.8
55+	10.5
Education	
Illiterate	3.8
Elementary	6.7
Preparatory	14.9
Secondary	31.8
Intermediate diploma	15.7
Bachelor's degree and higher	27.1
Sex	
Male	50.1
Female	49.9
Children under 18	
Yes	77.2
No	22.8

Variable	%
District	
Ramallah	22.3
Jenin	22.2
North Gaza	10.9
Gaza	13.6
Hebron	22.2
Rafah	8.8
Locality	
Urban	50.4
Rural	42.7
Camp	6.9
Marital status	
Single	16.5
Married	76.5
Engaged	2.7
Divorced	1.1
Widowed	2.9
Separated	.3

Variable	%
Number of family members	
1–2	7.9
3	7.6
4	11.3
5	13.7
6	13.9
7+	45.6
Employment status	
Currently employed	45.1
Unemployed but looking for work	9.4
Unemployed and not looking for work	9.4
Student	8.9
Housewife	26.4
Retired	.7
Unable to work	.1

TABLE **2**

Percentage Reporting Washing Hands Before Eating Among Selected Sociodemographic Variables

Variable	Reported Washing Hands Before Eating (%)			Pearson's Chi-Square Test	*p*-Value
	Always	Sometimes	No		
Sex				31.107	<.0001
Male	80.4	18.2	1.4		
Female	89.6	9.5	1.0		
Education				47.660	<.0001
Illiterate	75	18.1	6.9		
Elementary	80	19.2	0.8		
Preparatory	78.1	20.1	1.8		
Secondary	86.6	12.9	0.5		
Intermediate diploma	91.1	8.2	0.7		
Bachelor's degree and higher	86	12.8	1.2		
Region				66.595	<.0001
North West Bank	81.3	18.2	0.5		
Central West Bank	82.1	17.9	0.0		
South West Bank	80.6	18	1.4		
Gaza Strip	92.3	5.4	2.2		
Locality				22.212	<.0001
Urban	87	11.5	1.5		
Rural	81.3	17.7	1		
Camp	93.1	6.9	0.0		

washing promotion for nine months reported a 53% reduction in diarrhea compared to controls (Luby et al., 2009).

Palestine suffers from water scarcity, which in turn contributes to negative effects on health. A study that was conducted in the Gaza Strip revealed that poor sanitation and restriction of water may favor communicable diseases, especially diarrhea, which is one of the leading causes of morbidity in the area (Abouteir et al., 2011). A Palestinian study in the Nuseirat refugee camp reported that 61.2% of the interviewed women agreed that their hands should always be washed and 70.7% reported that their children's hands should be washed before and after eating (Abu Mourad, 2004).

Various surveys including a household survey carried out by UNICEF and the Palestinian Hydrology Group (2010) indicated that about 50% of the surveyed population suffered from diarrhea as well as skin diseases and parasites, particularly among children under the age of five. The survey also showed that hygiene practices are poorly applied. Accordingly, our study aimed to assess the socioeconomic and demographic characteristics associated with attitudes and practices of hand washing before eating, as well as par-

ents' participation in the personal cleaning of their children, using the West Bank and Gaza Strip as case examples.

Methods

Population and Sampling

A stratified multistage random sample approach of men and women over 18 years of age was chosen (three stages). This approach was used to make sure that the sample was distributed in a way commensurate with the population in every location of the West Bank and the Gaza Strip. In order to divide the study population into different classes, depending on the homogeneity of these classes, two variables were chosen—the region and type of communities.

Accordingly, the sample size of each area in the West Bank was estimated to be 418 individuals. Two people were selected from each family. Consequently, the sample size in every area was estimated at 209 families. In the Gaza Strip the sample size of individuals was estimated at 628, equivalent to 314 families. The total sample size was 1,882 residents living routinely in the Palestinian territories in the year 2010. The confidence level was 95% (confidence coefficient 1.96), and the margin of error about ±5.25%, covering the entire research sample in every geographical location.

TABLE **3**

Percentage Reporting Belief That It Is Necessary to Wash Hands Before Eating Among Selected Sociodemographic Variables

Variable	Reported Belief That It Is Necessary to Wash Hands Before Eating (%)			Pearson's Chi-Square Test	*p*-Value
	Always	Sometimes	No		
Sex				4.675	.097
Male	93.1	5.8	1.1		
Female	95.3	3.7	1		
Education				42.205	<.0001
Illiterate	90.3	2.8	6.9		
Elementary	96.8	3.2	0.0		
Preparatory	91.4	7.9	0.7		
Secondary	93.5	6	0.5		
Intermediate diploma	96.6	2.4	1		
Bachelor's degree and higher	95.1	3.8	1.2		
Region				39.403	<.0001
North West Bank	93.3	6.5	0.2		
Central West Bank	95.9	3.3	0.7		
South West Bank	91.3	8.4	0.2		
Gaza Strip	95.5	2.2	2.2		
Locality				21.725	<.0001
Urban	95	3.4	1.6		
Rural	92.6	7	0.4		
Camp	97.7	1.5	0.8		

Instruments

Primary data were acquired using a questionnaire that was designed following the structured questions method to provide useful information concerning the necessity of washing hands before eating and whether hand washing is actually practiced. Moreover, participants were asked if they help in the personal hygiene of their children. The questionnaire was pretested to ensure that the questions were understandable and clear to respondents. Twelve questions pertained to hand washing. The questionnaire also targeted other issues but those were not the focus of our study. It took between 20 and 25 minutes to administer the questionnaire. The response rate was 95%. In addition, a total of 15 focus group discussions (FGD) were held with the participation of both men and women from the West Bank and the Gaza Strip (eight FGDs for women and seven for men). Families were contacted and informed about the study through local committees. No incentive was given to participate in the study.

Data Management and Analysis

The collected data were numerically coded to facilitate the use of statistical programs, i.e., SPSS v. 17.0. Following the coding process, the data were subjected to statistical analysis on the premise of which conclusions were drawn.

Results and Discussion

A summary of the sociodemographic characteristics of the study sample is presented in Table 1. The age distribution shows that the 25–34 age group was the largest (31.9%). The secondary education level was the largest (31.8%); those with secondary level education and higher made up 74.6%. The distribution of gender was almost equal with 50.1% males and 49.9% females. About 77% of the sampled families had children under 18 years old. About 50% were from urban areas, 76.5% were married, and 45.1% were employed.

Almost all the sampled population (94.2%) believed that it is always necessary to wash hands before eating while only 1% of the people believed that it is not. Yet only 85% answered that they always wash their hands before eating. These rates are considered acceptable when compared to the results of a study conducted in Ghana and India, which revealed that hand washing with soap after using the toilet was uncommon, varying from 3% in one of the areas in Ghana to 42% in one of the areas in India (Curtis et al., 2011). No doubt exists that almost all people believe that hands should be washed before eating. Whether they practice what they believe or whether they do it right, however, are other issues.

One of the women from the Rafah camp focus group was asked, "How do you and your husband take care of your health and the health of the family?" She stated, "We teach our children to wash their hands before eating and clean up their bodies daily." A man from the Beach camp focus group in Gaza was asked, "How can you/should you improve the family environmental health in

TABLE **4**

Percentage Reporting Helping in Child Hygiene for Family Children Among Locality, Age, and Employment Status

Variable	Reported Helping in Child Hygiene for Family Children (%)			Pearson's Chi-Square Test	*p*-Value
	Always	Sometimes	No		
Locality				25.598	<.0001
Urban	56.4	20.3	22.3		
Rural	66.3	19.3	14.4		
Camp	66.3	22.8	10.9		
Age				23.631	.003
18–24	56.3	19.6	24.1		
25–34	67	19.2	13.8		
35–44	61.9	21.4	16.7		
45–54	57.1	21.5	21.5		
55+	55.8	16.8	27.4		
Employment status				176.343	<.0001
Currently employed	50	25.4	24.6		
Unemployed but looking for work	57.3	19.6	23.1		
Unemployed and not looking for work	59.7	16.9	23.4		
Student	49.3	23.9	26.8		
Housewife	86.7	10.4	2.9		
Retired	50	40	10		
Unable to work	0.0	100	0.0		

the home?" He stated, "The most important thing is to take care of our hygiene and our children's personal hygiene."

Washing Hands and Gender

Table 2 shows that 89.6% of women answered that they wash their hands before eating compared to 80.4% for men. A statistically significant correlation existed between washing hands before eating and gender (*p*-value < .0001). Men tend to be less likely than women to wash their hands. A study conducted by Harris Interactive (2010) on self-reported hand washing habits among adult Americans found that 83% of surveyed women said that they always wash hands before handling or eating food compared to 71% of men.

Washing Hands and Educational Level

A statistically significant relationship existed between the belief in the necessity of washing hands before eating and educational level (Table 3) (*p*-value < .0001). About 90% of illiterate people believed that it is always necessary to wash their hands before eating, while 6.9% of them believed that it is not. By contrast, 96.6% of those with an intermediate diploma believed that it is always necessary to wash their hands before eating while only 1% believed that it is not. Apparently, education positively influences the attitude of washing hands before eating.

Table 2 shows that a statistically significant relationship existed between washing hands before eating and educational level (*p*-value < .0001). As the educational level increased the percentage of people who wash their hands before eating increased. For example, 75% of the illiterate wash their hands before eating compared to 86.6% and 91.1% of the secondary and intermediate education levels, respectively. This finding is similar to the finding of a study that was conducted in Thailand, Kenya, and Ethiopia (International Rescue Committee, 2011) that reported that a higher level of education was associated with better hygiene practices. This may be attributable to the fact that the educated are more knowledgeable about the importance of hand washing.

Washing Hands and Region

As presented in Table 3, a statistically significant relationship existed between the belief in necessity of washing hands before eating and the region of residence (*p*-value < .0001). South West Bank had the lowest percentage (91.3%), which may be due to the scarcity of water in this region in comparison with the other regions.

Table 2 shows the results for cross tabulation between washing hands before eating and the region. A statistically significant relationship existed between these two variables (*p*-value = < .0001). The highest percentage (92.3%) of responses was in the Gaza Strip, while the lowest percentage was in the south West Bank.

Washing Hands and Locality

Tables 2 and 3 show that a statistically significant relationship existed between the belief in the necessity of washing hands and the actual washing before eating and the locality type (*p*-value < .0001) whether rural, urban, or camp. The lowest percentage (92.6%) existed in rural areas, which may be attributed to the lack of water and the lack of promotional programs of health education. The percentage of camp residents who wash their hands before eating was 93.1% as compared to 87% and 81.3% for urban and rural residents, respectively. This urban-rural difference was also found in a study from seven schools in Konya, Turkey (Yalcin, Yalcin, & Altin, 2004).

Helping With Hand Hygiene for Children

About 61.4% of those surveyed answered that they always help with their children's hygiene while 18.6% answered that they do not. Table 4 shows a statistical relationship between helping with children's hygiene and different age groups (*p*-value = .003), with the highest percentage for the 25–34 age group. By contrast, the age group 55 and more was least likely to help with children's hygiene, with only 55.8% always helping and 27.4% not helping at all.

Table 4 shows that a statistical relationship existed between helping with children's hygiene and different localities (*p*-value < .0001). Camps are the areas that help most with children's hygiene; 66.3% of them are

always helping with children's hygiene and only 10.9% are not helping. By contrast, urban areas help the least with children's hygiene, with 56.4% always helping and 22.3% not helping at all.

In addition to the above differences in helping with children's hygiene, regional differences and differences between gender and marital status existed. Figure 1 shows a significant relationship between gender and helping with children's hygiene in the family (p-value < .0001). About 82% of females answered that they always help with children's hygiene compared to only 40% for males. This vast female-male difference can be expected from some of the FGDs. A women from the Gaza focus group stated, "giving birth, upbringing, and being fully responsible for the kids' hygiene." Another women from the north camp group stated, "my husband may help with the laundry and dish washing and may give the kids a bath when I am busy." A man from the north of Gaza focus group stated, "I do the kids' laundry and I am responsible for their hygiene because my wife works." It can be concluded that since the majority of women in our study are housewives, caring for their homes and their children are their main duties.

Figure 2 shows a statistical relationship between helping with child hygiene in the family and the region (p-value < .0001). Likewise, Figure 3 shows a significant relationship between marital status and helping with child hygiene in the family (p-value < .0001) with the highest percentage (70.3%) for widows.

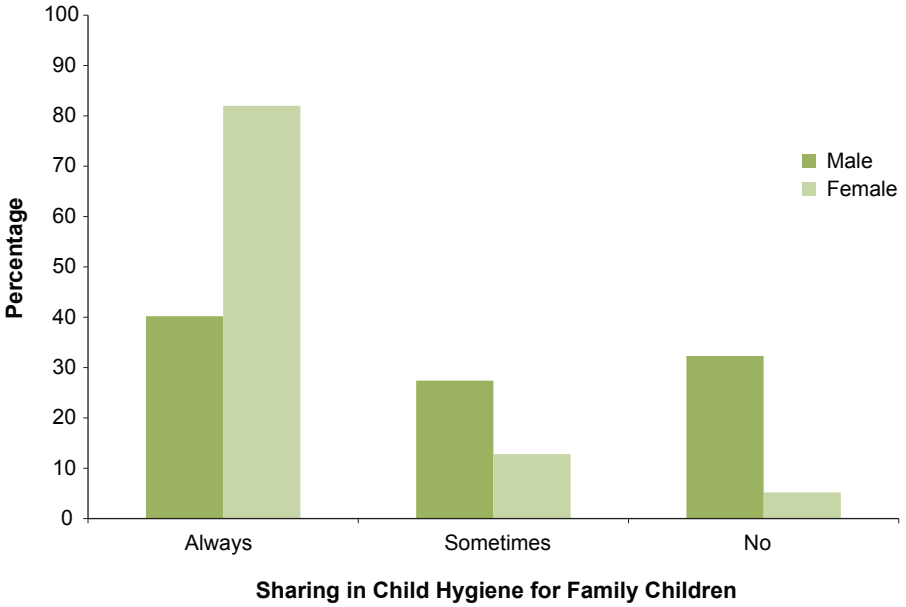
Table 4 shows a statistical relationship between helping with child hygiene and the work situation of the member of the family (p-value < .0001).

Conclusion and Recommendations

It can be concluded from our study that generally most people believe that it is always necessary to wash one's hands before eating, yet not all of them put this into practice. When it comes to helping with child hygiene, a considerable percentage (61.4%) answered that they always do. Females had higher rates than males in the belief in washing hands before eating as well as in the practice, and they exhibited higher rates of helping with child hygiene. Furthermore, a positive relationship existed between the educational level and practice of washing hands before eating.

FIGURE **1**

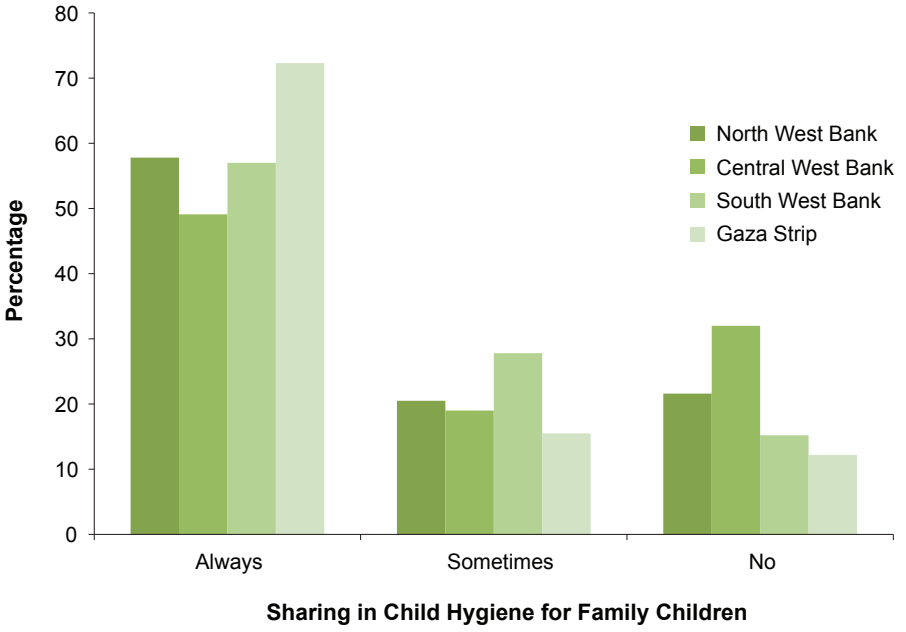
Relationship Between Gender and Helping With Child Hygiene



Pearson's Chi-square test = 301.873, df = 2, p-value < .0001.

FIGURE **2**

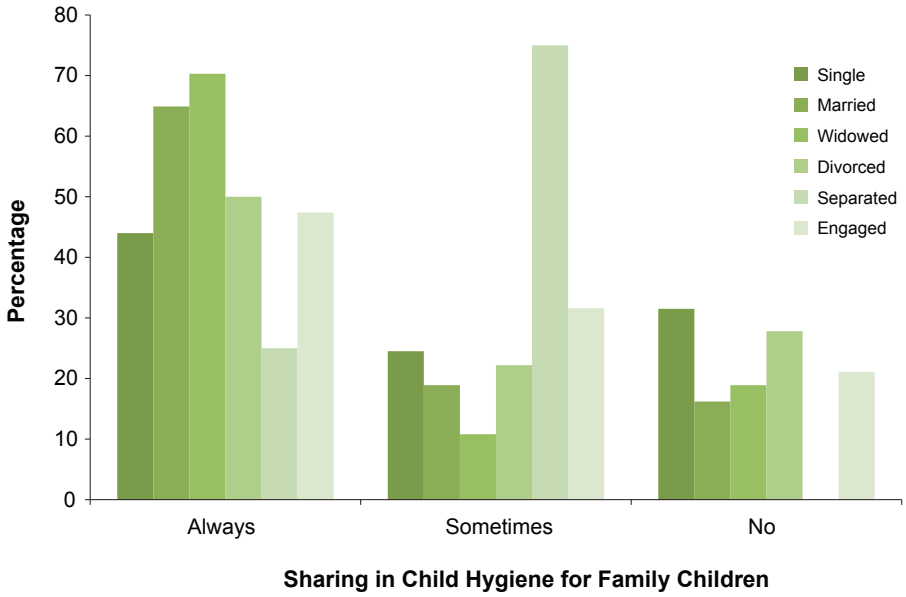
Relationship Between Region and Helping With Child Hygiene



Pearson's Chi-square test = 77.408, df = 6, p-value < .0001.

FIGURE **3**

Relationship Between Marital Status and Helping With Child Hygiene



Pearson's Chi-square test = 53.959, *df* = 10, *p*-value < .0001.

In the light of these findings and in the light of the overwhelming research that hand washing is one of the most important interventions in controlling the spread of infections, governments should prioritize the issue of hygiene and invest in programs to improve the populations' health. These programs should include hygiene education and the promotion of the benefits of hand washing. Awareness sessions about the necessity of personal hygiene should be conducted in all areas (urban, rural, and camps). In addition, addressing the issue of water scarcity and availability should be one of the government's priorities as this will contribute to better hygiene in general, leading to fewer communicable diseases.

Corresponding Author: Issam A. Al-Khatib, Associate Professor, Institute of Environmental and Water Studies, Birzeit University, P.O. Box 14, Birzeit, Palestine.
E-mail: ikhatib@birzeit.edu.

References

Abouteir, A., Yaagoubi, F., Bioh-Johnson, I., Kamel, A., Godard, N., Cormerais, L., Robin, F., & Lesens, O. (2011). Water access and attendance for diarrhea in primary health care centers, Gaza Strip. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 105*(10), 555–560.

Abu Mourad, T.A. (2004). Palestinian refugee conditions associated with intestinal parasites and diarrhea: Nuseirat refugee camp as a case study. *Public Health*, *118*(2), 131–142.

Bhojani, S., D'Costa, S., & Gupta, A. (2008). Hand hygiene: Simple, inexpensive, and an effective tool. *Journal of Infection Prevention, 9*(5), 15–17.

Centers for Disease Control and Prevention. (2012). *Hand washing: Clean hands save lives*. Retrieved from http://www.cdc.gov/handwashing/

Curtis, V., Biran, A., Deverell, K., Hughes, C., Bellamy, K., & Drasar, B. (2003). Hygiene in the home: Relating bugs and behavior. *Social Science & Medicine, 57*(4), 657–672.

Curtis, V., & Cairncross, S. (2003). Effect of washing hands with soap on diarrhea risk in the community: A systematic review. *The Lancet Infectious Diseases, 3*(5), 275–281.

Curtis, V., Danquah, L.O., & Aunger, R.V. (2009). Planned, motivated, and habitual hygiene behavior: An eleven country review. *Health Education Research, 24*(4), 655–673.

Curtis, V., Schmidt, W., Luby, S., Florez, R., Touré, O., & Biran, A. (2011). Hygiene: New hopes, new horizons. *The Lancet Infectious Diseases*, *11*(4), 312–321.

Fewtrell, L., Kaufmann, R.B., Kay, D., Enanoria, W., Haller, L., & Colford, J.M. (2005). Water, sanitation, and hygiene interventions to reduce diarrhea in less developed countries: A systematic review and meta-analysis. *Lancet Infectious Diseases, 5*(1), 42–52.

Harris Interactive. (2010). *A survey of hand washing behavior* (Prepared for the American Society for Microbiology). Retrieved from http://www.cleaninginstitute.org/assets/1/AssetManager/2010%20Hand%20Washing%20Findings.pdf

Hass, J.P., & Larson, E.L. (2007). Measurement of compliance with hand hygiene. *Journal of Hospital Infection, 66*(1), 6–14.

International Rescue Committee. (2011). *Understanding hand washing behavior*. Retrieved from http://www.rescue.org/sites/default/files/resource-file/Hand%20washing_0.pdf

Luby, S., Agboatwalla, M., Bowen, A., Kenah, E., Sharker, Y., & Hoekstra, R. (2009). Difficulties in maintaining improved hand washing behavior, Karachi, Pakistan. *American Journal of Tropical Medicine and Hygiene*, *81*(1), 140–145.

continued on page 56

References *continued from page 55*

Prüss, A., Kay, D., Fewtrell, L., & Bartram, J. (2002). Estimating the burden of disease from water, sanitation, and hygiene at a global level. *Environmental Health Perspectives, 110*(5), 537–542.

Prüss-Üstün, A., Bos, R., Gore, F., & Bartram, J. (2008). *Safer water, better health: Costs, benefits, and sustainability of interventions to protect and promote health*. Geneva: World Health Organization. Retrieved from http://whqlibdoc.who.int/publications/2008/9789241596435_eng.pdf

Rionda, Z., & Clements, A. (2000). *The burden of diseases in the West Bank and Gaza: An assessment report* (Prepared for U.S. Agency for International Development). Retrieved from http://pdf.usaid.gov/pdf_docs/PNACJ994.pdf

UNICEF. (2008). *State of the world's children*. Retrieved from http://www.unicef.org/sowc08/

UNICEF, & Palestinian Hydrology Group. (2010). *Water, sanitation and hygiene: Household survey, Gaza*. Retrieved from http://www.unicef.org/oPt/FINAL_WASH_REPORT.pdf

World Health Organization. (2012). *Clean care is safer care*. Retrieved from http://www.who.int/gpsc/clean_hands_protection/en/index.html

Yalcin, S.S., Yalcin, S., & Altin, S. (2004). Hand washing and adolescents. A study from seven schools in Konya, Turkey. *International Journal of Adolescent Medicine and Health*, *16*(4), 371–376.

Did You Know?

You can take a sneak peak at the NEHA 2015 AEC schedule in Orlando, Florida. Visit www.neha2015aec.org and start planning to attend.

DAVIS CALVIN WAGNER SANITARIAN AWARD

The American Academy of Sanitarians announces the annual Davis Calvin Wagner Award. The award will be presented by the academy during the Annual Educational Conference of the National Environmental Health Association. The award consists of a plaque and a $500 honorarium.

Nominations for this award are open to all diplomates of the academy who:

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

The nomination for the award may be made by a colleague or a supervisor and must include the following:

1. Name, title, grade, and current place of employment of the nominee.
2. A description of the nominee's educational background and professional experience.
3. A description of the nominee's employment history, including the scope of responsibilities.
4. A narrative statement of specific accomplishments and contributions on which the nomination is based, including professional association activities, publications, and community/civic activities.
5. Three endorsements (an immediate supervisor and two other members of the professional staff or other person as appropriate).

NOMINATIONS MUST BE RECEIVED BY APRIL 15, 2015. Nomination packages should be sent electronically to tcrow23701@aol.com. If desired, three hard copies of the nomination document may be submitted to:

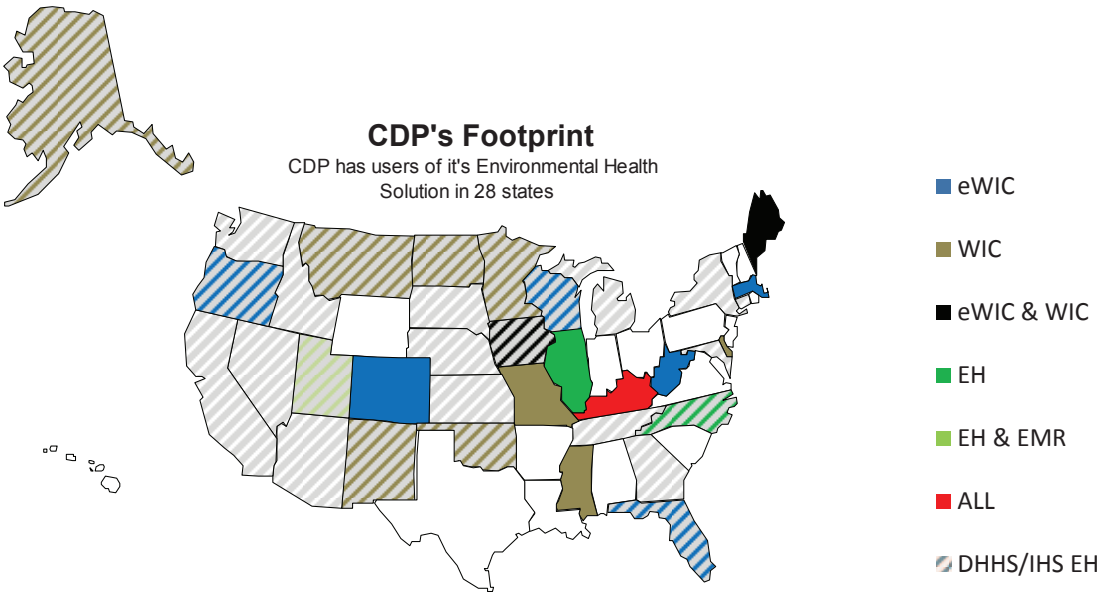
American Academy of Sanitarians
c/o Thomas E. Crow
25278 Kennebec Drive
South Riding, VA 20152

For more information, please visit www.sanitarians.org/aas-awards/.

Companies come and go … some companies are operated on a shoe-string budget …

Then there's CDP ⟶ Financially Secure ▪ Diversified ▪ Deep in Experience

CDP, Inc. is a nationally-recognized corporation specializing in custom software solutions for the public health industry. We are one of only a handful of companies worldwide that focus on the public health market, with applications ranging from **environmental health** to electronic medical records to WIC and WIC EBT. Our healthcare portfolio includes over 30 years' experience in custom software development, hosted software applications, web-based and mobile application development, network services, and a full-range of customer support services. **We continually enhance our solutions to meet the growing needs of our governmental client base while focusing on three important goals: security, portability, & interoperability.**



Key benefits of CDP's Environmental Health Solution include the capability to:

Provide timely information to all users ▪ Allow broad analysis across geographic boundaries ▪ Increase the efficiency of the mobile staff utilizing off-line with tablets ▪ Promote interoperable systems via compliance with standards ▪ Increase environmental public health capacity ▪ Ability to enhance and improve data ▪ Provide extensive reporting through different means

Let CDP help you improve your service delivery and workforce development throughout the complete inspection and permitting process.

http://www.cdpehs.com/neha.htm
800.888.6035

INTERNATIONAL PERSPECTIVES

Prepublished online July/August 2014,
National Environmental Health Association.

Isolation of *Legionella pneumophila* From Cooling Towers, Public Baths, Hospitals, and Fountains in Seoul, Korea, From 2010 to 2012

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 25 countries worldwide, are addressed. Our goal is to raise diverse issues of interest to all our readers, irrespective of origin.*

Changkyu Kim, MS
Sujin Jeon, MS
Jihun Jung, MS
Younghee Oh, PhD
Seoul Metropolitan Government Research Institute of Public Health and Environment

Yeonsun Kim, PhD
Department of Public Health Dankook University

Jaein Lee, PhD
Sungmin Choi, PhD
Youngzoo Chae, PhD
Seoul Metropolitan Government Research Institute of Public Health and Environment

Young-ki Lee, PhD
Department of Public Health Dankook University

Abstract **Legionnaire's disease is associated with a high mortality rate. The authors collected 3,495 water samples in Seoul, Korea, between 2010 and 2012 from public facilities (cooling towers, public baths, hospitals, and decorative fountains), which are considered the major habitats of *Legionella pneumophila*. In all, 527 (15.1%) isolates of *L. pneumophila* were obtained by microbial culture and polymerase chain reaction. Serological diagnosis and pulsed-field gel electrophoresis (PFGE) analysis were performed for the samples. The authors categorized the samples into four groups (A–D) on the basis of PFGE results. The analysis revealed that cooling towers containing the most samples with *L. pneumophila* serogroup 1 constituted the highest proportion of isolate. Samples from public facilities and serogroups could be distinctively classified by PFGE patterns. Thus, it is expected that source-specific features revealed through PFGE and serological analyses could serve as the basis for effectively coping with future outbreaks of *L. pneumophila*.**

Introduction

Since *Legionella pneumophila* was identified as the causative agent in the mass outbreak of pneumonia at the 1976 American Legion Convention in Philadelphia, several mass outbreaks and sporadic individual incidences have been reported worldwide (Fraser et al., 1977). An increased incidence of legionellosis since 2000 has been reported in the U.S. (Hicks, Garrison, Nelson, & Hampton, 2012) and Europe (European Centre for Disease Prevention and Control, 2012). *Legionella* detection tests were performed on specimens collected from patients with community-acquired pneumonia in 15 different hospitals in Korea from 2005 to 2011; the results of these tests revealed two (0.9%) *Legionella*-positive cases. Therefore, *Legionella* spp. is also considered a cause of pneumonia in Korea (Cho et al., 2012).

In 2008, 4,938 sets of environmental water samples were collected from 16 local autonomous entities in Korea. Analysis of these water samples revealed 560 (11.3%) positive cases. *L. pneumophila* was detected in 85% of these positive samples, in which *L. pneumophila* serogroup 1 (sg1) was predominant (Lee, Shim, Kim, Yu, & Kang, 2010). Pathogenic bacteria are often present as hidden contaminants in drinking water treatment. The *Legionella* sequences were found even after membrane purification, indicating the continued risk of legionellosis (Kwon, Moon, Kim, Hong, & Park, 2011).

Two cases of legionellosis were reported in Korea in 2001, and less than 10 cases were reported between 2002 and 2005. After 2006, however, the number of reported legionellosis cases increased to approximately 20–30 annually; in Seoul, an average of seven or eight cases of legionellosis have been reported each year since 2006 (except in 2011). From 2011 on, death due to legionellosis has been reported in Korea: one and three cases of deaths were reported in 2011 and 2012, respectively, of which one death in each year occurred in Seoul (Korea Centers for Disease Control & Prevention, 2013). Seoul has a very high population density of 16,936 people/km^2, with 10.25 million inhabitants in an area of 605.21 km^2. An increasing number of people are being exposed to pathogens, often because people frequently visit public facilities such as hotels, shopping malls, hospitals, and public baths.

TABLE **1**

Number of Positive Samples for *L. pneumophila* Isolated From Public Facilities in Seoul Over Three Years

Year	Isolates (%)[a]					Total
	Cooling Tower	Public Bath	Hospital	Fountain	Others	
2010	95 (22.2)	85 (19.4)	28 (10.7)	2 (3.9)	0 (0.0)	210 (17.5)
2011	91 (22.3)	71 (16.2)	32 (9.0)	0 (0.0)	1 (3.7)	195 (15.5)
2012	53 (17.4)	51 (15.1)	15 (4.7)	3 (11.5)	0 (0.0)	122 (11.8)
Subtotal	239 (21.0)	207 (17.0)	75 (8.0)	5 (4.7)	1 (1.1)	527 (15.1)[b]

[a]Water sampling for cooling towers was done at the cooling tower basins of large-scale shopping malls, department houses, hotels, large buildings, and hospitals; at public bath houses in taps, showers, and hot tubs; and at hospitals in toilets and showers. The fountains were decorative fountains in parks and squares.

[b]The average detection rate was 15.1% in decreasing order of cooling towers, public baths, hospitals, and fountains.

Pulsed-field gel electrophoresis (PFGE) patterns of samples from patients with legionellosis were identical to those observed in the water distribution system in five of the nine hospitals investigated from 1989 to 2006 (Garcia-Nuñez et al., 2008). Another study suggested that more studies need to be conducted on environmental contamination by *Legionella* spp. (Jonas et al., 2000). In Korea, PFGE testing was used to identify *L. pneumophila* sg1 in environmental water and clinical specimens collected from 1985 to 2007. The results indicated that certain PFGE types persisted over several years and also showed that some types of PFGE patterns can be found in both environmental water and clinical specimens (Lee, Kang, & Yu, 2010).

The objectives of our study were to analyze water samples collected from the major habitats of *L. pneumophila* (including cooling towers, public baths, hospitals, and fountains) as a step toward establishing preventive measures for legionellosis in Seoul, and to investigate the serological and molecular biological characteristics of *L. pneumophila* to collect epidemiological data and identify characteristic PFGE patterns. The epidemiological data obtained in our study will help quickly identify the sources of legionellosis outbreaks to prevent disease spread and recurrence.

Materials and Methods

From 2010 to 2012, 3,495 water samples were collected from several public facilities. The samples were categorized by origin (cooling towers, public baths, hospitals, or decorative fountains) and then analyzed. More than 40 water tests were performed on the samples collected from each of the 25 districts in Seoul. Water sterilization during the sample collection period was not considered. Water samples were collected annually from May to September. Isolates of *Legionella* spp. (n = 527) were identified by microbial culture and polymerase chain reaction (PCR) with *mip*- and *rpoB*-specific primers. Serological diagnosis and PFGE were also performed.

Culture of Water Samples

At each collection point, 1 L of water was obtained and filtered through 0.2-µm nitrocellulose membranes under vacuum. Each membrane was plated on buffered charcoal yeast extract (BCYE) agar with L-cysteine and antibiotic supplements and incubated for 10 days at 37°C. Colonies growing on BCYE agar, but not on blood agar, were definitively identified as *Legionella* spp.

PCR

PCR analysis was performed to determine whether the *L. pneumophila* isolates possessed the *rpoB* (RNA polymerase B) (Ko et al., 2003; Nielsen, Hindersson, Høiby, & Bangsborg, 2000) and *mip* (Lindsay, Abraham, & Fallon, 1994) genes, which encode toxin production. The reactions were conducted in a thermal cycler.

Agglutination Test

L. pneumophila isolates were cultured on BCYE agar, and their growth was confirmed using a serotyping kit. After the isolates were placed in physiological saline at a high concentration, they were heated at 100°C for one hour followed by serogroup determination based on the results of the slide agglutination test.

Chromosomal PFGE Analysis

Band patterns were obtained by *Sfi*I digestion and by following an established protocol with minor modifications. The gels were illuminated with a UV light source and photographed. Macrorestriction patterns were analyzed with BioNumerics software (version 3.5) in a similar manner to that used for subgrouping.

Results

L. pneumophila Detection

From 2010 to 2012, more than 1,000 water samples were collected annually. Among the 3,495 water samples collected throughout this period, *L. pneumophila* was identified by culture and PCR analysis. *L. pneumophila* was detected in 210 (17.5%), 195 (15.5%), and 122 (11.8%) samples in 2010, 2011, and 2012, respectively, indicating an average annual detection rate of 15.1%. Furthermore, *L. pneumophila* was detected in 239 (21.0%) of the 1,140 samples, 207 (17.0%) of the 1,215 samples, 75 (8.0%) of the 940 samples, and 5 (4.7%) of the 93 samples collected from cooling towers, public baths, hospitals, and fountains, respectively (Table 1).

Serological Diagnosis, PFGE Patterns, and Correlation Analysis According to the Sample Type and Serogroup

Serological diagnosis of sg1 through sg6 was performed for all 527 isolates. Moreover, 30% of these isolates were selected using proportional stratified sampling for each sample type based on the detection rate, and 170 (32%) isolates were analyzed by PFGE. These isolates were classified into groups A–D based on at least 65% homology; we confirmed that the serogroups and distribution of each sample type varied among the groups.

The Chi-square test revealed the relationship between PFGE patterns and serogroups. In Group A, sg1 isolates constituted a relatively high proportion (n = 36, 76.6%) of the whole sample population (60.6%). Compared to Group A, Group B possessed fewer sg1 isolates (n = 19, 47.5%) and more sg5 isolates (n = 9, 22.5%). Group C showed various serological distribution. Specifically, the number of sg1 isolates in Group C was slightly lower than the average distribution (n = 29, 50%), whereas 8

(13.8%) and 15 isolates (25.9%) were detected as sg3 and sg6, respectively, which was greater than the number indicated by the average distribution. Similar to Group A, Group D had 19 sg1 isolates (76.0%) and three sg2 isolates (12.0%), which was greater than the number indicated by the average distribution; Group D had no sg4, sg5, or sg6 isolates. In general, sg4 was not detected in any of the groups (Table 2).

As shown in Table 3, the Chi-square test was used to verify the relationship between the PFGE pattern and sample type. In Group A, 36 isolates (76.6%) were detected in cooling tower samples, which constituted a much higher proportion of the total isolates detected from cooling towers (46.4%). In Group B, a remarkably high number of isolates (n = 37, 92.5%) was detected in public bath samples. Interestingly, none of the isolates was detected in samples from the cooling towers, whereas a small number of isolates were identified in hospital samples (n = 3, 7.5%). In Group C, 20 isolates (35.7%) were detected in samples from cooling towers, which represents a lower distribution compared to the total number of isolates detected, whereas a relatively higher number of isolates (n = 15, 26.8%) were detected in samples from hospitals. Only two isolates of Group C were detected in fountain samples (data not shown because of the low overall frequency). In Group D, a high number of isolates (n = 22, 88.0%) were detected in cooling tower samples, indicating a pattern similar to Group A, and three isolates (12.0%) were detected in public bath samples. No strains were detected at the other facilities (Table 3).

Based on the fact the serogroups and sample types are correlated to yield specific PFGE patterns, we investigated the correlation between serogroups and sample types. In cooling tower samples, sg1 isolates constituted the highest proportion (n = 61, 78.2%). In samples from public baths and hospitals, sg1 isolates were detected in high numbers, whereas sg3, sg5, and sg6 isolates were detected at similar rates (constituting ~50%). Two isolates were detected in fountain samples (data not shown because of low frequency; Table 4).

TABLE **2**

Contingency Table Examining the Relationship Between the Pulsed-Field Gel Electrophoresis (PFGE) Group and Serogroup

PFGE Group	Serogroup (%)[a]					Total
	1	2	3	5	6	
A	36 (76.6)	2 (4.3)	0 (0.0)	5 (10.6)	4 (8.5)	47 (100.0)
B	19 (47.5)	3 (7.5)	4 (10.0)	9 (22.5)	5 (12.5)	40 (100.0)
C	29 (50.0)	1 (1.7)	8 (13.8)	5 (8.6)	15 (25.9)	58 (100.0)
D	19 (76.0)	3 (12.0)	3 (12.0)	0 (0.0)	0 (0.0)	25 (100.0)
Subtotal	103 (60.6)	9 (5.3)	15 (8.8)	19 (11.2)	24 (14.1)	170 (100.0)

Note. df = 12, p = .95, χ^2 = 33.3 (Chi-square observed) > χ^2 = 21.0 (Chi-square expected), p = .001. PFGE groups and serogroups were confirmed to be correlated.

[a]Overall, sg1 accounted for the largest proportion in all four groups. Groups A and D made up the highest percentages of sg1 with highly concentrated distribution patterns, whereas Group B and C showed even distributions of sg3, sg5, and sg6 apart from sg1.

TABLE **3**

Contigency Table Examining the Relationship Between the Pulsed-Field Gel Electrophoresis (PFGE) Group and Sample Type

PFGE Group	Sample Type (%)[a]			Total
	Cooling Tower	Public Bath	Hospital	
A	36 (76.6)	6 (12.8)	5 (10.6)	47 (100.0)
B	0 (0.0)	37 (92.5)	3 (7.5)	40 (100.0)
C	20 (35.7)	21 (37.5)	15 (26.8)	56 (100.0)
D	22 (88.0)	3 (12.0)	0 (0.0)	25 (100.0)
Subtotal	78 (46.4)	67 (39.9)	23 (13.7)	168 (100.0)

Note. df = 6, p = .95, χ^2 = 91.7 (Chi-square observed) > χ^2 = 12.6 (Chi-square expected), p = .000. PFGE groups and sample types were confirmed to be correlated.

[a]Groups A and D isolates showed the highest distributions at cooling towers, and Group B at public baths, whereas Group C isolates were evenly distributed at cooling towers, public baths, and hospitals.

Discussion

With time, utilization of public facilities has increased, leading to increased sharing of space by a large number of randomly gathered people. *Legionella* spp., the causative organism of legionellosis, is frequently isolated from public facilities, and more studies and information are needed to prevent legionellosis and to effectively block its transmission. Therefore, under the assumption that distinctive types of *L. pneumophila* are present in unique niches at different public places owing to the different environmental conditions, we investigated their distinctive characteristics using PFGE. In the analysis of PFGE patterns based on 65% homology, we verified the serogroups and characteristics of samples from public facilities according to the groups of *L. pneumophila*. Among all PFGE groups (A–D), sg1 was detected most frequently. In particular, isolates belonging to Groups A and D, which had the highest percentages of sg1 isolates, were detected in cooling tower samples in large quantities. In contrast, sg3, sg5, and sg6 were evenly distributed in Groups B and C. Many Group B isolates were detected in public bath samples. Group C isolates were distributed among the samples from cooling towers, public baths, and hospitals. In the 2008 Korean study, sg1 was the most prevalent serogroup based on sequence-based typing. That study also showed that the second most dominant strains differed with facility type (Lee, Shim, et al., 2010). In our study, we verified using

TABLE **4**

Contingency Table Examining the Relationship Between Serogroup and Sample Type

Sample Type[a]	Serogroup (%)					Total
	1	2	3	5	6	
Cooling Tower	61 (78.2)	4 (5.1)	1 (1.3)	4 (5.1)	8 (10.3)	78 (100.0)
Public Bath	32 (47.8)	4 (6.0)	8 (11.9)	12 (17.9)	11 (16.4)	67 (100.0)
Hospital	10 (43.5)	1 (4.3)	5 (21.7)	3 (13.0)	4 (17.4)	23 (100.0)
Subtotal	103 (61.3)	9 (5.4)	14 (8.3)	19 (11.3)	23 (13.7)	168 (100.0)

Note. df = 8, p = .95, χ^2 = 24.1 (Chi-square observed) > χ^2 = 15.5 (Chi-square expected), p = .002. Serogroups and sample types were confirmed to be correlated.

[a]Cooling towers showed the highest number of sg1 with a highly concentrated distribution pattern, whereas public baths and hospitals showed even distributions of sg3, sg5, and sg6 apart from sg1.

the Chi-square test of independence that the sample type, serogroup, and PFGE pattern are closely correlated. On the basis of these results, we conclude that facility-dependent different ecological environments affect the niche-formation behaviors of *L. pneumophila*.

Because cooling towers are exposed to the external environment and thus are more vulnerable to contamination through the infiltration of fugitive dust and particulate organic matter, we anticipated we would observe various kinds of serotype distribution; however, the results were surprising. Only the distribution for Groups A and D showed varying genotype distribution. In contrast, the samples collected from public baths and hospitals contained various serogroups other than sg1. In Korea, bathing in public baths has become more popular in recent years. This raises hygienic concerns about various contaminants such as dead skin cells, cosmetics, and body lotions, as well as people entering the tub without taking a shower first, which creates a suitable living environment for *L. pneumophila*. Thus, we predicted that such public baths would have niches for different kinds of serogroups. Indeed, different kinds of *Legionella* species and serogroups (sg1, sg5, and sg6) were found in the hot water distribution system in spas in the Czech Republic (World Health Organization, 2007). In hospitals, inpatients, outpatients, medical staff, guardians, and others continuously enter and exit the building, and a number of medical devices, namely, humidifiers, nebulizers, and respiratory machines, are constantly used, offering favorable environments for the niche construction of various types of *L. pneumophila*. According to a recent report, sg1, sg5, and sg6 were also detected in medical facilities in Russia (Gruzdeva, Tartakovskiĭ, & Mar'in, 2012).

Therefore, the PFGE characteristics of *Legionella* from each public facility may provide useful information for the rapid identification of pathogens and assist in the implementation of preventive measures for future outbreaks. The results of PFGE pattern analysis of isolates originating from facilities can be used in epidemiological investigations.

Conclusion

Our study identified *L. pneumophila* isolates in samples collected from public facilities and classified them according to their biological and molecular genetic characteristics. The PFGE analysis revealed different characteristics of *L. pneumophila* in each public facility; it was thus confirmed that different serogroups of *L. pneumophila* constructed varying niches according to the types of public facilities.

Acknowledgements: The authors would like to thank Director Seokju Cho and Miok Song, PhD, from the Institute of Health and Environment, Seoul, Korea, for providing invaluable advice and input.

Corresponding Author: Young-ki Lee, Professor, Department of Health, Graduate School of Health & Welfare, Dankook University, 119 Dandaero, Dongnam-gu Cheonan-si Chungnam, Korea 330-714.
E-mail: pp99pp@dreamwiz.com.

References

Cho, M.-C., Kim, H., An, D., Lee, M., Noh, S.-A., Kim, M.-N., Chong, Y.P., & Woo, J.H. (2012). Comparison of sputum and nasopharyngeal swab specimens for molecular diagnosis of *Mycoplasma pneumoniae*, *Chlamydophila pneumoniae*, and *Legionella pneumophila*. *Annals of Laboratory Medicine*, *32*(2), 133–138.

European Centre for Disease Prevention and Control. (2012). *Legionnaires' disease in Europe 2010*. Stockholm: Author.

Fraser, D.W., Tsai, T.R., Orenstein, W., Parkin, W.E., Beecham, H.J., Sharrar, R.G., Harris, J., Mallison, G.F., Martin, S.M., McDade, J.E., Shepard, C.C., & Brachman, P.S. (1977). Legionnaires' disease: Description of an epidemic of pneumonia. *The New England Journal of Medicine*, *297*(22), 1189–1197.

Garcia-Nuñez, M., Sopena, N., Ragull, S., Pedro-Botet, M.L., Morera, J., & Sabria, M. (2008). Persistence of *Legionella* in hospital water supplies and nosocomial Legionnaires' disease. *FEMS Immunology and Medical Microbiology*, *52*(2), 202–206.

Gruzdeva, O.A., Tartakovskiĭ, I.S., & Mar'in, G.G. (2012). Examination of the contamination aetiological agent of legionellosis in the water supply systems of medical treatment facilities [Article in Russian]. *Voenno-medisinskiĭ zhurnal*, *333*(5), 34–38.

Hicks, L.A., Garrison, L.E., Nelson, G.E., & Hampton, L.M. (2012). Legionellosis—United States, 2000–2009. *American Journal of Transplantation*, *12*(1), 250–253.

continued on page 62

References *continued from page 61*

Jonas, D., Meyer, H.-G.W., Matthes, P., Hartung, D., Jahn, B., Daschner, F.D., & Jansen, B. (2000). Comparative evaluation of three different genotyping methods for investigation of nosocomial outbreaks of Legionnaires' disease in hospitals. *Journal of Clinical Microbiology*, *38*(6), 2284–2291.

Ko, K.S., Hong, S.-K., Lee, K.-H., Lee, H.K., Park, M.-Y., Miyamoto, H., & Kook, Y.-H. (2003). Detection and identification of *Legionella pneumophila* by PCR-restriction fragment length polymorphism analysis of the RNA polymerase gene (rpoB). *Journal of Microbiological Methods*, *54*(3), 325–337.

Korea Centers for Disease Control & Prevention. (2013). *Infectious diseases surveillance yearbook, 2012*. Seoul: Author.

Kwon, S., Moon, E., Kim, T.-S., Hong, S., & Park, H.-D. (2011). Pyrosequencing demonstrated complex microbial communities in a membrane filtration system for a drinking water treatment plant. *Microbes and Environments*, *26*(2), 149–155.

Lee, H.K., Kang, Y.H., & Yu, J.Y. (2010). Genomic diversity of *Legionella pneumophila* serogroup 1 from environmental water sources and clinical specimens using pulsed-field gel electrophoresis (PFGE) from 1985 to 2007, Korea. *Journal of Microbiology (Seoul, Korea)*, *48*(5), 547–553.

Lee, H.K., Shim, J.I., Kim, H.E., Yu, J.Y., & Kang, Y.H. (2010). Distribution of *Legionella* species from environmental water sources of public facilities and genetic diversity of *L. pneumophila* serogroup 1 in South Korea. *Applied and Environmental Microbiology*, *76*(19), 6547–6554.

Lindsay, D.S.J., Abraham, W.H., & Fallon, R.J. (1994). Detection of *mip* gene by PCR for diagnosis of Legionnaires' disease. *Journal of Clinical Microbiology*, *32*(12), 3068–3069.

Nielsen, K., Hindersson, P., Høiby, N., & Bangsborg, J.M. (2000). Sequencing of the *rpoB* gene in *Legionella pneumophila* and characterization of mutations associated with rifampin resistance in the Legionellaceae. *Antimicrobial Agents and Chemotherapy*, *44*(10), 2679–2683.

World Health Organization. (2007). Legionella *and the prevention of legionellosis*. Geneva: Author.

neha.org

- Journal of Environmental Health
- e-Learning
- **R&D Programs**
- NEHA in Action
- Credentials
- Continuing Education
- NEHA Food Safety Training
- Awards & Sabbaticals
- Endowment Fund
- Scholarships
- Position Papers
- Affiliated Organizations
- Links
- Students Section

Information and opportunities abound behind the research and development (R&D) button on NEHA's homepage. Visit neha.org/research to obtain the latest on the following NEHA federally funded programs, many of which include free or low-cost training and educational opportunities:

- Biology and Control of Vectors and Public Health Pests Program
- Environmental Public Health Tracking Program
- Epi-Ready Team Training Program
- Food-Safe Schools Program
- Industry-Foodborne Illness Investigation Training and Recall Response (I-FIIT-RR) Program
- Land Use Planning and Design Program
- Onsite Wastewater Treatment Systems Program
- Radon/Indoor Air Quality Program
- Workforce Development Program

INTERNATIONAL PERSPECTIVES

Prepublished online September 2014,
National Environmental Health Association.

Association Between PM_{10} and Respiratory Hospital Admissions in Different Seasons in Heavily Polluted Lanzhou City

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 25 countries worldwide, are addressed. Our goal is to raise diverse issues of interest to all our readers, irrespective of origin.*

An Xingqin
Chinese Academy of Meteorological Sciences

Tao Yan
College of Earth and Environmental Science & Key Laboratory of Western China's Environmental Systems (Ministry of Education) Lanzhou University

Mi Shengquan
College of Arts and Science Beijing Union University

Sun Zhaobin
Environmental Meteorology Forecast Center of Beijing-Tianjin-Heibei China Meteorological Administration

Hou Qing
Chinese Academy of Meteorological Sciences

Abstract

Exposure-response relationship between particulate matter less than 10 µm in diameter (PM_{10}) and human health in different seasons from 2001 to 2005 was examined based on hospital admissions data of respiratory system diseases from four major hospitals in Lanzhou, China. To quantify associations of respiratory system diseases with multiple air pollutants and meteorological conditions, a semiparametric generalized additive model was used in the authors' study by implementing daily ambient sulfur dioxide, nitrogen dioxide, and PM_{10} data collected from the Lanzhou Environmental Monitoring Station and daily meteorological data from Lanzhou Meteorological Bureau.

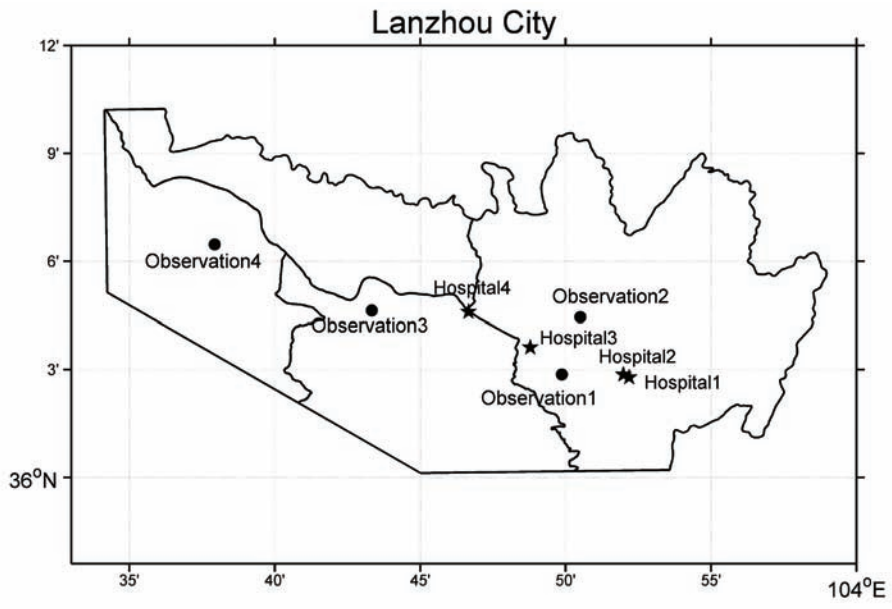
Results showed that daily averaged PM_{10} increased per interquartile range the hospital admissions number of respiratory diseases by 3.3% in spring, 1.4% in summer, 3.6% in autumn, and 4.0% in winter from a single-pollutant model, or 3.1%, 1.4%, 3.0%, and 4.0% from a multi-pollutant model, respectively. The effect of PM_{10} on respiratory hospital admissions was lowest in summer and highest in winter. The relative risks of PM_{10} on female or the elderly (≥65 yrs.) were higher, showing a stronger association of PM_{10} with respiratory diseases in female and elderly groups than in males and people younger than 65.

Introduction

Extensive epidemiological studies have revealed the associations between air pollutants, especially particulate matter, and human health (Dominici et al., 2006; Schwartz, 1994; Schwartz et al., 1996; Tecer, Alagha, Karaca, Tuncel, & Eldes, 2008; Zanobetti, Schwartz, & Dockery, 2000). For example, Schwartz has shown that in the U.S., the number of hospital admissions increased 2.48% per day (95% confidence interval [*CI*]: 1.82%–3.15%) subject to an interquartile range (*IQR*) determined by particulate matter less than 10 µm in diameter (PM_{10}) concentrations (Schwartz, 1999). Lee and co-authors (2000) found that in seven major cities across South Korea, total suspended particulate (TSP) and sulfur dioxide (SO_2) were significantly related to the all-cause mortality. If these two pollutants increased per 100 µg/m^3 and 50 parts per billion (ppb), the mortality would increase 0.5%–4% and 1%–12%, respectively. It was also reported that when the daily concentration of the fine particulate matter ($PM_{2.5}$) increased per 10 µg/m^3, total mortality and cardiopulmonary mortality would increase 13% (95% *CI*: 4.4%–23%) and 17% (95% *CI*: 5.8%–42%), respectively (Dockery et al., 1993). Similar results have also been summarized by an American Cancer Society project, which concluded that total mortality and cardiopulmonary mortality increased 4%–13% induced by an increase of daily $PM_{2.5}$ at 10 µg/m^3 (Pope et al., 1995; Pope et al., 2002). Meng and co-authors (2006, 2007, 2008) investigated the relationship between the atmospheric particles from sand-dust weather and daily number of outpatients with respiratory and cardiovascular diseases in China

FIGURE **1**

Locations of Hospitals and Air Pollutant Monitoring Stations in Lanzhou



and found that atmospheric particles from sand-dust weather may increase the number of respiratory and cardiovascular diseases.

As primary air pollutants, atmospheric particles have been significantly affecting China's urban air quality, especially in cities in northern China. Located in northwest China and characterized by extensive petrochemical, metallurgy, and machinery industries, Lanzhou has been ranked one of most polluted cities in China and the world, and a top PM_{10}– contaminated city in China (World Health Organization, 2011). Heavy air pollution in Lanzhou has been also attributed to its typical mountain-valley topography, which forces a very stable atmospheric stratification, weak winds, and strong inversions. Concern has been raised about the impact of PM_{10} pollution on the health of local residents. To address this concern, our study quantitatively assessed the relationship between the change in inhalation of daily averaging concentration of atmospheric particles and the number of respiratory hospital admissions for different seasons in Lanzhou, aiming also to provide insight into how reducing environmental pollution would help protect people from respiratory disease.

Methods

Materials

Disease Data

Disease data from January 1, 2001, to December 31, 2005, were collected from four major general hospitals in Lanzhou whose locations are illustrated in Figure 1. These data have been coded by the International Classification of Diseases 10th revision (ICD-10) for the respiratory diseases (ICD-10: J00–99). The data excluded those diseases caused by unintentional injuries or surgeries as well as those caused primarily by other human activities. In general, over 60% of local residents mainly choose these hospitals for diagnosis and treatment of respiratory diseases.

Air Pollutant Data

The daily averaged concentrations for three major pollutants (PM_{10}, SO_2, and nitrogen dioxide [NO_2]) from January 1, 2001, to December 31, 2005, in Lanzhou were collected from the Lanzhou Environmental Monitoring Stations. These stations are part of a national network that conducts regular measurements of criteria air pollutants and reports daily monitored data to the Chinese Environmental Protection Agency. Daily concentrations of each selected pollutant were averaged over four monitoring stations in the urban area of Lanzhou (Figure 1). In calculating daily concentrations of selected pollutants from hourly measured data at each station, we requested that at least 18-hour data must be available during a single day, and for each monitoring station at least 75% of daily data must be available for the whole study period. The measurement methods for NO_2, SO_2, and PM_{10} used chemiluminescence, ultraviolet fluorescence, and beta-ray absorption techniques, respectively. The missing data during the observation were SO_2 on February 18 and 19, 2002, and PM_{10} on July 10, 2001. The linear interpolation method through SPSS 13.0 was adopted to fill the missing data, thereby constructing a complete sequence of daily averaging concentrations throughout the period of January 1, 2001, through December 31, 2005.

Meteorological Data

Daily surface meteorological data from January 1, 2001, to December 31, 2005, in Lanzhou were collected from the Meteorological Bureau of Gansu Province, including mean surface temperature, daily maximum and minimum temperatures, atmospheric pressure, relative humidity, and other meteorological variables.

Statistical Analysis

For the general population, the daily respiratory hospital admission is regarded as a small probability event, and the actual distribution of admission numbers follows approximately the Poisson distribution (Schwartz, 1996). Therefore, our study combined the Poisson regression model with the semi-parametric generalized additive model (GAM) (Hastie & Tibshirani, 1990) in order to explore the associations of air pollutants with daily hospital admissions for respiratory disease.

The GAM model can be written as follows:

$$\log[E(Y_k)]=\alpha+DOW+\beta X_k+s(time, df)+s(Z_k, df)$$

where Y_k is the number of respiratory hospital admissions; $E(Y_k)$ is an expectation value of respiratory hospital admissions; β is a regression coefficient, known as the expo-

TABLE **1**

Description of Air Pollutants, Meteorological Factors, and Respiratory Hospital Admissions From 2001 to 2005 in Lanzhou

Item	Variables	$\bar{x} \pm s$	Min	P_{25}	Median	P_{75}	Max	*IQR*
Air pollutants	PM_{10}[a] (mg/m^3)	0.197±0.170	0.016	0.101	0.149	0.241	2.561	0.139
	SO_2[a] (mg/m^3)	0.079±0.062	0.002	0.037	0.058	0.106	0.371	0.069
	NO_2[a] (mg/m^3)	0.046±0.029	0.004	0.025	0.0375	0.056	0.26	0.031
Meteorological factors	Maximum temperature (ºC)	16.79±10.35	-8.9	7.8	17.6	25.5	36.6	17.7
	Minimum temperature (ºC)	6.53±9.79	-15.2	-2.1	7.4	15.1	26.7	17.2
	Mean temperature (ºC)	11.19±9.93	-12.2	2.2	12.20	20.1	30.1	17.9
	Pressure (hPa)	846.5±5.5	831.2	842.4	846.5	850.5	864.3	8.1
	Relative humidity (%)	50.7±14.0	15.9	40.4	51.00	60.5	89.8	20.1
Respiratory diseases	Number of hospital admissions (persons/day)	15.4	1	9	14	20	51	11

Note: P_{25} = 25th percentile; P_{75} = 75th percentile; *IQR* = interquartile range (P_{75}–P_{25}).

[a]PM_{10} = particulate matter less than 10 µm in diameter; SO_2 = sulfur dioxide; NO_2 = nitrogen dioxide.

sure-response relation coefficient; X_k is the concentration of air pollutants (PM_{10}, SO_2, and NO_2) on day *k*; *s* is the spline smoothing function, which is used to remove the long-term trend of a time series, calendar effect, weather, and other confounding factors; *df* is the degree of freedom; *DOW* is the indicator for the days of a week, which is a dummy variable; *time* is the calendar time; and Z_k denotes a meteorological variable or air pollutant on day *k*.

A smoothing function was chosen to remove long-term trends from the data. Other meteorological parameters, such as average temperature, pressure, and relative humidity were controlled by simulations using nonparametric smoothing functions in the GAM model. The Akaike information criterion was used to select the degree of freedom and measure goodness of fit (Akaike, 1973).

The association between air pollutants and respiratory hospitalizations is expressed by relative risks (*RR*s) and the 95% *CI*s corresponding to an increase per *IQR* for each air pollutant. The changes in exposure to air pollutants were estimated for the same day (lag0) as well as on the lags of days 1–6 (lag1, lag2,…lag6). These lag periods were selected *a priori* to investigate the short-term effects of air pollutants on respiratory hospitalizations. We investigated the association between air pollutants in different seasons and hospital admissions. Such association was examined for spring (March–May), summer (June–August), autumn (September–November), and winter (December–February). Additionally, we also examined the association between air pollutants and hospital admissions subject to gender (female and male) and age (<65 yrs., ≥65 yrs.). We fitted both single-pollutant models and multiple-pollutant models to assess the stability of the effects of the selected air pollutants on respiratory admissions. We have estimated the effects of PM_{10} on respiratory hospital admissions in each season from the models, in order to elucidate if the observed effects in different seasons were statistically significant. All analyses were performed using the mgcv package of the R software.

Results

Statistical Results

In 2001–2005, PM_{10} remained a considerably high level in air at the daily averaged concentration of 0.197 mg/m^3. This value is much higher than the standard value of 0.05 mg/m^3 of daily particle concentration recommended by the World Health Organization (WHO). It also exceeds the Chinese national air quality level 2 standard (0.15 mg/m^3). By contrast, SO_2 and NO_2 daily averaged concentrations did not exceed the national air quality level 2 standard of 0.15 mg/m^3 and 0.08 mg/m^3, respectively. During this period, the daily average maximum and minimum temperatures were 30.1°C and -12.2°C, respectively (Table 1). The total number of respiratory hospital admissions was 28,057, among which 66% were male and 34% were female. In these two groups, 29% were elderly (≥ 65 years) and the rest (71%) were younger than 65 years.

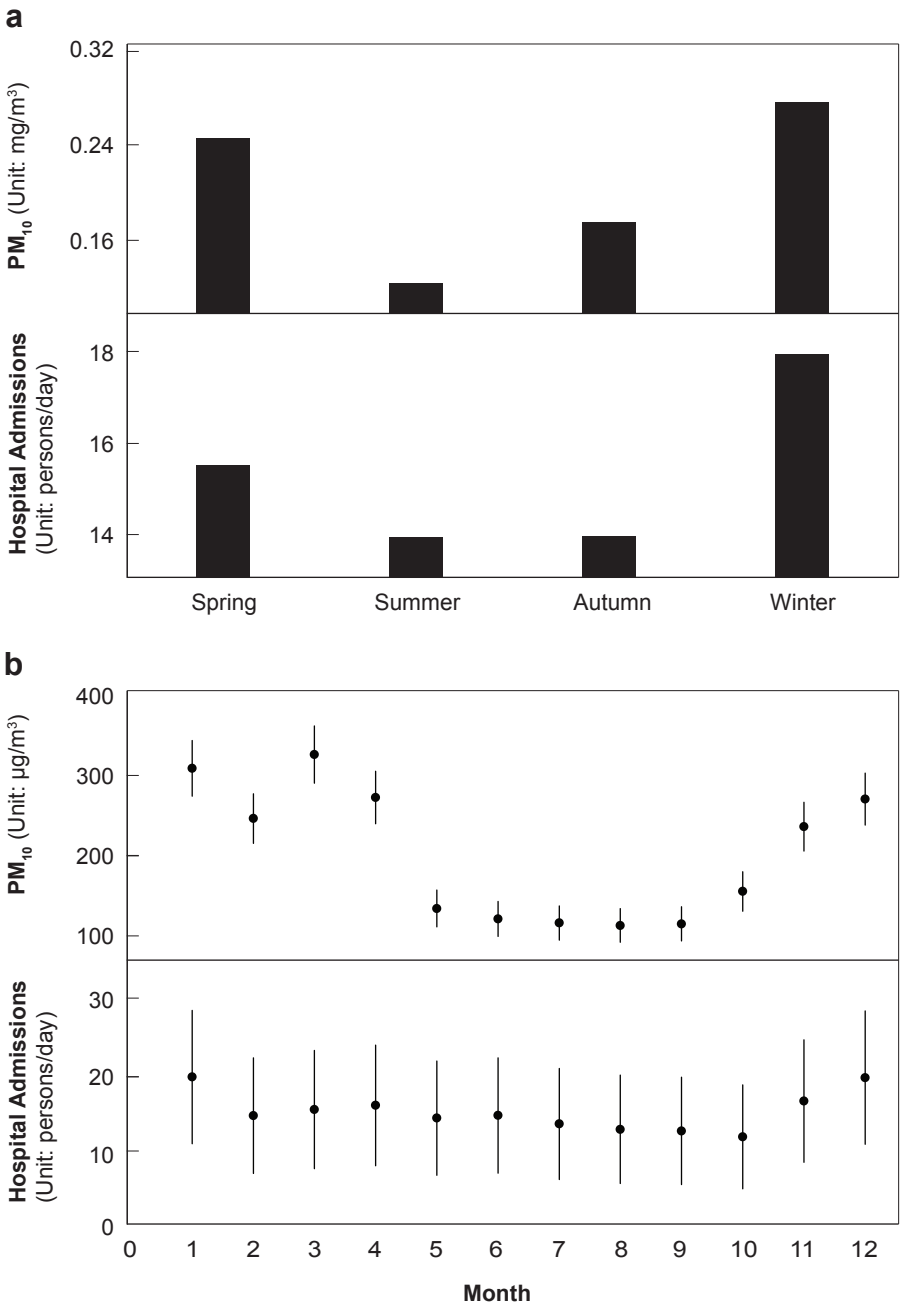
The daily concentration of PM_{10} was the highest in winter, reaching 0.27 mg/m^3, followed by spring, autumn, and summer. The daily number of respiratory hospital admissions was also the highest in winter at 18 persons per day, followed by spring, summer, and autumn. During summer and autumn, the daily number of respiratory hospital admissions was identical at 13.9 persons per day (Figure 2).

Single-Pollutant Model

The *RR*s (95% *CI*) of PM_{10} to total respiratory hospital admissions in spring, summer, autumn, and winter were 1.033 (0.993–1.074), 1.014 (0.991–1.037), 1.036 (0.968–1.108), and 1.040 (1.001–1.081), respectively (Table 2). The *RR* in Lanzhou was the highest in winter, followed by autumn, spring, and summer. As for gender, the *RR*s of PM_{10} in female respiratory hospital admissions were higher than that of males in all seasons. As for age, the *RR*s of PM_{10} in elderly people (≥65 yrs.) respiratory hospital admissions were higher than those people younger than 65 yrs. The *RR*s

FIGURE **2**

Average Daily Respiratory Hospital Admissions and Average Daily PM_{10} Concentration in Different Seasons in Lanzhou (2001–2005)



PM_{10} = particulate matter less than 10 μm in diameter.

of PM_{10} showed the greater association with the respiratory hospital admissions of females and the elderly group than that in males and those younger than 65 yrs. The *RR*s were the highest in winter, followed by autumn, spring, and summer in the same gender or aged group in Lanzhou, indicating that the strongest association between respiratory hospital admissions and PM_{10} occurred in winter.

Multi-Pollutant Model

In the context of respiratory hospital admissions, the *RR* of PM_{10} showed the change in different respiratory hospital admissions groups and season after adjusting SO_2 and NO_2. For example, the *RR*s of PM_{10} almost reduced but still remained significant in winter for different groups of people. The *RR*s (95% *CI*) of PM_{10} in respiratory hospital admissions during the winter for the four groups of patients were 1.040 (1.000–1.082) for total, 1.053 (1.007–1.100) for male, 1.093 (1.058–1.130) for female, 1.049 (1.012–1.087) for elderly people (≥65 yrs.), and 1.034 (0.967–1.106) for those younger than 65 (Table 3).

Table 4 compares the results from single pollutant and multiple pollutant models. As seen from Table 4, the best lag time in the spring, summer, autumn, and winter was the current day (lag0), lag day 2 (lag2), lag day 5 (lag5), and lag day 4 (lag4), respectively. The effect of PM_{10} on total respiratory hospital admissions was less significant in spring and autumn after adjusting SO_2 and NO_2, and remained the same in summer and winter. Significant association was found between PM_{10} and daily hospital admissions for respiratory disease in Lanzhou during the wintertime.

Discussion

As mentioned earlier, in Lanzhou, the daily averaging ambient concentration of PM_{10} at 0.197 mg/m^3 from 2001 to 2005 is much higher than the standard value of 0.05 mg/m^3 of daily particle concentration recommended by WHO. In particular, the urban area with larger population density suffers from higher concentrations of air pollutants, resulting in a higher exposure to pollutants and a serious health risk of local residents. A previous study has shown that the level of atmospheric pollutions during winter in Lanzhou was the highest, attributable primarily to high level of TSP in the atmosphere as compared to SO_2 (An, Ma, & Wang, 2006).

Several previous investigations have estimated the effects of particulates on respiratory diseases in mortality (Katsouyanni et al., 2001; Kim, Kim, & Hong, 2003; Lee et al., 2000; Medina-Ramón, Zanobetti, & Schwartz, 2006; Samet, Dominici, Curriero, Coursac, & Zeger, 2000) and morbidity (Goldberg et al., 2001; Goldberg, Burnett,

TABLE **2**

Relative Risk (95% Confidence Interval) of PM_{10}[a] on Daily Respiratory Hospital Admissions in Different Seasons (Single-Pollutant Models)

Group	Spring	Summer	Autumn	Winter
Total	1.033 (0.993–1.074)	1.014 (0.991–1.037)	1.036 (0.968–1.108)	1.040 (1.001–1.081)*
Male	1.043 (1.006–1.082)*	1.022 (0.998–1.066)	1.027 (0.943–1.118)	1.054 (1.009–1.101)*
Female	1.060 (1.003–1.120)*	1.023 (0.984–1.063)	1.065 (1.002–1.113)*	1.097 (1.062–1.134)*
<65 yrs.	1.031 (0.994–1.070)	1.023 (0.997–1.050)	1.036 (0.944–1.137)	1.044 (1.011–1.116)*
≥65 yrs.	1.053 (1.000–1.109)*	1.025 (0.986–1.064)	1.045 (0.805–1.329)	1.056 (1.021–1.093)*

[a]PM_{10} = particulate matter less than 10 μm in diameter.
*Statistical significance of relative risk value $p < .05$.

TABLE **3**

Relative Risk (95% Confidence Interval) of PM_{10}[a] on Daily Respiratory Hospital Admissions in Different Seasons (Multi-Pollutant Models)

Group	Spring	Summer	Autumn	Winter
Total	1.031 (0.991–1.072)	1.014 (0.992–1.037)	1.030 (0.990–1.073)	1.040 (1.000–1.082)*
Male	1.043 (1.005–1.083)*	1.024 (0.988–1.062)	1.015 (0.932–1.107)	1.053 (1.007–1.100)*
Female	1.065 (1.008–1.126)*	1.022 (0.983–1.062)	1.085 (1.026–1.148)*	1.093 (1.058–1.130)*
<65 yrs.	1.032 (0.995–1.071)	1.022 (0.996–1.049)	1.056 (0.921–1.137)	1.034 (0.967–1.106)*
≥65 yrs.	1.060 (1.005–1.117)*	1.019 (0.981–1.059)	1.069 (0.725–1.275)	1.049 (1.012–1.087)*

[a]PM_{10} = particulate matter less than 10 μm in diameter.
*Statistical significance of relative risk value $p < .05$.

Yale, Valois, & Brook, 2006; Lin et al., 2008) in many regions of the world. The association between PM_{10} and respiratory hospital admissions revealed in this study confirm those earlier analyses in North America (Dockery et al., 1994; Zanobetti et al., 2000) and Europe (Atkinson et al., 2001; Morgan et al., 2003 ; Sunyer et al., 2000; Sunyer & Basagaña, 2001). The result derived from the single-pollutant model and multi-pollutant model show that when PM_{10} concentration increases the *IQR* (0.139 mg/m^3) to 3.3% in spring, 1.4% in summer, 3.6% in autumn, and 4.0% in winter, the daily hospital admission increases 3.1%, 1.4%, 3.0%, and 4.0% in these seasons, respectively.

The highest daily respiratory hospital admission in winter is likely associated with a higher level of PM_{10} and other air pollutants (e.g., SO_2) due to domestic heating from November to March in Lanzhou, which causes increased air emission of these pollutants. This aside, during the wintertime, with winter large-sale atmospheric circulation and mountain-valley topography, a strong temperature inversion dominates Lanzhou, which could even extend to the next afternoon and winds are almost calm within the valley (An & Lv, 2007). These environmental conditions all together lead to very stable atmospheric stratification and weak turbulent mixing, which retard air pollutants out of the valley, resulting in high PM_{10} concentrations. In spring, sandstorms frequently occur in Gansu Hexi Corridor, resulting in a spread of a large number of particulates increasing considerably the particulate pollution over Lanzhou (Wang, Yang, Qi, Xin, & Yang, 1999). Since dust weather also impacts the respiratory hospital admissions (Tao, An, Sun, Hou, & Wang, 2012), atmospheric particulate matter should be also taken as the primary air pollutant in the assessment of the relationship between particulate matter from natural sources and the respiratory hospital admissions. Hence, it is necessary to consider both anthropogenic and natural atmospheric particulate matters caused by coal-fired, local heavy industry emission, and dust storms that link with the respiratory hospital admissions in Lanzhou.

Females and elderly people had higher risks to PM_{10} than the male and younger patients based on respiratory hospital admissions. This agrees with the results from previous studies that suggested that females and the aged people were more vulnerable to outdoor air pollution (Kan et al., 2008). They were usually susceptible to air pollution as the high-risk group compared with males and younger people.

TABLE **4**

Relative Risk (95% Confidence Interval) of PM_{10}[a] on Daily Total Respiratory Hospital Admissions in Different Seasons in Single- and Multiple-Pollutant Models

Season	Single-Pollutant Model	Multiple-Pollutant Model
Spring (lag0)	1.033 (0.993–1.074)	1.031 (0.991–1.072)
Summer (lag2)	1.014 (0.991–1.037)	1.014 (0.992–1.037)
Autumn (lag5)	1.036 (0.968–1.108)	1.030 (0.962–1.103)
Winter (lag4)	1.040 (1.001–1.081)*	1.040 (1.000–1.082)*

[a]PM_{10} = particulate matter less than 10 µm in diameter.
*Statistical significance of relative risk value $p < .05$.

TABLE **5**

Comparison of Relative Risk for a 10 µg/m³ Increase of PM_{10}[a] in Different Areas

Area	Relative Risk	95% Confidence Interval
Hong Kong (Wong et al., 1999)	1.016	1.010–1.022
Guangzhou (Zheng, 2001)	1.004	1.002–1.006
Jinan (Wang et al., 2008)	1.002	1.001–1.004
Tacoma (Schwartz, 1995)	1.019	1.006–1.032
Spokane (Schwartz, 1996)	1.016	1.007–1.026
London (Atkinson et al., 1999)	1.010	1.004–1.016
APHEA (Atkinson et al., 2001)	1.009	1.006–1.013
USA (Zanobetti et al., 2000)	1.020	1.015–1.024
Ontario (Luginaah et al., 2005)	1.012	1.008–1.016
New York (Schwartz, 1995)	1.010	1.002–1.019
New Haven (Schwartz, 1995)	1.012	1.000–1.025

[a]PM_{10} = particulate matter less than 10 µm in diameter.

Table 5 compares the *RR* (95% *CI*) of daily respiratory hospital admission when the pollutants increase per 10 µg/mg³ of daily averaged concentrations in different regions. In this case, the *RR* of Lanzhou residents ranged from 1.002 to 1.003. As mentioned above, while higher PM_{10} concentration has occurred in Lanzhou than other Chinese cities and high risks to this pollutant exist for people, the sensitivity of the people to PM_{10} air pollution appeared low, agreeing with the finding reported by Xie and co-authors (2009). This is likely related to the difference of susceptibility of local people to air pollution and the typical population's age structure compared with Europe, the U.S., and other developed countries where there are large aging societies who are mostly a susceptible population. The particulate composition may also differ between China and developed countries. In developed countries, PM_{10} is mainly emitted from motor vehicles (Mann et al., 2002). These emissions contain a large number of secondary aerosols and are highly toxic, yielding more adverse health risks to the human body. In Lanzhou, the result from particulate matter source apportionment analysis indicated that urban dust and soil sand made greater contribution to PM_{10} levels in air. These dust and soil sand are primarily composed of inorganic minerals with low toxicity and weak influence on human health. As a result, the influence on human health of particulate toxicity induced by different particle characteristics and sources may vary widely.

Conclusion

Due to unique mountain-valley topography, special weather conditions, and large anthropogenic and natural emissions, Lanzhou is one of the most heavily polluted cities in China and the world. The daily concentration of PM_{10} was the highest in winter and the lowest in summer. Accordingly, the daily number of respiratory hospital admissions was also the highest in winter at 18 persons per day, followed in summer and autumn, both at 13.9 persons per day.

A good association existed between increasing PM_{10} and hospital admissions of respiratory diseases in different seasons in Lanzhou during 2001–2005. Increasing PM_{10} enhanced respiratory hospital admissions in different seasons. The effect of PM_{10} on respiratory hospital admissions was stronger in winter than other seasons.

In the case of gender and age, the *RR*s of PM_{10} on female and elderly people (≥65 yrs.) respiratory hospital admissions were higher than male and the people younger than 65 in every season. The health risk of female and elderly people (≥65 yrs.) was associated more strongly with PM_{10} atmospheric concentration than for males and people younger than 65.

Acknowledgements: The study was funded by the Natural Science Foundation of China (41075102 and 41005087), the Fundamental Research Funds for the Central Universities (lzujbky-2013-m03), the National Key Technology Support Program (2014BAC16B04), and the Beijing Municipal Science and Technology Commission Easy Access project (Z131100005613024). The authors are indebted to anonymous reviewers for their valuable comments.

Corresponding Author: Tao Yan, College of Earth and Environmental Science, Lanzhou University; Key Laboratory of Western China's Environmental Systems (Ministry of Education), Lanzhou University, 222 Tianshui South Road, Lanzhou, 730000, China.
E-mail: taoyan@lzu.edu.cn.

References on page 70

References *continued from page 69*

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principle. In B.N. Petrov & F. Csaki (Eds.), *Second international symposium on information theory* (pp. 267–281). Budapest: Academiai Kiado.

An, X.Q., & Lv, S.H. (2007). Observation and simulation study on structure characteristics of atmospheric boundary layer over Lanzhou in winter. *Scientia Meteorologica Sinica, 27*(4), 374–380.

An, X.Q., Ma, A.Q., & Wang, H.L. (2006). Analyzing air pollution spatial distribution of Lanzhou using GIS. *Arid Land Geography, 29*(4), 576–581.

Atkinson, R.W., Anderson, H.R., Sunyer, J., Ayres, J., Baccini, M., Vonk, J.M., Boumghar, A., Forastiere, F., Forsberg, B., Touloumi, G., Schwartz, J., & Katsouyanni, K. (2001). Acute effects of particulate air pollution on respiratory admissions results from APHEA 2 Project. *American Journal of Respiratory and Critical Care Medicine, 164*(10), 1860–1866.

Atkinson, R.W., Bremner, S.A., Anderson, H.R., Strachan, D.P., Bland, J.M., & de Leon, A.P. (1999). Short-term associations between emergency hospital admissions for respiratory and cardiovascular disease and outdoor air pollution in London. *Archives of Environmental Health, 54*(6), 398–411.

Dockery, D.W., Pope, C.A., Xu, X.P., Spengler, J.D., Ware, J.H., Fay, M.E., Ferris, B.G., Jr., & Speizer, F.E. (1993). An association between air pollution and mortality in six U.S. cities. *The New England Journal of Medicine, 329*(24), 1753–1759.

Dominici, F., Peng, R.D., Bell, M.L., Pham, L., McDermott, A., Zeger, S.L., & Samet, J.M. (2006). Fine particulate air pollution and hospital admission for cardiovascular and respiratory diseases. *The Journal of the American Medical Association, 295*(10), 1127–1134.

Goldberg, M.S., Burnett, R.T., Bailar, J.C., 3rd, Brook, J., Bonvalot, Y., Tamblyn, R., Singh, R., Valois, M.F., & Vincent, R. (2001). The association between daily mortality and ambient air particle pollution in Montreal, Quebec. 2: Cause-specific mortality. *Environmental Research, 86*(1), 26–36.

Goldberg, M.S., Burnett, R.T., Yale, J.F., Valois, M.F., & Brook, J.R. (2006). Associations between ambient air pollution and daily mortality among persons with diabetes and cardiovascular disease. *Environmental Research, 100*(2), 255–267.

Hastie, T.J., & Tibshirani, R.J. (1990). *Generalized additive models* (pp. 136–171). Boca Raton, FL: Chapman & Hall/CRC.

Kan, H.D., London, S.J., Chen, G.H., Zhang, Y.H., Song, G.X., Zhao, N.Q., Jiang, L.L., & Chen, B.H. (2008). Season, sex, age, and education as modifiers of the effects of outdoor air pollution on daily mortality in Shanghai, China: The public health and air pollution in Asia (PAPA) study. *Environmental Health Perspectives, 116*(9), 1183–1188.

Katsouyanni, K., Touloumi, G., Samoli, E., Gryparis, A., Le Tertre, A., Monopolis, Y., Rossi, G., Zmirou, D., Ballester, F., Boumghar, A., Anderson, H.R., Wojtyniak, B., Paldy, A., Braunstein, R., Pekkanen, J., Schindler, C., & Schwartz, J. (2001). Confounding and effect modification in the short-term effects of ambient particles on total mortality: Results from 29 European cities within the APHEA2 project. *Epidemiology, 12*(5), 521–531.

Kim, H., Kim, Y., & Hong, Y.C. (2003). The lag-effect pattern in the relationship of particulate air pollution to daily mortality in Seoul, Korea. *International Journal of Biometeorology, 48*(1), 25–30.

Lee, J.T., Kim, H., Hong, Y.C., Kwon, H.J., Schwartz, J., & Christiani, D.C. (2000). Air pollution and daily mortality in seven major cities of Korea, 1991–1997. *Environmental Research, 84*(3), 247–254.

Lin, S., Bell, E.M., Liu, W., Walker, R.J., Kim, N.K., & Hwang, S.A. (2008). Ambient ozone concentration and hospital admissions due to childhood respiratory diseases in New York State, 1991–2001. *Environmental Research, 108*(1), 42–47.

Luginaah, I.N., Fung, K.Y., Gorey, K.M., Webster, G., & Wills, C. (2005). Association of ambient air pollution with respiratory hospitalization in a government-designated "area of concern": The case of Windsor, Ontario. *Environmental Health Perspectives, 113*(3), 290–296.

Mann, J.K., Tager, I.B., Lurmann, F., Segal, M., Quesenberry, C.P., Jr., Lugg, M.M., Shan, J., & Van Den Eeden, S.K. (2002). Air pollution and hospital admissions for ischemic heart disease in persons with congestive heart failure or arrhythmia. *Environmental Health Perspectives, 110*(12), 1247–1252.

Medina-Ramón, M., Zanobetti, A., & Schwartz, J. (2006). The effect of ozone and PM_{10} on hospital admissions for pneumonia and chronic obstructive pulmonary disease: A national multicity study. *American Journal of Epidemiology, 163*(6), 579–588.

Meng, Z.Q., Lu, B., Zhou, Y., Huang, W.Q., Wang, T., Geng, H., & Zhang, J. (2006). Association of dust events with daily respiratory hospitalization: A time series approach (1995–2003). *Acta Scientiae Circumstantiae, 26*(11), 1900–1908.

Meng, Z.Q., Zhang, J., & Lu, B.(2007). Association of $PM_{2.5}$ in dust and sand events with hypertension outpatient number. *Journal of Environmental and Occupational Medicine, 24*(5), 473–476.

Meng, Z.Q., Zhang, J., Yang, Z.H., & Lu, B. (2008). Association of $PM_{2.5}$ from dust events with the number of daily outpatient for respiratory and cardiovascular diseases. *Journal of Environmental and Occupational Medicine, 25*(3), 225–231.

Morgan, G., Lincoln, D., Sheppeard, V., Jalaludin, B., Beard, J.F., Simpson, R.W., Petroeschevsky, A., O'Farrell, T., & Corbett, S. (2003). The effects of low level air pollution on daily mortality and hospital admissions in Sydney, Australia, 1994 to 2000. *Epidemiology, 14*(5), 111–112.

Pope, C.A., 3rd, Burnett, R.T., Thun, M.J., Calle, E.E., Krewski, D., Ito, K., & Thurston, G.D. (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *Journal of the American Medical Association, 287*(9), 1132–1141.

Pope, C.A., 3rd, Thun, M.J., Namboodiri, M.M., Dockery, D.W., Evans, J.S., Speizer, F.E., & Heath, C.W., Jr. (1995). Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. *American Journal of Respiratory and Critical Care Medicine, 151*(3), 669–674.

References

Samet, J.M., Dominici, F., Curriero, F.C., Coursac, I., & Zeger, S.L. (2000). Fine particulate air pollution and mortality in 20 U.S. cities, 1987–1994. *The New England Journal of Medicine, 343*(24), 1742–1749.

Schwartz, J. (1994). Air pollution and hospital admissions for the elderly in Birmingham, Alabama. *American Journal of Epidemiology, 139*(6), 589–598.

Schwartz, J. (1995). Short-term fluctuations in air pollution and hospital admissions of the elderly for respiratory disease. *Thorax, 50*(5), 531–538.

Schwartz, J. (1996). Air pollution and hospital admissions for respiratory disease. *Epidemiology, 7*(1), 20–28.

Schwartz, J. (1999). Air pollution and hospital admissions for heart disease in eight U.S. counties. *Epidemiology, 10*(1), 17–22.

Schwartz, J., Spix, C., Touloumi, G., Bachárová, L., Barumamdzadeh, T., le Tertre, A., Piekarksi, T., Ponce de Leon, A., Pönkä, A., Rossi, G., Saez, M., & Schouten, J.P. (1996). Methodological issues in studies of air pollution and daily counts of deaths or hospital admissions. *Journal of Epidemiology and Community Health, 50*(Suppl. 1), S3–S11.

Sunyer, J., & Basagaña, X. (2001). Particles, and not gases, are associated with the risk of death in patients with chronic obstructive pulmonary disease. *International Journal of Epidemiology, 30*(5), 1138–1140.

Sunyer, J., Schwartz, J., Tobías, A., Macfarlane, D., Garcia, J., & Antó, J.M. (2000). Patients with chronic obstructive pulmonary disease are at increased risk of death associated with urban particle air pollution: A case-crossover analysis. *American Journal of Epidemiology, 151*(1), 50–56.

Tao, Y., An, X.Q., Sun, Z.B., Hou, Q., & Wang, Y. (2012). Association between dust weather and number of admissions for patients with respiratory diseases in spring in Lanzhou. *Science of the Total Environment, 423*, 8–11.

Tecer, L.H., Alagha, O., Karaca, F., Tuncel, G., & Eldes, N. (2008). Particulate matter ($PM_{2.5}$, $PM_{10-2.5}$, and PM_{10}) and children's hospital admissions for asthma and respiratory diseases: A bidirectional case-crossover study. *Journal of Toxicology and Environmental Health, Part A, 71*(8), 512–520.

Wang, S.G., Yang, M., Qi, B., Xin, C.L., & Yang, M.F. (1999). Influence of sand-dust storms occurring over the Gansu Hexi district on the air pollution in Lanzhou city. *Journal of Desert Research*, *19*(4), 354–358.

Wang, Y., Zhang, Y.S., & Li, X.P. (2008). The effect of air pollution on hospital visits for respiratory symptoms in urban areas of Jinan. *China Environmental Science, 28*(6), 571–576.

Wong, T.W., Lau, T.S., Yu, T.S., Neller, A., Wong, S.L., Tam, W., & Pang, S.W. (1999). Air pollution and hospital admissions for respiratory and cardiovascular diseases in Hong Kong. *Occupational and Environmental Medicine, 56*(10), 679–683.

World Health Organization. (2011). *Public health and environment database: Outdoor air pollution in cities.* Retrieved from http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/

Xie, P., Liu, X.Y., Liu, Z.R., Li, T.T., & Bai, Y.H. (2009). Exposure-response functions for health effects of ambient particulate matter pollution applicable for China. *China Environmental Science, 29*(10), 1034–1040.

Zanobetti, A., Schwartz, J., & Dockery, D.W. (2000). Airborne particles are a risk factor for hospital admissions for heart and lung disease. *Environmental Health Perspectives, 108*(11), 1071–1077.

Zheng, Y.D. (2001). *Study the relationship between air pollution and public health using time-series method.* Sun Yat-sen Medical University.

Boys, Not Girls, Are Negatively Affected on Cognitive Tasks by Lead Exposure: A Pilot Study

Prepublished online October 2014,
National Environmental Health Association.

Maya M. Khanna, PhD
Department of Psychology
Creighton University

Abstract **The study described in this article provides behavioral evidence that boys experience the deleterious cognitive effects of lead more than girls do. In fact, girls with elevated blood lead levels (BLLs ≥ 10 µg/dL) performed as well as girls without elevated BLLs on behavioral measures of cognition. This was shown by testing executive function and reading readiness skills of 40 young children (aged three to six years; 23 with elevated blood lead levels, 17 without) residing within a U.S. Environmental Protection Agency–designated lead Superfund site. The results also indicate that elevated BLLs are related to a more pronounced negative impact on executive function than on reading readiness. These findings support recent research on adults indicating that lead exposure is related to atrophy within the prefrontal cortex and other work suggesting that estrogen and estradiol may act as neuroprotectants against the negative impact of neurotoxins.**

Introduction

The Centers for Disease Control and Prevention estimate that at least 450,000 children in America are exposed to lead at levels requiring immediate intervention (National Center for Healthy Housing, 2012). Lead exposure adversely affects the renal, endocrine, and reproductive systems, as well as impeding central nervous system development (Agency for Toxic Substances and Disease Registry, 2007). In fact, many studies indicate that lead exposure, even at relatively low levels, adversely affects cognitive development (for a thorough review see Lanphear et al., 2005). The outcomes for nonrehabilitated individuals exposed to lead can be bleak. For example, Braun and colleagues (2008) reported that environmental lead exposure was associated with elevated rates of conduct disorder among children. Similarly, Haynes and co-authors (2011) found that lead exposure was related to elevated levels of adolescent criminal activity. Lead exposure has also been linked to increased rates of attention deficit hyperactivity disorder (Eubig, Aguiar, & Schantz, 2010), and increased rates of psychopathy (Wright, Boisvert, & Vaske, 2009). Children exposed to lead during prenatal development, infancy, or childhood get dramatically lower scores on tests of memory, attention, inhibition, and decision making than do children from similar demographic backgrounds who have not been exposed to lead (Lanphear et al., 2005). In addition, Cecil and co-authors (2008) found that adults exposed to lead as children exhibited greater atrophy in frontal brain areas as compared to other areas of the cerebral cortex.

Substantial evidence exists that the neurobiological consequences of lead exposure may affect males more than females. For example, recent work by Brubaker and co-authors (2010) on adult participants has suggested that young males are more susceptible to the negative consequences of neurotoxin exposure than are females. Specifically, those researchers found that males exposed to lead during childhood and adolescence experienced significantly more gray matter volume loss than did young females exposed to lead. They argued that males are more vulnerable to these negative effects of neurotoxins because they do not have the neuroprotective action of estrogen and estradiol that their female counterparts do. Similar neuroprotection for females has been found in studies of Parkinson's disease, stroke, and schizophrenia (Amantea, Russo, Bagetta, & Corasaniti, 2005). In fact, several cytological studies have documented the neuroprotectant action of estrogen and estradiol against the actions of neurotoxins such as lead (Chetty, Vermuri, Reddy, & Suresh, 2007). Chetty and colleagues (2007) found that neurons pretreated with 17-β estradiol exhibited less apoptosis, or cell death, when exposed to lead as compared to neurons not pretreated with estradiol. See Gillies and McArthur (2010) for a review of the neuroprotective actions of estrogen.

Although substantial evidence exists that estrogen and estradiol act as neuroprotectants against neurotoxins, most of this evidence is provided by cytological studies using neuron cultures. Limited evidence exists documenting the cognitive performance differences in males and females exposed to neurotoxins. Because females have much higher levels of estradiol than do their male peers, they should be less susceptible to the deleterious effects of lead. Further, the difference in estrogen and estradiol levels between males and females is pronounced during childhood and adolescence. Thus, any cortical development that occurs during childhood and puberty will be susceptible to these estradiol-related sex differences. As the frontal cortex (especially the prefrontal cor-

tex) is developing during childhood and adolescence (Diamond, 2002), functions housed in the frontal areas are the most vulnerable to sex differences resulting from the actions of lead exposure. Executive functions such as working memory, planning, and attention are controlled by the frontal areas and appear to develop within childhood. Therefore, these skills should be particularly impacted by lead exposure, and this lead exposure should have an especially negative impact on males.

In the study described here, the effects of lead exposure on the cognitive functioning of boys and girls were examined. Children served as participants (aged three to six years) in order to see if differential effects of lead exposure on males and females are present even at an early age, as suggested by Brubaker and co-authors (2010). Furthermore, participants' performance on executive functioning tasks was compared to their performances on reading readiness tasks. The executive function tasks rely on areas of the prefrontal cortex (Kesler, Lacayo, & Jo, 2011), while the reading readiness tasks should rely more heavily on the temporal or parietal areas of the cerebral cortex (Lovio, Halttunen, Lyytinen, Näätänen, & Kujala, 2012). Thus, the current study explored not only potential sex differences in the cognitive impact of lead exposure, but also how the impact of lead exposure may be different across brain areas and across the cognitive functions associated with those areas.

Based on the findings of Brubaker and co-authors (2010) and Cecil and co-authors (2008), sex differences and task differences were expected in the performance displayed by boys and girls with and without elevated blood lead levels (BLLs). Specifically, it was expected that among participants who have been exposed to lead, boys would exhibit greater cognitive deficits than girls. In addition, these lead-related cognitive deficits seen in boys would be greater for executive function tasks (i.e., tasks that rely on frontal lobe functioning) than for reading readiness tasks that should rely on other areas of the brain.

Methods

Participants

Forty children ranging from three to six years of age served as participants. All participants resided within the U.S. Environmental Protection Agency (U.S. EPA) Omaha lead Superfund site. U.S. EPA Superfund sites are locations within the U.S. in which high levels of uncontrolled hazardous waste have been identified and cleanup efforts are underway. The Superfund site of Omaha has significant lead contamination in the surface soils due to the emissions of a lead refinery that operated for 125 years in the area. In addition, many homes within the area are relatively old and have lead-based paint still present. Furthermore, U.S. EPA has identified the Omaha lead Superfund site as one in which many environmental justice concerns are present. The residents within this area are predominantly low-income and members of racial minorities and most dwellings within the area are older rented homes. The children residing within this area are at an elevated risk for lead poisoning due to the presence of lead within the surface soils and due to the presence of lead-based paint within their residences.

A convenience sample of 40 participants was recruited. All participants resided within a three-ZIP-code area of eastern Omaha. This area has been found to have the highest levels of lead concentration within the Omaha lead Superfund site. In addition, the participant search was narrowed to this area because children residing in these ZIP code regions have very similar demographic backgrounds. The residences of these neighborhoods qualify for free and reduced lunch at a rate of 70%–100% (Omaha Public Schools, 2011). The annual family income of participants ranged from <$10,000 to $70,000. The majority of participating children were racial minorities (20 were African-American, 9 were Caucasian, 2 were African, and 9 were multiracial). The average educational attainment of the participants' parents was a high school diploma or GED with a range of middle school education to graduate level education. The majority of children in this sample did not attend preschool; instead, they were cared for in their homes or via neighborhood in-home daycare centers.

Members of the Douglas County (Nebraska) Health Department (DCHD) identified eligible participants based on the results of standard blood level testing conducted at their one-year and two-year pediatrician visits. Because Omaha is a U.S. EPA–designated lead Superfund site, pediatricians are encouraged to test the BLLs of all children residing within the ZIP codes of the Superfund site. The results of these tests are reported to DCHD. If a child is found to have an elevated BLL, members of the DCHD visit the family and educate them on lead abatement practices. Then the parents are strongly encouraged to have their child tested again after the family begins using lead-safe practices. Thus, children within the current study have had their BLLs tested at least once. Many children within the Superfund site and in the current study have had their BLLs tested several times, however. As this was a pilot study with limited financial support, the goal was to recruit and test 40 children (about half with elevated BLLs and half without) residing within the selected ZIP codes of the Superfund site. Members of DCHD recruited participants who either had a history of elevated BLLs (at least 10 µg/dL) or whose blood lead tests indicated little or no lead in their bloodstreams (<3 µg/dL). From this recruitment, 23 children had elevated BLLs (at least 10 µg/dL; average age 4.4 years; 15 males) and 17 children with nonelevated BLLs (less than 3 µg/dL; average age 4.6 years; 8 males).

Procedure

The procedure and testing protocol used in the present study were reviewed and approved by the Creighton University biomedical sciences institutional review board. Initial recruitment of participants was conducted by members of DCHD based on reported BLL test results. Members of DCHD contacted parents of children with the most recent BLL test results indicating that the child had an elevated BLL and children whose blood test results indicated that they never had elevated BLLs. Once parents/guardians agreed to their child's participation, they then gave the DCHD staff members permission to release the child's BLL status to the researcher after the testing appointment was completed.

For each participant, the same research protocol was followed during the testing appointment. First, the researcher explained to the child what they would be doing during the research session and explained to the child that he/she could request to end participation at any time. Next, they began the executive function skill component of the research protocol. This included the forward digit span, backward digit span, and letter/number sequencing tasks. After these tasks were completed, they proceeded onto the reading readiness tasks (see Table 1 for a

summary of the executive function and reading readiness tasks). All participants completed all measures. No children or parents chose to end participation after testing began.

Executive Function Tasks

The executive function tasks used (forward digit span, backward digit span, and letter number sequencing) are taken from the Wechsler Intelligence Scale for Children (Wechsler, 2004).

Forward Digit Span

In this task, participants are given an auditory list of digits one at a time that they report back to the experimenter in the order presented. Participants then progress through increasingly long lists with two lists at a given list length. When the participant incorrectly recalls the items from two lists of the same length, the task is ended. Each participant's forward digit span is calculated by counting the number of lists recalled correctly.

Backward Digit Span

This is similar to the forward digit span task except that participants recall list items in the reverse order of presentation.

Letter/Number Sequencing

In this task, participants are told that they will hear a list of numbers AND letters (e.g., 5-J-3-C). They are to report the numbers first, in numerical order starting with the lowest number (e.g., 3-5), and then the letters in alphabetical order (e.g., C-J). Participants are given three lists at a list length before progressing onto longer lists. When participants are unable to accurately report any of the entire lists from a list length, the task is ended. Each participant's letter/number sequencing span is calculated by counting the number of lists that are reported correctly.

The total time needed to conduct the executive function tasks ranged from 10 to 15 minutes across participants.

Reading Readiness Tasks

The next series of tasks was designed to gauge many of the skills that are necessary for reading. These tasks were from the Fountas and Pinnell Benchmark Assessment Systems (2011). The public school district that serves the children from the Superfund site uses this assessment to gauge the reading readiness skills of children entering prekindergarten. This reading assessment along with the companion reading intervention program have been tested and validated by a number of studies (e.g., Ransford-Kaldon et al., 2010, for a recent test and review). To assess their reading readiness, participants were tested on their letter knowledge, letter sound knowledge, their familiarity with books, their ability to read very simple words, and their picture vocabulary. In the first task, each participant was shown a series of flashcards, one for each uppercase letter of the alphabet. The participant was to name the letter and to indicate the sound the letter made (any possible pronunciation of the letter was scored as correct). For each letter, the child was scored for letter name knowledge and letter sound knowledge. Next, this task was repeated for lowercase letters. Participants were then shown a basic children's book; the researcher asked each child a series of questions about the book. First, the child was asked to point to the place on the page where the researcher should start to read the book (i.e., child should have pointed to the upper left hand corner of the first page). Next, the researcher asked the participant to point to a particular letter on a page of the book ("Please point to the letter 'a'"). The researcher then pointed to a punctuation mark (e.g., a question mark) and asked the participant what that meant. The researcher and participant proceeded with a few addi-

TABLE **1**

Executive Function and Reading Readiness Tasks

Task Type	Brief Description	Designed to Measure
Executive function tasks		
Forward digit span	Repeat back list of numbers	Short-term memory span
Backward digit span	Repeat back lists of numbers in reverse order	Short-term and working memory
Letter-number sequencing	Remember and reorganize a sequence of numbers and letters	Short-term memory, working memory, and planning
Reading readiness tasks		
Letter identification	Identify upper and lower case letters	Does child know the letters
Letter sounds	Identify the sounds associated with letters	Does child know the sounds associated with letters
Book familiarity	Answer questions (e.g., *Where on the page should I start reading?*) about a book	How familiar the child is with the reading process
Sight word reading	Read short easy words such as *on, mom, at,* etc.	Whether the child knows how to read simple words
Picture vocabulary	Identify the name of objects when shown a line drawing of the picture	The child's vocabulary

TABLE **2**

Composite Scores for Executive Function and Reading Readiness Tasks

Participant Type	Executive Function Tasks		Reading Readiness Tasks	
	Males	Females	Males	Females
Elevated blood-lead level	3.73 (.71)	6.88 (2.17)	0.13 (.032)	0.34 (.12)
Nonelevated blood-lead level	8.88 (1.86)	7.56 (1.38)	0.29 (.086)	0.16 (.04)

Note. Standard error of the mean appears within parentheses.

FIGURE **1**

Composite Executive Function Scores for Children With Elevated Blood Lead Levels (BLLs) and With Nonelevated BLLs

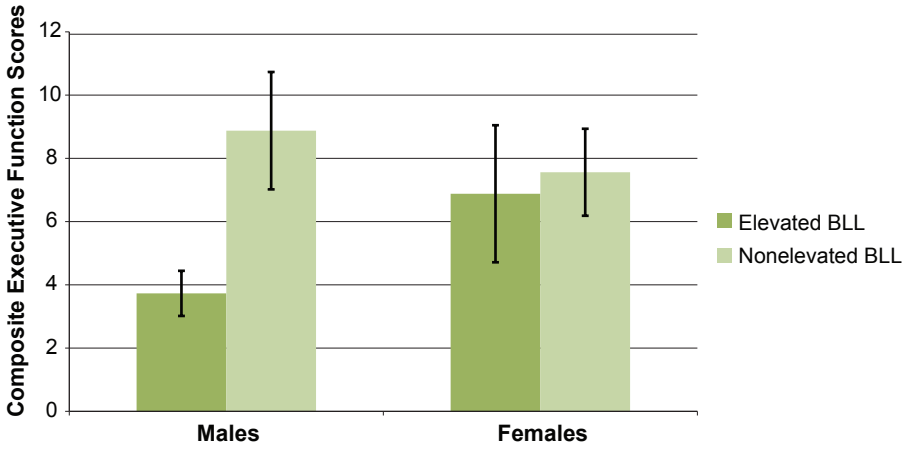
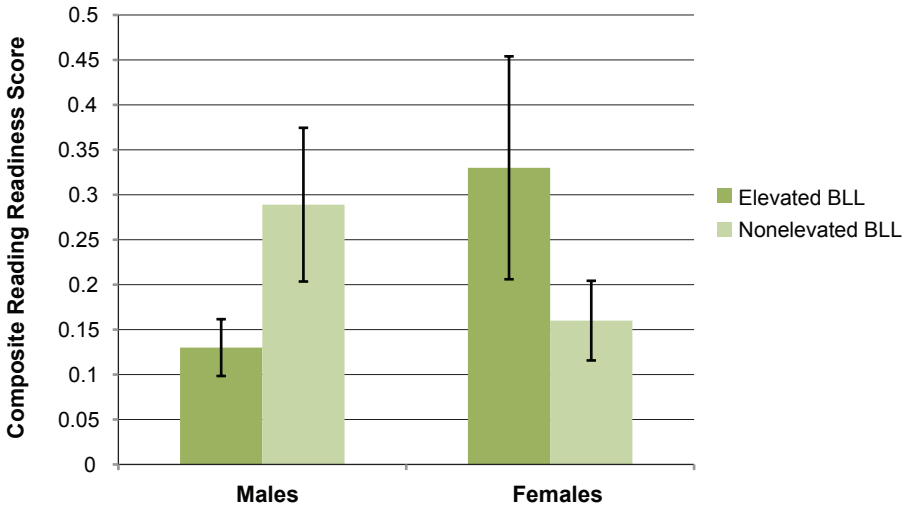


FIGURE **2**

Reading Readiness Scores for Child Participants With Elevated Blood Lead Levels (BLLs) and Nonelevated BLLs



tional questions designed to measure whether or not the child was familiar with the mechanics of the reading process.

In the next task, participants were shown a series of simple words (e.g., *on, mom, no*, etc.) on note cards and asked to read them aloud. These words were all considered "sight" words that children should know upon entering kindergarten. The final task that each participant completed was a brief picture vocabulary task. For this, each child was shown line drawings of common objects (e.g., a *cup*) and was asked to identify the object in the picture. The series of reading readiness tasks took the participants between 10 and 15 minutes to complete.

For each child, a composite executive function score and a composite reading readiness score were calculated. The composite executive function score was calculated by adding each of the span scores for the forward digit span, backward digit span, and letter number sequencing tasks. The reading readiness score was calculated by finding the average proportion correct across the reading tasks. For any analyses in which both executive function performance and reading readiness performance were included, the *Z* scores for each composite score were used because the two measures were on distinct and different scales. To calculate each participant's *Z* score for each task type, the group mean and standard deviation for that task were used. See Table 2 for a summary of the composite scores for the executive function tasks and reading readiness tasks for the elevated BLL and nonelevated BLL males and females.

Results

First, the effects of lead status (elevated BLL vs. nonelevated BLL) across male and female participants in the executive function tasks were found by conducting a 2 (elevated BLL status) x 2 (sex) analysis of variance (ANOVA) with participant age serving as a covariate. This indicated a marginal effect of lead status existed, $F(1, 35) = 3.23$, $MSE = 12.07$, $\eta^2 = .085$, $p = .081$, such that children with elevated BLLs did not perform as well as did the children with nonelevated BLLs (4.83 and 8.18, respectively). A trend suggesting an effect of sex on executive function performance also existed, $F(1, 35) = 2.65$, $MSE = 12.07$, $\eta^2 = .070$, $p = .11$. Females ($M = 7.24$) performed better on the executive function tasks than did the males ($M = 5.52$). Most importantly, an interaction occurred between lead status and sex, $F(1, 35) = 6.24$, $MSE = 12.07$, $\eta^2 = .151$, $p = .017$. This arose because elevated BLL status had a much greater effect on males than on females, as can be seen in Figure 1 and Table 2.

Next, the effects of lead status and participant sex on reading readiness were analyzed using a 2 (elevated BLL status) x 2 (sex) ANOVA with participant age serving as a covariate. An effect of sex occurred, $F(1, 35) = 4.29$, $MSE = .020$, $\eta^2 = .109$ $p = .046$; with the females ($M = .245$) performing better than the males ($M = .18$). No effect of lead status occurred on reading readiness, *F*

< 1.32, $p > .25$. An interaction of lead status and sex occurred, however, on reading readiness, $F(1, 35) = 18.85$, $MSE = .020$, $\eta^2 = .35$, $p = .000$, as the reading readiness of elevated BLL males ($M = .13$) was lower than nonelevated BLL males (.29), $t(21) = 2.14$, $\eta^2 = .387$, $p = .044$. Females, by contrast, did not show an effect of elevated BLL status on reading readiness, $t < 1.36$, $p > .195$, as can be seen in Figure 2.

Finally, to examine the effects of sex, lead status, and test type, a 2 (test type: executive function vs. reading readiness) x 2 (lead status: elevated BLL vs. nonelevated BLL) x 2 (sex) repeated measures ANOVA was conducted with participant age serving as a covariate. A main effect of sex occurred on task scores ($F[1, 35] = 4.75$, $MSE = .413$, $\eta^2 = .12$, $p = .036$) with females performing better than males (.1884 and -.1244, respectively). A suggested interaction of test type and lead status occurred ($F[1, 35] = 3.69$, $MSE = .887$, $\eta^2 = .095$, $p = .063$). This interaction was suggested because elevated lead levels were associated with poorer executive function performance ($t[38] = 2.37$, $\eta^2 = .359$, $p = .023$), but were not related to differences in reading readiness scores ($t < 1$). Most importantly, an interaction occurred between lead status and sex on cognitive performance, $F(1, 35) = 21.87$, $MSE = .413$, $\eta^2 = .385$, $p < .0001$, because lead status was related to the performance of boys, but was not related to the cognitive performance of girls.

Discussion and Conclusion

The purpose of the current pilot study was to see if differential cognitive effects of lead exposure occur on young males and females. In addition, the study allowed the examination of potential differential effects of lead exposure on executive function tasks and reading readiness tasks. These tasks recruit different areas of the cerebral cortex (the frontal and temporal/parietal areas, respectively). Brubaker and co-authors (2010) and Cecil and co-authors (2008) have found that frontal area gray matter volume decreases when one is exposed to lead during childhood and adolescence, while the other areas of the brain are not as highly impacted. Furthermore, this frontal lobe atrophy associated with lead exposure is more pronounced in males than females (Brubacker et al., 2010). Thus, participants in the current study who have elevated BLLs should exhibit relatively greater cognitive deficits in executive function tasks (i.e., tasks that rely on frontal areas) as compared to reading readiness tasks (i.e., tasks that do not rely as heavily on frontal areas). Moreover, these deficits in executive function skills should be more pronounced for males than females.

The results discussed here do indicate that participants exposed to lead experienced deficits in executive function performance. Most notably, the results suggest that lead exposure affects male executive function performance much more than female executive function performance. In addition, males exposed to lead experienced deficits in reading readiness as compared to males not exposed to lead. Females, however, did not exhibit deficits in reading readiness related to lead exposure. The overall analysis in which both reading readiness and executive function skills were examined simultaneously did suggest that lead exposure does impact cognitive functioning, with the impact being the greatest on males and on executive function skills.

Thus, the current study results support the hypothesis that tasks relying upon the frontal areas of the brain are more susceptible to the negative effects of lead exposure than are tasks relying on other areas of the brain. Furthermore, these results indicate that males are more susceptible to these negative consequences of lead exposure than are females.

Although the findings discussed here are very limited for several reasons (e.g., small participant number, limited tasks used, etc.), they do suggest the strong need for additional research in this area. In particular, the sex-specific effects of lead exposure should be explored through additional work. In combination with the previous work of Brubaker and co-authors (2010), cytological studies (e.g., Chetty et al., 2007) as well as pharmacological studies (Amantea et al., 2005) the current work suggests that differential effects of neurotoxin exposure may be due to the action of estrogen and estradiol. These substances are present in higher concentrations in females than males even at an early age. The current study provides behavioral support for the hypothesis that estradiol acts as a neuroprotectant against toxic substances and prevents neuronal apoptosis (Chetty et al., 2007). In addition, because the participants in the current study were so young (three to six years old), it is further suggested that estradiol aids in neurogenesis and the developing neurocircuitry.

The need for expanded research on the differential impact of lead exposure on males and females and the mechanisms of neuroprotection afforded by estrogen and estradiol is suggested by these results. Furthermore, future studies should expand the types of behavioral tests used to include a broader range of executive function tasks as well as tasks that rely on a range of different brain areas. Future studies should also include examinations of the neurocognitive functioning seen in males and females who have and have not been exposed to lead. Finally, future research should examine the potential of estrogen as a treatment or pretreatment to counteract the negative consequences of lead exposure.

This study clearly indicates that boys are more susceptible to the negative effects of lead exposure than are girls for both executive function and reading-based skills. The current findings indicate that these differences are not exclusively due to the activity of estrogen during puberty, as Brubaker and co-authors (2010) suggested. Instead, because the current participants were so young, the protective nature of estrogen is more likely due to its neuroprotection and actions on neurogenesis.

In addition, these findings indicate that the detrimental effects of lead are more pronounced for executive function skills than for reading-based skills. One reason for this is that the action of lead is the most deleterious in areas of the frontal cortex as compared to other cortical areas, as suggested by Cecil and co-authors (2008). The executive function tasks that the current participants performed rely more heavily upon areas of the frontal cortex than do the reading-based tasks (e.g., Kesler et al., 2010; Lovio et al., 2012).

This study adds to the evidence that lead exposure has a negative impact on cognitive functioning, especially on functions housed within frontal areas. Unlike previous research, however, this is the first study indicating that very young children already suffer the negative consequences of lead exposure and that the cognitive consequences of lead exposure are more severe for boys than girls.

Corresponding Author: Maya M. Khanna, Associate Professor, Department of Psychology, Creighton University, 2500 California Plaza, Omaha, NE 68178.
E-mail: mayakhanna@creighton.edu.

References

Agency for Toxic Substances and Disease Registry. (2007). *Public health statement on lead* (Publication No. CAS #7439-92-1). Atlanta, GA: Author.

Amantea, D., Russo, R., Bagetta, G., & Corasaniti, M.T. (2005). From clinical evidence to molecular mechanisms underlying neuroprotection afforded by estrogens. *Pharmacological Research, 52*(2), 119–132.

Braun, J.M., Kahn, R.S., Froehlich, T., Auinger, P., & Lanphear, B.P. (2006). Exposures to environmental toxicants and attention deficit hyperactivity disorder in U.S. children. *Environmental Health Perspectives, 114*(12), 1904–1909.

Brubaker, C.J., Dietrich, K.N., Lanphear, B.P., & Cecil, K.M. (2010). The influence of age of lead exposure on adult gray matter volume. *Neurotoxicology, 31*(3), 259–266.

Cecil, K.M., Brubaker, C.J., Adler, C.M., Dietrich, K.N., Altaye, M., Egelhoff, J.C., Wessel, S., Elangovan, I., Hornung, R., Jarvis, K., & Lanphear, B.P. (2008) Decreased brain volume in adults with childhood lead exposure. *PLoS Medicine, 5*(5), 0741–0750.

Chetty, C.S., Vemuri, M.C., Reddy, G.R., & Suresh, C. (2007). Protective effect of 17-beta-estrodiol in human neurocellular models of lead exposure. *Neurotoxicology*, *28*(2), 396–401.

Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood: Cognitive functions, anatomy, and biochemistry. In D.T. Stuss & R.T. Knight (Eds.), *Principles of frontal lobe function* (pp. 466–503). London: Oxford University Press.

Eubig, P.A., Aguiar, A., & Schantz, S.L. (2010). Lead and PCBs as risk factors for attention deficit/hyperactivity disorder. *Environmental Health Perspectives, 118*(12), 1654–1667.

Fountas, I.C., & Pinnell, G.S. (2011). *Fountas and Pinnell benchmark assessment systems 1 and 2* (2nd ed.). Portsmouth, NH: Heinemann.

Gillies, G.E., & McArthur, S. (2010). Estrogen actions in the brain and the basis for differential action in men and women: A case for sex-specific medicines. *Pharmacological Reviews*, *62*(2), 155–198.

Haynes, E.N., Chen, A.M., Ryan, P., Succop, P., Wright, J., & Dietrich, K.N. (2011). Exposure to airborne metals and particulate matter and risk for youth adjudicated for criminal activity. *Environmental Research, 111*(8), 1243–1248.

Kesler, S.R., Lacayo, N.J., & Jo, B. (2010). A pilot study of an online cognitive rehabilitation program for executive function skills in children with cancer-related brain injury. *Brain Injury, 25*(1), 101–112.

Lanphear, B.P., Hornung, R., Khoury, J., Yolton, K., Baghurst, P., Bellinger, D.C., Canfield, R.L., Dietrich, K.N., Bornschein, R., Greene, T., Rothenberg, S.J., Needleman, H.L., Schnaas, L., Wasserman, G., Graziano, J., & Roberts, R. (2005). Low-level environmental lead exposure and children's intellectual function: An international pooled analysis. *Environmental Health Perspectives, 113*(7), 894–899.

Lovio, R., Halttunen, A., Lyytinen, H., Näätänen, R., & Kujala, T. (2012). Reading skill and neural processing accuracy improvement after a three-hour intervention in preschoolers with difficulties in reading-related skills. *Brain Research, 1448,* 42–55.

National Center for Healthy Housing. (2012). *CDC accepts advisory committee recommendation to replace "level of concern" for lead poisoning with new reference level.* Columbia, MD: Author.

Omaha Public Schools. (2011). *Free and reduced-priced lunch report, 2011–2012.* Retrieved from http://district.ops.org/DEPARTMENTS/GeneralFinanceandAdministrativeServices/Research/StatisticalReports/tabid/2338/Agg7692_SelectTab/5/Default.aspx

Ransford-Kaldon, C.R., Flynt, E.S., Ross, C.L., Franceschini, L.A., Zoblotsky, T.A., Huang, Y., & Gallagher, B. (2010). *Implementation of effective intervention: An empirical study to evaluate the efficacy of Fountas & Pinnell's leveled literacy intervention program (LLI) for 2009–2010*. Memphis, TN: The University of Memphis, Center for Research in Educational Policy.

Wechsler, D. (2004). *The Wechsler intelligence scale for children* (4th ed.). London: Pearson Assessment.

Wright, J.P., Boisvert, D., & Vaske, J. (2009). Blood lead levels in early childhood predict adulthood psychopathy. *Youth Violence and Juvenile Justice, 7*(3), 208–222.

INTERNATIONAL PERSPECTIVES

Prepublished online November 2014,
National Environmental Health Association.

Evaluation of HACCP System Implementation on the Quality of Mixed Fresh-Cut Salad Prepared in a University Canteen: A Case Study

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 25 countries worldwide, are addressed. Our goal is to raise diverse issues of interest to all our readers, irrespective of origin.*

Andrea Osimani, PhD
Lucia Aquilanti, PhD
Francesca Clementi
Dipartimento di Scienze Agrarie, Alimentari, ed Ambientali
Università Politecnica delle Marche

Abstract **The increasing awareness that foods can represent vehicles for health risk factors has caused scientists and public authorities to multiply their efforts to reduce these risks to within acceptable limits. Nevertheless, some challenging issues still remain unsolved and new ones have recently emerged, such as the increase in outbreaks of foodborne diseases originating from the consumption of meals at catering facilities. The study described in this article was aimed at evaluating the microbiological quality of mixed fresh-cut salads at an Italian university canteen operating in conformity with the hazard analysis and critical control point (HACCP) system. The effectiveness of the preventive and corrective measures taken was also assessed with respect to the frequency of unsatisfactory salad samples. During the investigation, *E. coli*, *Salmonella* spp., and *Listeria monocytogenes* were never detected. By contrast, a high number of samples exceeded the mandatory or suggested limits for food processing hygiene (in terms of mesophilic aerobes, coliforms, *Staphylococcus aureus*, *Bacillus cereus*, and sulfite-reducing clostridia counts). Despite the introduction of a series of preventive and corrective actions, the results were only partially satisfactory; this was most likely due to the impossibility of having available an adequate level of human resources that are indispensable to correctly putting the HACCP procedures into daily practice.**

Introduction

Foods should be a source of nourishment, not an opportunity for parasites, viruses, and bacteria to enter the food chain and cause outbreaks of disease; therefore, scientists and public authorities have to make an incessant effort to reduce these risks to within acceptable limits (Clementi, Aquilanti, & Garofalo, 2009). In the European Union, a milestone towards the containment of foodborne diseases was the introduction of the mandatory application of hazard analysis and critical control point (HACCP) principles with the EEC Directive 93/43. Since then, a novel preventive approach (forward control) focused on the food-chain (food processing, storage, and distribution/serving) has been combined with the traditional inspective approach (backward control) centered on the product. The EC Regulation 852/2004, promulgated with the so-called "Hygiene Package," abrogated the EEC Directive 93/43, but reaffirmed its principles. Afterwards, with the EC Regulation 2073/2005 and subsequent amendments, two sets of microbiological criteria were established that must be observed in order to guarantee food safety and food processing hygiene, respectively (Petruzzelli et al., 2010).

The application of the HACCP system and the observance of the established microbiological criteria are particularly challenging in a canteen where a great number of meals have to be prepared daily, and a wide variety of ingredients and procedures have to be managed (Osimani, Aquilanti, Tavoletti, & Clementi, 2013a; Osimani, Aquilanti, Tavoletti, & Clementi, 2013b; Osimani, Babini, Aquilanti, Tavoletti, & Clementi, 2011; Petruzzelli et al., 2014). Accordingly, despite the routine application of the HACCP system, the consumption of meals at institutional catering facilities is still responsible for a significant proportion of foodborne infections and poisoning (Maruzumi et al., 2005; Mizoguchi et al., 2011; Moffat et al., 2006).

Among all the meals served daily in mass catering facilities, fresh-cut salads are of growing concern as a potential source of foodborne

pathogens (Sospedra, Rubert, Soriano, & Mañes, 2013; Warriner, Huber, Namvar, Fan, & Dunfield, 2009) since recent estimates suggest that around 5% of disease outbreaks are linked to minimally processed ready-to-eat vegetables, especially green leafy ones (Doyle & Erickson, 2008). Human pathogens associated with the consumption of fresh-cut salads include natural inhabitants of soil, such as *Listeria monocytogenes* and *Bacillus cereus* and natural inhabitants of the gut and feces, such as *Salmonella* spp. and enteropathogenic *E. coli* strains (Sospedra et al., 2013). The contamination of fresh produce by these human pathogens may occur at many stages in the food supply chain (Martinez-Tomè, Vera, & Murcia, 2000), due to the use of contaminated raw vegetables, improper handling, or a contaminated processing environment. Furthermore, the high moisture content of fresh vegetables, the great number of cut surfaces releasing plant cell fluids, and the possibility of time and temperature abuse during preparation/serving magnify the risk of microbial growth. By contrast, only a few preventive measures can be implemented in order to control microbial risk, namely the proper selection of raw materials, effective cleaning and sanitizing, and adequate storage.

To date, some reports are available on the microbiological quality of fresh minimally processed vegetables prepared by catering (Sospedra et al., 2013), retail (Abadias, Usall, Anguera, Solsona, & Viñas, 2008), or production (Lehto, Kuisma, Määttä, Kymäläinen, & Mäki, 2011; Martini-Rodrigues & Salay, 2012) facilities, but, to our knowledge, only a few of them were also aimed at implementing preventive/corrective procedures following HACCP principles. In our study the functioning of the HACCP system at a university canteen was verified with respect to the preparation and serving of mixed fresh-cut salads; to that end, microbiological analyses and monitoring of the maintenance temperature were periodically carried out on salad samples between 2003 and 2011 and preventive and corrective measures were introduced on the basis of the results obtained.

Methods

Description of the Canteen

Our study was carried out in a university canteen, located in the city of Ancona (central Italy) that serves up to 1,200 meals a day. The HACCP system was applied in accordance with the EC Regulation 852/2004 and the HACCP manual was written in accordance with a Caterer Hygiene Manual of Procedures validated by the *Istituto Superiore di Sanità* (www.iss.it/), which is the leading technical and scientific public body in the Italian National Health Service. The flow chart for mixed fresh-cut salad preparation at the university canteen is shown in Figure 1. The varieties of raw vegetables delivered to the reception point may vary, including different types of lettuce, chicory, carrots, tomatoes, and other vegetables, all purchased from reputable and approved wholesalers. On arrival, the raw vegetables are inspected in order to discard those with signs of spoilage or damage; afterwards, they are stored at 5°C–6°C (critical control point [CCP]) in a dedicated cold room equipped with an internal temperature data logger and managed in accordance with the "first-in-first-out" stock rotation. The vegetables entering the preparation procedure are manually sorted, washed for five minutes with cold water in a dedicated washing machine, and manually chopped or shredded. As of 2005 the cut leafy vegetables have been subjected to a further 15-minute washing with 2% (wt/vol) food-grade sodium hypochlorite solution followed by two rinses. After removing the washing water, the different types of vegetables are mixed in varying proportions, stored in a refrigerator (CCP), and served within three hours of preparation. The CCPs are monitored by recording temperature maintenance in both the cold room and the refrigerator.

Temperature Monitoring

Prior to sampling, ready-to-eat salads underwent temperature monitoring using a high precision thermometer. The threshold value for temperature ($T \leq 10°C$) was established on the basis of national legislation (Art. 31 of D.P.R. no. 327 of March 26, 1980, published in the Official Gazette of the Italian Republic no. 193, July 16, 1980).

Sampling

Forty-eight salad preparations were sampled from 2003 to 2011 with a casual frequency and with no prior notice to the university canteen personnel. Sterile instruments (gloves and stainless steel spoons) and sterile bags were used during sampling; samples were quickly stored in a cool box and transferred to the laboratory; then the sterile bags were opened under a laminar flow cabin and samples analyzed (within two hours).

Microbiological Analyses

From 2003 to 2007 the microbiological analyses concerning the search for *Salmonella* spp. and *Listeria monocytogenes* and the counts of total mesophilic aerobes (TMA), coliforms, *E. coli*, *Staphylococcus aureus*, *Bacillus cereus*, and sulfite-reducing clostridia (SRC) were carried out as previously described by Osimani and co-authors (2011). The same methods were also applied in the following years except for the search for *L. monocytogenes* and *Salmonella* spp., which was carried out in accordance with AFNOR BIO 12/11-03/04 and AFNOR BIO 12/16-09/05 standard methods, respectively. When applicable, the acceptability of samples was established on the basis of the microbiological limits set by EC Regulation 2073/2005, namely absence of *Salmonella* spp. and *L. monocytogenes* in 25 g (in the product) and *E. coli* between 100 and 1,000 CFU/g (during processing). For all the other microorganisms, in the absence of legal limits, the following values established by the Italian guidelines for food microbiological quality of cold gastronomy products were set as reference limits: TMA < 5.7 Log CFU/g; coliforms < 3 Log CFU/g; *E. coli* < 1 Log CFU/g; *S. aureus* < 2 Log CFU/g; *B. cereus* < 2 Log CFU/g; and SRC < 1 Log CFU/g.

Results and Discussion

Microbiological Analyses

As established by EC Regulation 2073/2005 for ready-to-eat vegetables, *Salmonella* spp. and *L. monocytogenes* were never detected in 25 g of samples. These two human pathogens contaminate in-field vegetables through many different sources (such as feces of birds and animals, fertilization with manure or sewage, or irrigation with polluted waters), hence their occurrence in ready-to-eat salads may be due to improper washing/sanitizing procedures (Carrasco, Morales-Rueda, & García-Gimeno, 2012; Nastou et al., 2012). Moreover, cross contamination (with personnel, environment, raw foodstuff) may occur in the final steps of salad preparation (after

TABLE **1**

Samples of Fresh-Cut Salads Exceeding Microbial Reference Limits

Year	# of Samples Exceeding Reference Limits[a]						% Unsatisfactory Samples*
	TMA	C	Ec	Sa	Bc	SRC	
2003	2 (5.8; 5.8)[b]	2 (4.7; 4.8)	0	3 (3.1; 2.2; 2.3)	0	0	50.0 [4 out of 8][b]
2004	3 (6.4; 6.2; 6.0)	2 (3.7; 3.8)	0	0	0	0	83.3 [5 out of 6]
2005	1 (6.5)	0	0	0	0	0	33.3 [1 out of 3]
2006	1 (5.8)	0	0	0	0	0	33.3 [1 out of 3]
2007	3 (5.8; 6.2; 5.8)	4 (5.6; 4.1; 5.2; 3.1)	0	1 (2.4)	0	0	66.7 [4 out of 6]
2008	3 (6.2; 6.8; 5.7)	3 (5.2; 3.8; 5.4)	0	0	2 (3.3; 3.2)	0	100 [6 out of 6]
2009	2 (6.2; 6.0)	3 (3.8; 5.3; 3.8)	0	0	2 (4.1; 2.8)	0	85.7 [6 out of 7]
2010	0	0	0	0	0	0	0 [0 out of 3]
2011	0	1 (4.1)	0	0	2 (3.1; 2.8)	1 (2.1)	66.7 [4 out of 6]
Total unsatisfactory samples	15	15	0	4	6	1	64.6 [31 out of 48]

*Unsatisfactory samples exceeding reference limits for one or more parameters.
[a]TMA = total mesophilic aerobes; C = coliforms; Ec = *E. coli*; Sa = *Staphylococcus aureus*; Bc = *Bacillus cereus*; SRC = sulphite-reducing clostridia.
[b]Parentheses = the values of viable counts expressed as Log CFU/g. Square brackets = the number of unsatisfactory samples out of the total number of samples analyzed.

washing and sanitizing) if good manufacturing practices are not carefully followed (Sapers, 2009). The finding that all the mixed fresh-cut salads analyzed met the EC food safety criteria was of utmost importance in order to prove that the HACCP system implemented at the canteen and its application were able to guarantee the absence of immediate risks for the customers' health. Much broader microbiological analyses were needed, however, to check the proper working of an HACCP system; the results of such analyses are shown in Table 1.

In general, TMA viable counts exceeded the limits suggested by national guidelines in 38.5% of the samples examined from 2003 to 2009, whereas unacceptable samples were never found in the last two years of this survey. It is worth mentioning, however, that only in one sample (2008) did the value found exceed the reference threshold by more than 1 Log, whereas in most samples the differences detected were ≤ 0.3 Log. Furthermore, it is well acknowledged that the occurrence of excess loads of TMA is not indicative of an effective health risk, although it could be used as a broad indicator of the poor microbiological quality of ready-to-eat salads (Aycicek, Oguz, & Karci, 2006).

TABLE **2**

Samples of Fresh-Cut Salads Exceeding Temperature Reference Limits

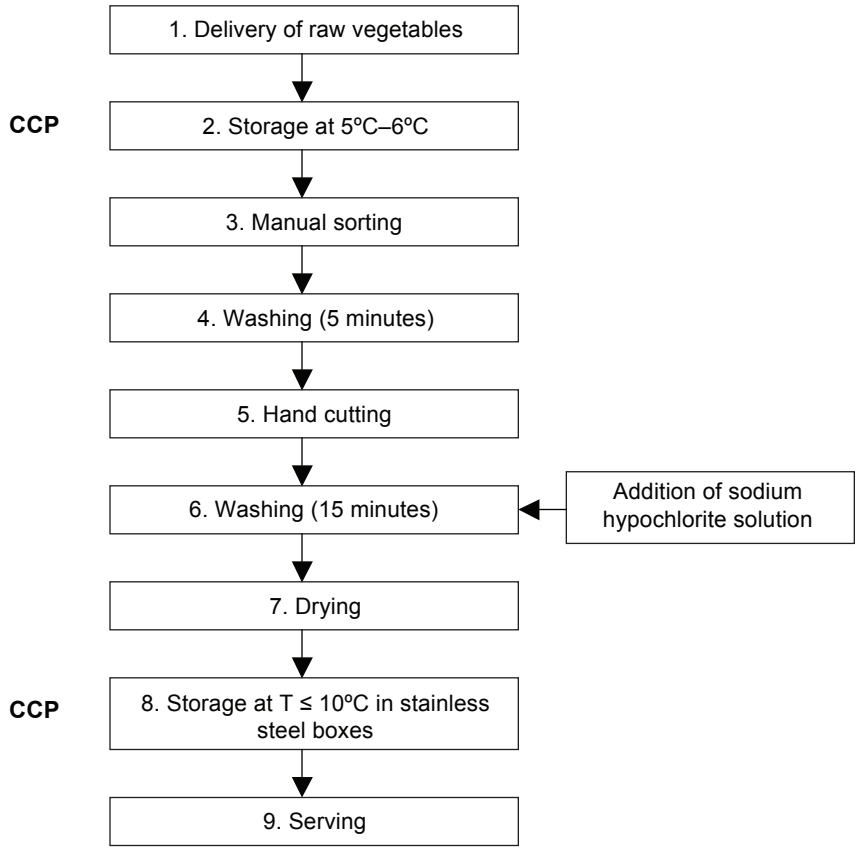
Year	# of Samples Exceeding Reference Limits	% Unsatisfactory Samples
2003	8 (22.4; 23.1; 19.4; 17.2; 16.2; 21.3; 22.0; 23.2)[a]	100 [8 out of 8][a]
2004	6 (24.7; 24,7; 20.0; 21.3; 24.5; 24.6)	100 [6 out of 6]
2005	2 (12.0; 19.1)	66.7 [2 out of 3]
2006	3 (12.0; 15.0; 15.5)	100 [3 out of 3]
2007	3 (17.7; 19.3; 17.7)	50.0 [3 out of 6]
2008	4 (18.0; 19.2; 17.4; 15.5)	66.7 [4 out of 6]
2009	6 (15.8; 11.0; 18.0; 17.2; 22.3; 15.0)	85.7 [6 out of 7]
2010	3 (19.6; 15.9; 20.1)	100 [3 out of 3]
2011	4 (13.3; 15.5; 15.1; 14.5)	66.7 [4 out of 6]
Total unsatisfactory samples	39	81.2 [39 out of 48]

Note. Temperature acceptance limits: T ≤ 10°C. The acceptability of food samples was established on the basis of D.P.R. no. 327 of the 26/03/1980 (Art. 31), published in the Official Gazette of the Italian Republic no. 193 of the 16/07/1980.
[a]Parentheses = temperature values expressed as °C. Square brackets = the number of unsatisfactory samples out of the total number of samples analyzed.

Unfortunately, besides high TMA values, viable counts exceeding the reference limits were also detected quite constantly for coliforms. In this case, the values ranged between 3.1 Log CFU/g and 5.6 Log CFU/g throughout the whole monitoring period, except in 2005, 2006, and 2010 (Table 1; Figure 2). Coliforms make up a group of microorganisms that is also generally accepted as a food hygiene indicator, although only the presence of *E. coli*,

FIGURE **1**

Flow Chart of Mixed Fresh-Cut Salad Preparation at the University Canteen



CCP = critical control point; T = temperature threshold value.

which is capable of growing and producing indole at 44°C ± 1°C can be considered real evidence of fecal contamination. Accordingly, EC Regulation 2073/2005 barely considers this latter microorganism as an indicator of process hygiene in the production of ready-to-eat vegetables and suggests an improvement in hygiene practices and raw material selection only in the case of unobserved criteria. In fact, although most *E. coli* strains are nonpathogenic, food poisoning caused by Shiga-toxin producing strains may have serious clinical consequences, including death. Among these strains, those belonging to the *E. coli* O157:H7 serotype have been recognized as one of the major causes, together with *Salmonella*, of foodborne illness outbreaks linked to fresh leafy vegetables (Warriner et al., 2009). Recently, the large outbreak related to the consumption of sprouts contaminated with the rare mutant of Shiga toxin–producing *E. coli* strain O104:H4 (Wu, Hsueh, & Ko, 2011) confirmed the primary importance of controlling the risk of *E. coli* contamination and growth in minimally processed ready-to-eat vegetables. Once again, it is worth noticing that during the nine years of our survey no presumptive *E. coli* colonies were detected.

The results concerning *S. aureus* (a common inhabitant of human skin and *mucosae*) were quite different from those obtained for coliforms. Samples exceeding the reference limits for this parameter were found only in 4 of the 48 samples analyzed (3 in 2003 and 1 in 2007). Moreover, only one of these samples reached a value of 3.1 Log CFU/g, which exceeded the reference limit by more than 1 Log, although it was still far from the load needed for the production of toxins; in the other three cases differences as low as 0.2–0.4 Log from the reference limit were detected (Table 1).

The two further analyses carried out on the salad samples concern spore-forming bacteria (*B. cereus* and SRC), whose resistant spores largely contaminate soils and vegetable produce. As far as *B. cereus* is concerned, 28.6% to 33.3% of the samples collected in 2008, 2009, and 2011 exceeded the reference limit, with viable counts from 2.8 Log CFU/g to 4.1 Log CFU/g (Table 1; Figure 2). Although most of these values were beyond the reference limit by more than 1 Log, they are always much lower than the threshold of Log 6 CFU/g that has been reported as indicative of *B. cereus* active growth and proliferation in foodstuffs (Schneider, Parish, Goodrich, & Cookingham, 2004). The results emerging from our study, however, confirm the need to go ahead with the survey of fresh-cut salads for the presence of this toxin-forming microorganism.

As suggested by the Scientific Panel on Biological Hazards of *B. cereus* and other *Bacillus* spp. in foodstuffs (European Food Safety Authority, 2009), the major control measures to prevent or slow down the germination and growth of the spores of this emerging foodborne pathogen are proper cleaning and disinfection of equipment as well as a careful control of the maintenance temperature. While several European Union member states have already introduced microbiological criteria concerning *B. cereus* into their national legislation or guidelines, the current European Union Community legislation does not include any specific provisions on *B. cereus* in foodstuffs, although in 2005, the European Food Safety Authority was asked to formulate a risk assessment in order to evaluate the possibility of including microbiological criteria for this foodborne pathogen in European regulations.

Concerning SRC, its detection in the canteen salad samples was clearly sporadic, since it was found only in one sample during the nine years of investigation.

HACCP System Functioning

Several types of preventive/corrective measures were carried out from 2003 to 2011 (Figure 2), as the results of the microbiological analyses became available.

In parallel with the microbiological analyses, the real temperature of the ready-to-eat

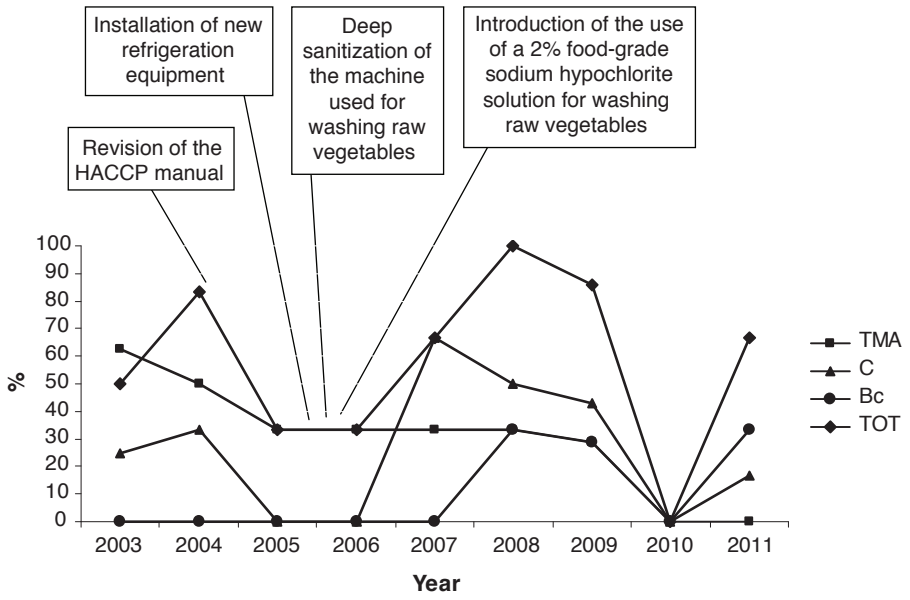
salads was also measured since temperature abuse plays a key role in causing microbial multiplication over acceptable values, and the growth kinetics of microorganisms in foods is strictly dependent on this parameter (Koseki & Itoh, 2001). The number of fresh-cut salad samples exceeding temperature reference limits is shown in Table 2. In general a high number of samples beyond the limits were found throughout the monitoring period. Notably higher temperature values (>20°C) were mostly recorded in the first two years, however, whereas in the following years more than 50% of the samples showed temperatures ranging between 11.0°C and 15.9°C. This improvement in maintenance temperature was due to the replacement in 2005 of the existing self-service line with a new one equipped with a refrigerator expressly designed for cold-served meals (Osimani et al., 2011). This intervention was decided in 2004 when the general revision of the HACCP manual was carried out. At the same time, other improvements in good manufacturing practices were also introduced for the production process of mixed fresh-cut salads (Figure 2). These measures concerned, in particular, the washing of cut green leafy vegetables and consisted in 1) the use of a 2% (wt/vol) food-grade sodium hypochlorite solution for a better control of bacterial contamination (step 6, Figure 1); and 2) deep sanitization of the dedicated washing machine for the reduction of bacterial cross contamination caused by unclean washing nozzles.

Besides the general revision of the HACCP manual, cleaning procedures were constantly examined during the nine years of our survey in order to minimize cross contamination. Moreover, the canteen operators were periodically informed about the results of the inspection activities during training sessions that were held twice a year; each session focused on both general issues concerning food hygiene and specific problems related to the canteen operations.

As can be seen in Table 1, our efforts appeared to determine a quite stable control of *S. aureus* contamination and growth (except for one sample exceeding the reference limits in 2007). This positive result can probably be attributed to improvements either in the personal hygiene of the canteen operators or in the maintenance temperature control. Indeed, it is well known that this toxigenic microorganism is mainly harbored on human skin and *mucosae* and that it does not possess a psychrotrophic attitude. Conversely, the results recorded for TMA, coliforms, and *B. cereus* loads (Table 1; Figure 2) revealed only a temporary improvement starting from the year 2005, but worsening again from 2007 (TMA and coliforms) and 2008 (*B. cereus*). A new improvement was recorded in 2010 and 2011, despite some fluctuations. As these microorganisms are ubiquitous and generally contaminate raw materials, their persistence in the ready-to-eat salads (in the years 2007–2009) was most likely due to improper execution of the washing procedures. Subsequent growth probably occurred given the presence of psychrotrophes among them. On this point, it is worth noticing that from 2007 the personnel working at the canteen gradually decreased from 22 to 17 units due to retirement, equivalent to a reduction of about 23%. In the same years, the remaining operators also had to face an increase in the number of served meals that gradually increased from 1,000 to 1,200. It is therefore probable that in the last years of this investigation the inadequacy of human resources caused malfunctions in the preventive measures necessary to control microbial contamination and growth (even if they were correctly planned in the HACCP manual). In fact this problem emerged during the training meetings with the canteen personnel and was reported to the canteen management, but unfortunately it remained unsolved since the hiring of new personnel is not a simple task in a public body. The continuous recommendations given to the canteen operators during the training sessions to pay more attention to the careful application of the procedures described in the HACCP manual seemed to have led to a reduction in the number of unsatisfactory samples (completely absent in 2010). Nevertheless, this improvement turned out to be only temporary, since the microbiological quality of the salads samples once again worsened in the last year, thus suggesting the necessity of further corrective action.

FIGURE **2**

Percentages of Fresh-Cut Salad Samples Exceeding the Reference Limits Over the Years



The percentages refer to the number of samples exceeding the limits for one single parameter: total mesophilic aerobes (TMA), coliforms (C), and *Bacillus cereus* (Bc), or to the total (TOT) number of unsatisfactory samples (exceeding reference limits for one or more parameters).

The main corrective actions related to the year of application are reported in the boxes.

Conclusion

The HACCP system should not be considered as a system capable in itself of ensuring food safety but rather as a dynamic instrument whose application must be continuously subjected to careful auditing and updating. Accordingly, a considerable effort was put into the periodic inspection of fresh-cut salads and the monitoring of their storage temperature over a period of nine years, and preventive and corrective measures were implemented on the basis of the results obtained. Nonetheless, the results obtained were only in part satisfactory most likely due to the impossibility of maintaining an adequate workforce at the university canteen where the investigation was carried out. It is in fact evident that the durably good functioning of an HACCP system relies on the description of proper operative procedures as well as on the availability of adequate resources (equipment and personnel) to put them into daily practice.

Acknowledgements: The authors wish to thank the Marche Regional Agency, *Ente Regionale per il Diritto allo Studio Universitario,* in Ancona, Italy, for their collaboration in this research.

Corresponding Author: Francesca Clementi, Dipartimento di Scienze Agrarie, Alimentari, ed Ambientali, Università Politecnica delle Marche, Via Brecce Bianche 60131 Ancona, Italy. E-mail: f.clementi@univpm.it.

References

Abadias, M., Usall, J., Anguera, M., Solsona, C., & Viñas, I. (2008). Microbiological quality of fresh, minimally-processed fruit and vegetables and sprouts from retail establishments. *International Journal of Food Microbiology, 123*(1–2), 121–129.

Aycicek, H., Oguz, U., & Karci, K. (2006). Determination of total aerobic and indicator bacteria on some raw eaten vegetables from wholesalers in Ankara, Turkey. *International Journal of Hygiene and Environmental Health, 209*(2), 197–201.

Carrasco, E., Morales-Rueda, A., & García-Gimeno, R.M. (2012). Cross contamination and recontamination by *Salmonella* in foods: A review. *Food Research International*, *45*(2), 545–556.

Clementi, F., Aquilanti, L., & Garofalo, C. (2009). Quality and safety of traditional foods: The role of microbiology. *Italian Journal of Agronomy, 4*(3), 101–118.

Doyle, M.P., & Erickson, M.C. (2008). Summer meeting 2007—the problems with fresh produce: An overview. *Journal of Applied Microbiology, 105*(2), 317–330.

European Food Safety Authority. (2005). Opinion of the scientific panel on biological hazards on *Bacillus cereus* and other *Bacillus* spp. in foodstuffs. (Question No. EFSA-Q-2004-010). *EFSA Journal*, *175,* 1–48.

Koseki, S., & Itoh, K. (2001). Prediction of microbial growth in fresh-cut vegetables treated with acidic electrolyzed water during storage under various temperature conditions. *Journal of Food Protection*, *64*(12), 1935–1942.

Lehto, M., Kuisma, R., Määttä, J., Kymäläinen, H.R., & Mäki, M. (2011). Hygienic level and surface contamination in fresh-cut vegetable production plants. *Food Control*, *22*(3–4), 469–475.

Martinez-Tomè, M., Vera, A.M., & Murcia, M.A. (2000). Improving the control of food production in catering establishments with particular reference to the safety of salads. *Food Control*, *11*(6), 437–445.

Martini-Rodrigues, K.R., & Salay, E. (2012). Food safety control practices in in-house and outsourced foodservices and fresh vegetable suppliers. *Food Control*, *25*(2), 767–772.

Maruzumi, M., Morita, M., Matsuoka, Y., Uekawa, A., Nakamura, T., & Fuji, K. (2005). Mass food poisoning caused by beef offal contaminated by *Escherichia coli* O157. *Japanese Journal of Infectious Diseases*, *58*(6), 397.

Mizoguchi, Y., Suzuki, E., Tsuchida, H., Tsuda, T., Yamamoto, E., Nakase, K., & Doi, H. (2011). Outbreak of *Salmonella* Braenderup infection originating in boxed lunches in Japan in 2008. *Acta Medica Okayama*, *65*(2), 63–69.

Moffatt, C.R., Combs, B.G., Mwanri, L., Holland, R., Delroy, B., Cameron, S., & Givney, R.C. (2006). An outbreak of *Salmonella* Typhimurium phage type 64 gastroenteritis linked to catered luncheons in Adelaide, South Australia, June 2005. *Communicable Diseases Intelligence Quarterly Report*, *30*(4), 443–448.

Nastou, A., Rhoades, J., Smirniotis, P., Makri, I., Kontominas, M., & Likotrafiti, E. (2012). Efficacy of household washing treatments for the control of *Listeria monocytogenes* on salad vegetables. *International Journal of Food Microbiology*, *159*(3), 247–253.

Osimani, A., Aquilanti, L., Tavoletti, S., & Clementi, F. (2013a). Evaluation of the HACCP system in a university canteen: Microbiological monitoring and internal auditing as verification tools. *International Journal of Environmental Research and Public Health*, *10*(4), 1572–1585.

Osimani, A., Aquilanti, L., Tavoletti, S., & Clementi, F. (2013b). Microbiological monitoring of air quality in a university canteen: An 11-year report. *Environmental Monitoring and Assessment*, *185*(6), 4765–4774.

Osimani, A., Babini, V., Aquilanti, L., Tavoletti, S., & Clementi, F. (2011). An eight-year report on the implementation of HACCP in a university canteen: Impact on the microbiological quality of meals. *International Journal of Environmental Health Research, 21*(2), 120–132.

Petruzzelli, A., Blasi, G., Masini, L., Calza, L., Duranti, A., Santarelli, S., Fisichella, S., Pezzotti, G., Aquilanti, L., Osimani, A., & Tonucci, F. (2010). Occurrence of *Listeria monocytogenes* in salami manufactured in the Marche Region (central Italy). *Journal of Veterinary Medical Science, 72*(4), 499–502.

continued on page 84

References

continued from page 83

Petruzzelli, A., Foglini, M., Paolini, F., Framboas, M., Altissimi, M.S., Haouet, N.M., Mangili, P., Osimani, A., Clementi, F., Cenci, T., & Tonucci, F. (2014). Evaluation of the quality of foods for special diets produced in a school catering facility within a HACCP-based approach: A case study. *International Journal of Environmental Health Research, 24*(1), 73–81.

Sapers, G.M. (2009). Disinfection of contaminated produce with conventional washing and sanitizing technology. In G.M. Sapers, E.B. Solomon, & K.R. Matthews (Eds.), *The produce contamination problem* (pp. 393–424).

Schneider, K.R., Parish, M.E., Goodrich, R.M., & Cookingham, T. (2004). *Preventing foodborne illness:* Bacillus cereus *and* Bacillus anthracis. Gainesville: Florida Cooperative Extension Service, University of Florida.

Sospedra, I., Rubert, J., Soriano, J.M., & Mañes, J. (2013). Survey of microbial quality of plant-based foods served in restaurants. *Food Control*, *30*(2), 418–422.

Warriner, K., Huber, A., Namvar, A., Fan, W., & Dunfield, K. (2009). Recent advances in the microbial safety of fresh fruits and vegetables. *Advances in Food and Nutrition Research*, *57*, 155–208.

Wu, C.J., Hsueh, P.R., & Ko, W.C. (2011). A new health threat in Europe: Shiga toxin-producing *Escherichia coli* O104:H4 infections. *Journal of Microbiology, Immunology and Infection*, *44*(5), 390–393.

Students Don't Miss This Opportunity!

Applications for the 2015 National Environmental Health Association/American Academy of Sanitarians (NEHA/AAS) Scholarship Program are now available. Last year, $4,000 was awarded to two students who demonstrated the highest levels of achievement in their respective environmental public health degree programs. If you would like an application or information about the NEHA/AAS Scholarship, do one of the following before the deadline:

Visit

www.neha.org/scholarship/scholarship.html.

Application and qualification information is available to download from NEHA's scholarship Web page.

Contact

Cindy Dimmitt
with a request for
an application and information.
E-mail: cdimmitt@neha.org
Phone: 303.756.9090, ext. 300
Write: NEHA/AAS Scholarship
720 S. Colorado Blvd.,
Ste.1000-N
Denver, CO 80246-1926

Deadline: February 1, 2015

INTERNATIONAL PERSPECTIVES

Prepublished online December 2014,
National Environmental Health Association.

Geostatistical Analysis of the Relationship Between Heavy Metals in Drinking Water and Cancer Incidence in Residential Areas in the Black Sea Region of Turkey

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 25 countries worldwide, are addressed. Our goal is to raise diverse issues of interest to all our readers, irrespective of origin.*

Ebru Husniye Colak
Faculty of Engineering
Karadeniz Technical University

Tahsin Yomralioglu
Faculty of Civil Engineering
Istanbul Technical University

Recep Nisanci
Volkan Yildirim
Faculty of Engineering
Karadeniz Technical University

Celal Duran
Faculty of Science
Karadeniz Technical University

Abstract **In the study described in this article, the authors examined the relationship between heavy metals in the drinking water and cancer densities in residential areas. The Turkish cities of Trabzon, Rize, and Giresun in the eastern Black Sea region were chosen as the study areas. Cancer registry data, population information, heavy metal chemical analysis results for drinking water, and other spatial information for the region were collected in a database designed in GIS. Information on a total of 13,012 registered cancer cases from the years 2000–2007 was obtained from a cancer record center and depicted spatially on a map. The incidence values explaining cancer density in residential units were calculated. Chemical analyses were then conducted to determine the presence of 17 different heavy metals by collecting a total of 541 drinking water samples. It was determined that among the 17 analyzed heavy metals, beryllium, nickel, antimony, and molybdenum had a significant relationship with cancer incidence values in the residential units.**

Introduction

Cancer is a significant community health care problem worldwide, and it is the second most common cause of death. Problems concerning recording cancer cases exist across Turkey. Cancer registry centers were established, however, to record the cases regionally. As a result, cancer incidence values have now been calculated across Turkey. Cancer incidence is the number of new cases arising in a given period in a specified population. The cancer incidence rate in Turkey for 2005 was 173.85 per 100,000 (Yilmaz et al., 2010). In European Union countries, the cancer incidence rate is 236.7 per 100,000 (GLOBACAN, 2008).

Cancer emerges gradually depending upon a variety of factors. Genetic features play a role in some types of cancer, while environmental factors such as people's lifestyle, eating habits, and exposure to chemicals play a role in most types of cancer (Boyle & Levin, 2008). Today, hundreds of chemicals that can lead to cancer have been identified. According to World Health Organization (WHO) data, environmental factors are responsible for more than 70% of cancer cases. A list of carcinogens published by the International Agency for Research on Cancer (IARC) includes 783 items. A small number of metals or metalloids was classified as carcinogenic by IARC/WHO, e.g., chromium, arsenic, nickel, cadmium, beryllium, lead, cobalt, mercury, and compounds (Dissanayake & Changrajith, 1999; International Agency for Research on Cancer [IARC], 2012). For example, the studies of people with high levels of arsenic in their drinking water have found higher

FIGURE **1**

Study Area Map

risks of cancers of the bladder, kidney, lung, skin, and, less consistently, colon and liver (American Cancer Society, 2013). Cadmium is known to cause lung, prostate, and kidney cancer and aluminum is associated with lung and bladder cancer (IARC, 2012).

It is necessary to consider the environmental factors and genetic predispositions together when conducting studies that investigate the causes of cancer. As genetic studies are resource and labor intensive, not many studies have been done in which cancer and its genetic features have been investigated. Most of the studies have been concerned with the environmental factors leading to cancer. In Turkey, epidemiological studies in different regions have been conducted on cancers that are a consequence of environmental impacts (Baris et al., 1987; Emri et al., 2002; Kadir et al., 2008; Taskin, Karavus, Topuzoglu, Hidiroglu, & Karahan, 2009; Tokmak, Capar, Dilek, & Yetis, 2004; Turkdogan, Kilicel, Kara, Tuncer, & Uygan, 2003).

The environmental factors causing cancer have been investigated in many scientific studies. In particular, the relationship between heavy metals and cancer risk has been investigated in a number of epidemiological small-area studies (Chhabra et al., 2012; Hinwood, Jolley, & Sim, 1999; Karagas et al., 1998; Kuo, Wong, Lin, Lai, & Lee, 2006; Lang et al., 2009; Linos et al., 2011; Liu, Ni, & Xia, 2011; Matthew, 1992; McElroy, Shafer, Trentham-Dietz, Hampton, & Newcomb, 2006; Wongsasuluk, Chotpantarat, Siriwong, & Robson, 2014; Yenugadhati, Birkett, Momoli, & Krewski, 2009; You, Harvey, & Harvey, 2003). Georeferenced health and environmental data are often used in conjunction with GIS to conduct spatial epidemiology (Bailony et al., 2011; Katayama, 2012). In many public health and epidemiology studies, GIS has emerged as an innovative component (Blanco & Cooper, 2004; Brewer, 2006; Cromley & McLafferty, 2002; Elliott, Wakefield, Best, & Briggs, 2000). GIS technology has already become a powerful tool for the epidemiologic investigation of the effects of environmental factors on diseases (Birmingham & McLaughlin, 2006; Colak, 2010; Craig et al., 2008; Jerrett et al., 2003; Poulstrup & Hansen, 2004; Yeganeh et al., 2013; Yomralioglu, Colak, & Aydinoglu, 2009). Health events that are spatially referenced allow the exploration of the causes of these events. Therefore, GIS technology is important for such investigations because it allows both spatial and statistical analyses to be performed. The data, methodology, spatial queries, and statistical analysis change depending on the features of the investigated hypothesis. Modeling the relationship between disease rates and other spatially referenced data requires spatial regression or generalized linear models for statistical analysis.

In our study, data including health, environment, chemistry, geography, and statistical parameters were investigated using an integrated approach. Our study was based on the TUBITAK project (Yomralioglu, 2008) and was aimed at investigating the relationship between cancer density in residential areas and heavy metals in drinking water. All data that have been used to conduct our study were collected in a geodatabase using GIS. Based upon cancer data with spot features and population size in residential areas, a cancer incidence map was created to determine cancer density in residential areas. Moreover, samples obtained from drinking water from the residential areas were used for chemical analyses to determine the presence of 17 heavy metals that are known to be carcinogenic. A linear regression statistical analysis was carried out to investigate the relationship between cancer incidence and the presence of 17 heavy metals in the drinking water of the studied regions. The influence of the heavy metals on incidence was also examined.

Methods

Overview of the Study Area

Turkey has a total area of 785,562 km^2 and comprises seven geographical regions. According to an address-based population registration system in 2011, Turkey has a population of 74,724,269 people (Turkish Statistical Institute [TurkStat], 2012). The study area was composed of three cities in the eastern Black Sea region in Turkey. These cities are Giresun, Trabzon, and Rize (Figure 1).

Trabzon is a central city located in the eastern Black Sea region. The population of Trabzon in 2011 was 757,353. The population of Rize in 2011 was 323,012, and the population of Giresun was 419,498 (TurkStat, 2012). Trabzon, Rize, and Giresun cover areas of 4,685 km^2, 3,920 km^2, and 6,934 km^2, respectively.

Cancer Data

Statistical cancer data belonging to the study area were obtained from a Trabzon population-based cancer registration center. This center records the information of cancer patients who were diagnosed in the cities of the Black Sea region in Turkey in accordance with ICD-100 disease registry standards. In this study, during the years 2000–2007, 13,012 cancer cases were registered in the three cities within the study area. First, the cancer case registry obtained from the cancer registry center was added to a map based on the address information of the patients. Furthermore, the cancer incidence values in a total of 1,526 residential units were calculated by using population information from the Turkish Statistical Institute from between these dates. The residential units were evaluated on the basis of village/district for small area studies. The cancer incidence values calculated for the residential units were calculated by standardizing against a population size of 100,000. GIS were used to provide cancer incidence values based on geography. The cancer incidence values in the residential units were added to a specially designed geodatabase and were mapped with ArcGIS 10 software using the Kriging geostatistics technique. Geostatistics is often used for spatial prediction modeling of the spatial variability of cancer. In particular, Kriging produces output surfaces from point-based cancer data, including predictions, prediction standard errors, probabilities, and quartiles (Buzzelli & Jerrett, 2003; ESRI, 2001; Figueira, Sérgio, Lopes, & Sousa, 2007; Sloan et al., 2012). On the map created by the GIS, it is possible to see the range of the cancer incidence value densities (Figure 2).

FIGURE **2**

Cancer Incidence Map Created Using the Ordinary Kriging Technique

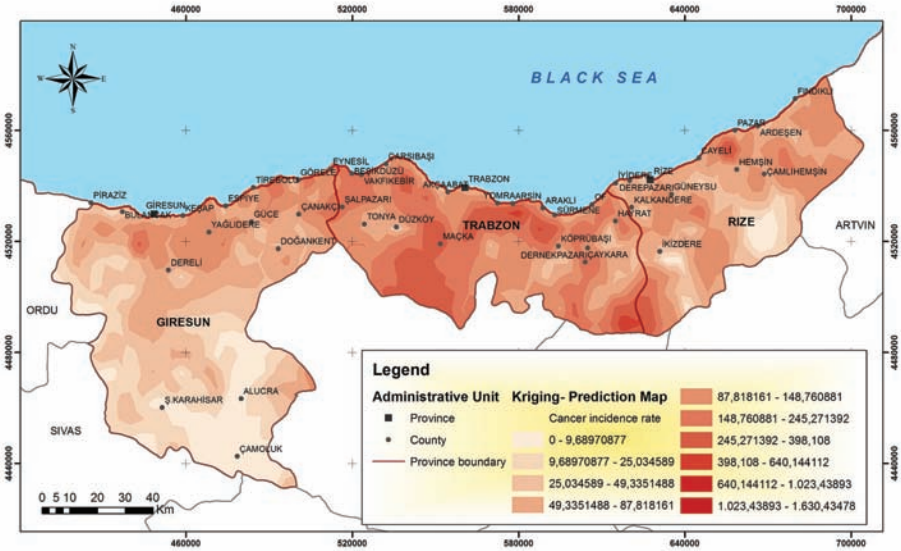
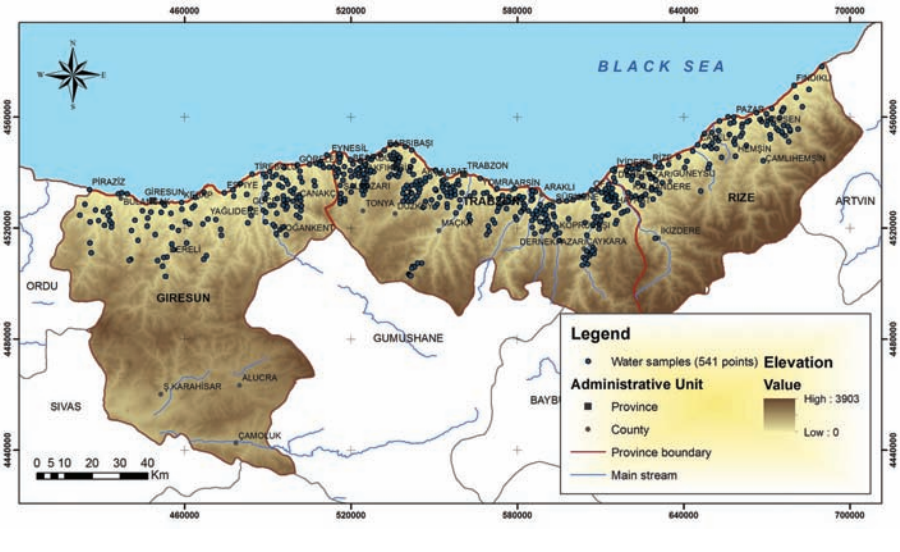


FIGURE **3**

Map Showing the Distribution of the Water Sampling Points



Collection and Chemical Analysis of Water Samples

A water values map was created for the study area by putting water samples that were provided by the water supply networks and taken from different sources in the study area for chemical analysis. In our study, to determine the carcinogenic elements that might exist in the water samples in the area, preliminary studies were carried out to establish the presence and concentration of the carcinogenic elements arsenic, beryllium, cadmium, cobalt, chromium, mercury, nickel, lead, selenium, vanadium, antimony, barium, strontium, copper, bismuth, molybdenum, and aluminum.

For this purpose, stations where samples were to be collected were designated. Overall, 541 water samples were collected in the area at a 95% confidence interval. The map in Figure 3 shows the stations where water samples were taken. The number of samples and stations for collection in all areas and residential units were determined. Determining the stations where samples would be taken also benefited the cancer incidence map. The points where water samples were taken were designated on the map of the study area (Figure 3).

Water samples were taken from mostly drinking water supplies. The water samples

TABLE **1**

Number of Samples of Chemical Analysis That Were Higher Than World Health Organization (WHO) Recommended Limits

Heavy Metal Elements	WHO Recommended Limits	# of Samples Above the Limit
Beryllium, bismuth	No guideline	–
Mercury, antimony, molybdenum	6 µg/L, 20 µg/L, 0.07 µg/L	under WHO limits
Chromium, barium, copper	50 µg/L, 700 µg/L, 2000 µg/L	under WHO limits
Cadmium	1 µg/L	5
Arsenic	10 µg/L	103
Lead	10 µg/L	290
Selenium	10 µg/L	306
Aluminum	200 µg/L	21
Nickel	70 µg/L	5
Strontium	10 µg/L	8
Cobalt	10 µg/L	1

were collected in accordance with standards of TS ISO 5667-6 and TS ISO 5667-14. The station coordinates of the samples were recorded with the aid of mobile GPS. The samples were filtered through a 0.45-µm cellulose nitrate porous filter and were also soured by nitric acid and kept in sea-cap polyethylene covers. Ultra-pure chemicals (Trace SELECT) and ultra-pure water (bidistilled, deionized) were used.

The analysis of the collected water samples was conducted using a Spectro GENESIS model horizontal plasma inductively coupled plasma-atomic emission spectrometer. Chemical analyses to determine the presence of the 17 heavy metals identified above were conducted. The results of these heavy metal chemical analyses were added to the GIS database. International water quality standards, as defined by WHO, were used when evaluating the analysis results.

GIS-Based Mapping Chemical Analyses

A spatial database in GIS was designed to map the results of the chemical analyses. After the analyses of the water samples were conducted, the results were added to a database and associated with points that were represented spatially on the map and were also integrated with a cancer-based geographical database. Thus, the heavy metals presence and concentration in the water sources were associated with the map data. GIS-based mapping chemical analysis used ArcGIS 10 software extensions such as ArcGIS spatial analyst and ArcGIS geostatistical analyst. ArcGIS spatial analyst provides a wide range of powerful analysis tools and queries. ArcGIS geostatistical analyst allows you to create a statistically valid prediction surface, along with prediction uncertainties, from a limited number of data measurements. With the aid of spatial analyses and an investigation conducted in GIS, the drinking water heavy metal analysis results for the residential units and the cancer incidence values were arranged in a table for statistical analysis. By using spatial analyses and statistical mapping, maps were created based on the heavy metal analyses. Especially the Kriging method was used for statistical mapping in ArcGIS geostatistical analyst.

Statistical Analysis

The potential relationship between heavy metals in the drinking water of residential units and cancer incidence was examined using a statistical analysis. To test the hypothesis, "Do heavy metals in water samples collected in residential units have an impact on cancer incidence values in residential units?", a linear regression analysis was conducted. A regression analysis is a method to investigate the impact of one or multiple independent variables on a dependent variable. This statistical analysis technique is also used in studies that investigate the impact of environmental factors on health (Hinwood et al., 1999; Lang et al., 2009; Sloan et al., 2012; Yenugadhati et al., 2009).

The regression analysis revealed to what extent heavy metals in the drinking water explained the observed cancer incidence values in residential units. In conducting this analysis, the analysis values associated with the presence in water samples of the 17 tested heavy metals were considered independent variables, while the cancer incidence calculated for the residential units was considered the dependent variable.

The data obtained with the spatial queries and analysis in ArcGIS also evaluated statistical software. A linear regression analysis of the data was conducted using the SPSS v. 10 statistical package. The square roots of the cancer incidence values were used in the analysis to reduce the effect of extreme values (SPSS, 2004). The values of beta (normalized coefficient) and p (significance) for each factor, and the adjusted R^2, F (F-test statistic) and p were given for the model was examined in the table of the results of the analysis (Grand & Garland, 2006).

Results

Chemical Analysis Results

The results of chemical analysis for the water samples in the study area were evaluated based on WHO international standards. In the study area, 541 drinking water samples were collected, and chemical analyses were carried out to evaluate the presence of 17 heavy metals. Drinking water samples were size based on a 95% confidence level with a margin of error of ±10%. The evaluation for each metal was conducted separately after entry into the geographical database.

The investigations of mercury, antimony, and molybdenum indicated levels under the quantification limit of 6 µg/L, 20 µg/L, and 0.07 µg/L, respectively, and no WHO guideline for beryllium and bismuth is available. Cadmium was detected at five stations at a level higher than the values recommended by WHO (1 µg/L). It was determined that new and detailed studies are necessary to gather more water samples in these areas. The values of chromium, barium, and copper were found to be under the WHO recommended limits, which are 50 µg/L, 700 µg/L, and 2,000 µg/L, respectively.

When examining the arsenic data from 103 stations, arsenic levels were discovered to be higher than the WHO recommended limit

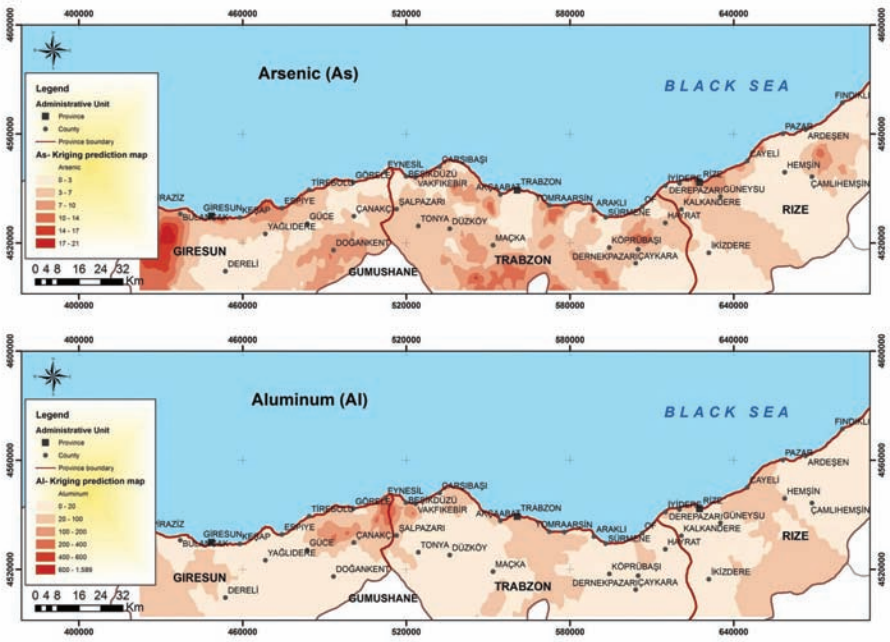
(10 µg/L), but the levels were in accordance with TS 266 recommended limits (50 µg/L). Lead levels were higher than the WHO recommended limit (10 µg/L) in samples from 290 stations and were higher than the TS 266 recommended limits (50 µg/L) at 23 stations. Selenium values were higher than the WHO recommended limit (10 µg/L) in samples from 306 stations. In samples from 46 out of 306 stations, however, the selenium values were discovered to be higher than the limit of quantification (60 µg/L). Aluminum values were higher than the WHO recommended limit (200 µg/L) in samples from 21 stations.

Nickel values were higher than the WHO recommended limit (70 µg/L) in samples from five stations. Strontium values were found to be higher than the limit of quantification (10 µg/L) in samples from eight stations. Cobalt values were found to exceed WHO recommend limits (10 µg/L) in samples from one station. The number of samples of chemical analysis that were higher than the WHO recommended limits are shown in Table 1.

Seventeen heavy metals were examined via chemical analyses conducted on 541 water samples from the study areas, and it was determined that eight chemical elements (cadmium, arsenic, lead, nickel, selenium, strontium, cobalt, and aluminum) were present at levels higher than the recommended human health and safety–related WHO limits. The Kriging prediction maps of arsenic, lead, aluminum, and selenium values of drinking water using geostatistical analyst of GIS are presented in Figures 4 and 5.

FIGURE **4**

The Prediction Map of Arsenic and Aluminum Values of Drinking Water by Ordinary Kriging Techniques



Statistical Analysis

A statistical evaluation of the relationship between the chemical analysis and the cancer densities in the residential units was conducted via linear regression. In this analysis, the dependent variable was residential unit cancer incidence, and 17 independent variables represented the 17 different heavy metals in the water samples.

Linear regression analyses were performed (at the 95% confidence level). The 17 heavy metal variables were significantly associated with cancer incidence. Cancer incidence values in the residential units were associated with beryllium, nickel, antimony, and molybdenum ($RR = 2.798$). The level of significance was set at $p < .01$. The linear regression had a regression ratio of $R = 0.287$ and $R^2 = 8.2\%$. The effect of the 17 independent variables over the model is 8.2%.

The regression equation is as follows:

Incidence = 252,214 – 31,690*Be – 0,850*Ni + 15,770*Sb – 16,286*Mo

According to this analysis, the elements beryllium (Be), nickel (Ni), antimony (Sb), and molybdenum (Mo) have an effect on incidence. A negative relationship exists between beryllium, nickel, and molybdenum and cancer incidence and a positive relationship exists between antimony and cancer incidence ($p < .01$).

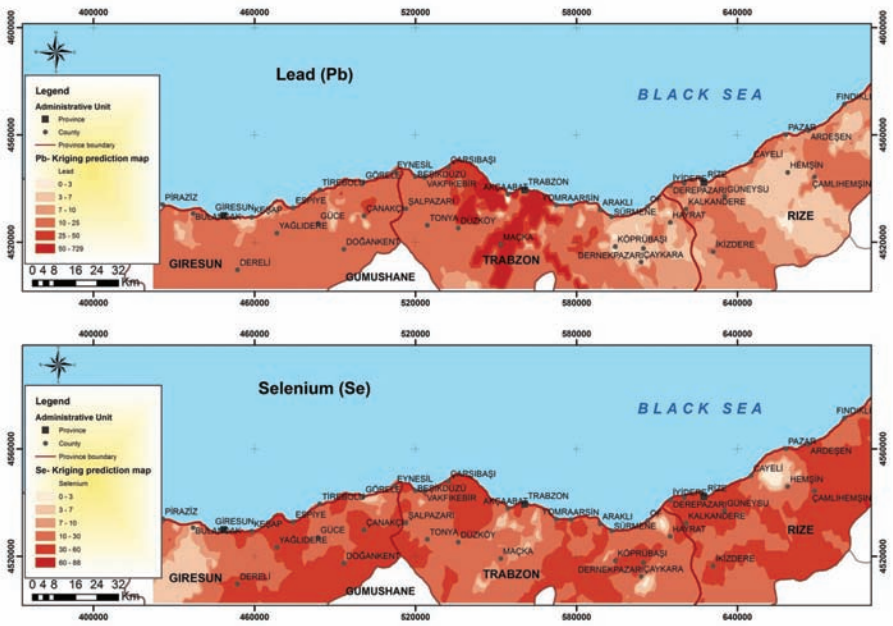
Discussion

Studies on the effect of heavy metals on cancer are available. An examination of existing studies, however, indicates that the studies primarily examine the relationship of one or more heavy metals and their influence on a particular type of cancer. Our study utilized both GIS and geostatistical analyses to assess cancer incidence and the influence of environmental factors. Furthermore, ours is also a general study in which densities of all types of cancer in residential units were evaluated rather than the densities of particular types of cancer. The residential units were evaluated in terms of village/districts for the small-area study, which included populations from three cities. That is, the cancer incidence ratios were calculated on village/district scale.

Seventeen different heavy metals were examined in 541 water samples. The relationship of these metals with cancer densities in the residential units was examined statistically. The statistical analyses were performed at the 95% confidence level. The results of the statistical analysis indicate the drinking water values of the 17 heavy metals explain an 8.2% incidence change in the residential units. The reason why this percentage is so low is that many environmental factors lead to cancer. In addition, genetic factors were ignored for our study. A negative relationship existed between beryllium, nickel, and molybdenum and cancer incidence and a positive relationship existed between antimony and cancer incidence ($p < .01$). Considering the chemical analysis results in the context of the recommended WHO limits, beryllium, molybdenum, and antimony were under the limit in the samples from all

FIGURE **5**

The Prediction Map of Lead and Selenium Values of Drinking Water by Ordinary Kriging Techniques



stations, and nickel was over the recommended limit in samples from only five stations.

Conclusion

The results of our study are products of a general study conducted on a fairly broad scale. It would be quite difficult to conduct a study that investigated the relationship between all of the cancer types and heavy metals. In our study, multiple types of cancer and multiple heavy metals have not been addressed. These results can serve as a useful guide in the future for more locally directed studies and for studies focused on specific types of cancer. Our study is distinctive in that the chemical analyses and cancer data were evaluated via both spatial and statistical analyses.

Acknowledgements: The authors gratefully acknowledge the financial support of the Scientific and Technical Research Council of Turkey (TUBITAK) under project ID 105Y308.

Corresponding Author: Ebru Husniye Colak, Assistant Professor, Karadeniz Technical University, Faculty of Engineering, Geomatics Engineering, GISLab, 61080, Trabzon, Turkey. E-mail: ecolak@ktu.edu.tr.

References

American Cancer Society. (2013). *What causes cancer?* Retrieved from http://www.cancer.org/cancer/cancercauses

Bailony, M.R., Hararah, M.K., Salhab, A.R., Ghannam, I., Abdeen, Z., & Ghannam, J. (2011). Cancer registration and healthcare access in West Bank, Palestine: A GIS analysis of childhood cancer, 1998–2007. *International Journal of Cancer, 129*(5), 1180–1189.

Baris, I., Artvinli, M., Saracci, R., Simonato, L., Pooley, F., Skidmore, J., & Wagner, C. (1987). Epidemiological and environmental evidence of the health effects of exposure to erionite fibres: A four-year study in the Cappadocian region of Turkey. *International Journal of Cancer, 39*(1), 10–17.

Birmingham, B., & McLaughlin, D. (2006). Soil investigation and human health risk assessment for nickel in community soils near a former nickel refinery in southern Ontario, Canada. *Journal of Toxicology and Environmental Health, Part A, 69*(9), 845–892.

Blanco, G.A., & Cooper, E.L. (2004). Immune systems, geographic information systems (GIS), environment, and health impacts. *Journal of Toxicology and Environmental Health, Part B: Critical Reviews, 7*(6), 465–480.

Boyle, P., & Levin, B. (Eds.). (2008). *World cancer report 2008*. Lyon, France: International Agency for Research on Cancer, World Health Organization.

Brewer, C.A. (2006). Basic mapping principles for visualizing cancer data using Geographic Information Systems (GIS). *American Journal of Preventive Medicine, 30*(2 Suppl.), 25–36.

Buzzelli, M., & Jerrett, M. (2003). Comparing proximity measures of exposure to geostatistical estimates in environmental justice research. *Environmental Hazards, 5*(1–2), 13–21.

Chhabra, D., Oda, K., Jagannath, P., Utsunomiya, H., Takekoshi, S., & Nimura, Y. (2012). Chronic heavy metal exposure and gallbladder cancer risk in India, a comparative study with Japan. *Asian Pacific Journal of Cancer Prevention, 13*(1), 187–190.

Colak, H.E. (2010). *Spatial analysis of cancer cases by geographic information systems in the eastern Black Sea region of Turkey*. Unpublished doctoral dissertation, Karadeniz Technical University (in Turkish).

Craig, L., Brook, J.R., Chiotti, Q., Croes, B., Gower, S., Hedley, A., Krewski, D., Krupnick, A., Krzyzanowski, M., Moran, M.D., Pennell, W., Samet, J.M., Schneider, J., Shortreed, J., & Williams, M. (2008). Air pollution and public health: A guidance document for risk managers. *Journal of Toxicology and Environmental Health, Part A, 71*(9–10), 588–698.

continued on page 92

References *continued from page 91*

Cromley, E., & McLafferty, S.L. (2002). *GIS and public health*. New York: The Guilford Press.

Dissanayake, C.B., & Changrajith, R. (1999). Medical geochemistry of tropical environments. *Earth Science Reviews, 47*(3–4), 219–258.

Elliott, P., Wakefield, J.C., Best, N.G., & Briggs, D.J. (2000). *Spatial epidemiology: Methods and applications*. Oxford, UK: Oxford University Press.

Emri, S., Demir, A., Dogan, M., Akay, H., Bozkurt, B., Carbone, M., & Baris, I. (2002). Lung diseases due to environmental exposures to erionite and asbestos in Turkey. *Toxicology Letters, 127*(1–3), 251–257.

ESRI. (2001). *ArcGIS geostatistical analyst: Statistical tools for data exploration, modeling, and advanced surface generation*. Redlands, CA: Author.

Figueira, R., Sérgio, C., Lopes, J.L., & Sousa, A.J. (2007). Detection of exposition risk to arsenic in Portugal assessed by air deposition in biomonitors and water contamination. *International Journal of Hygiene and Environmental Health, 210*(3–4), 393–397.

GLOBACAN. (2008). *GLOBACAN 2008 online database, cancer incidence, mortality, and prevalence worldwide in 2008*. Lyon, France: International Agency for Research on Cancer, World Health Organization. Retrieved from http://globocan.iarc.fr/

Grand, W.B., & Garland, C.F. (2006). The association of solar ultraviolet B (UVB) with reducing risk of cancer: Multifactorial ecologic analysis of geographic variation in age-adjusted cancer mortality rates. *Anticancer Research, 26*(4A), 2687–2700.

Hinwood, A.L., Jolley, D.J., & Sim, M.R. (1999). Cancer incidence and high environmental arsenic concentrations in rural populations: Results of an ecological study. *International Journal of Environmental Health Research, 9*(2), 131–141.

International Agency for Research on Cancer. (2012). *IARC monographs on the evaluation of carcinogenic risks to humans, agents classified by the IARC monographs*. Retrieved from http://monographs.iarc.fr/ENG/Classification/index.php

Jerrett, M., Burnett, R., Goldberg, M., Sears, M., Krewski, D., Catalan, R., Kanaroglou, P., Giovis, C., & Finkelstein, N. (2003). Spatial analysis for environmental health research: Concepts, methods, and examples. *Journal of Toxicology and Environmental Health, Part A: Current Issues, 66*(16–19), 1783–1810.

Kadir, S., Piril, Ö.A., Aydin, N.S., Yakicier, C., Akarsu, N., & Tuncer, M. (2008). Environmental effect and genetic influence: A regional cancer predisposition survey in the Zonguldak region of northwest Turkey. *Environmental Geology, 54*(2), 391–409.

Karagas, M.R., Tosteson, T.D., Blum, J., Morris, J.S., Baron, J.A., & Klaue, B. (1998). Design of an epidemiologic study of drinking water arsenic exposure and skin and bladder cancer risk in a U.S. population. *Environmental Health Perspectives, 106*(Suppl. 4), 1047–1050.

Katayama, K. (2012). Consideration of regional clustering of breast cancer in Kanagawa prefecture: Application of cancer registries data using by GIS. *Japanese Journal of Hygiene, 67*(2), 1–105.

Kuo, C., Wong, R., Lin, J., Lai, J., & Lee, H. (2006). Accumulation of chromium and nickel metals in lung tumors from lung cancer patients in Taiwan. *Journal of Toxicology and Environmental Health, Part A: Current Issues, 69*(14), 1337–1344.

Lang, I.A., Scarlett, A., Guralnik, J.M., Depledge, M.H., Melzer, D., & Galloway, T.S. (2009). Age-related impairments of mobility associated with cobalt and other heavy metals: Data from NHANES 1999–2004. *Journal of Toxicology and Environmental Health, Part A, 72*(6), 402–409.

Linos, A., Petralias, A., Christophi, C.A., Christoforidou, E., Kouroutou, P., Stoltidis, M., Veloudaki, A., Tzala, E., Makris, K.C., & Karagas, M.R. (2011). Oral ingestion of hexavalent chromium through drinking water and cancer mortality in an industrial area of Greece—an ecological study. *Environmental Health, 10,* 50.

Liu, N., Ni, T., & Xia, J. (2011). Noncarcinogenic risks induced by metals in drinking source water of Jiangsu Province, China. *Environmental Monitoring and Assessment, 177*(1–4), 449–456.

Matthew, G.K. (1992). Health and the environment: The significance of chemicals and radiation. In P. Elliott, J. Cuzick, D. English, & R. Stern (Eds.), *Geographical and environmental epidemiology: Methods for small-area studies* (pp. 23–33). Oxford, UK: Oxford University Press.

McElroy, J.A., Shafer, M.M., Trentham-Dietz, A., Hampton, J.M., & Newcomb, P.A. (2006). Cadmium exposure and breast cancer risk. *Journal of the National Cancer Institute, 98*(12), 869–873.

Poulstrup, A., & Hansen, H.L. (2004). Use of GIS and exposure modeling as tools in a study of cancer incidence in a population exposed to airborne dioxin. *Environmental Health Perspectives, 112*(9), 1032–1036.

Sloan, C.D., Andrew, A.S., Gruber J.F., Mwenda, K.M., Moore, J.H., Onega, T., Karagas, M.R., Shi, X., & Duell, E.J. (2012). Indoor and outdoor air pollution and lung cancer in New Hampshire and Vermont. *Toxicological and Environmental Chemistry, 94*(3), 605–615.

SPSS. (2004). *SPSS 13.0 brief guide*. Chicago: Author.

Taskin, H., Karavus, M., Topuzoglu, A., Hidiroglu, S., & Karahan, G. (2009). Radionuclide concentrations in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli, Turkey. *Journal of Environmental Radioactivity, 100*(1), 49–53.

Tokmak, B., Capar, G., Dilek, F.B., & Yetis, U. (2004). Trihalomethanes and associated potential cancer risks in the water supply in Ankara, Turkey. *Environmental Research, 96*(3), 345–352.

Turkdogan, M.K., Kilicel, F., Kara, K., Tuncer, I., & Uygan, I. (2003). Heavy metals in soil, vegetables, and fruits in the endemic upper gastrointestinal cancer region of Turkey. *Environmental Toxicology and Pharmacology, 13*(3), 175–179.

Turkish Statistical Institute (2012). *Address based population registration system (ABPRS): Population census Results 2010*. Retrieved from http://www.turkstat.gov.tr/PreHaberBultenleri.do?id=13425

Wongsasuluk, P., Chotpantarat, S., Siriwong, W., & Robson, M. (2014). Heavy metal contamination and human health risk

References

assessment in drinking water from shallow groundwater wells in an agricultural area in Ubon Ratchathani province, Thailand. *Environmental Geochemistry and Health*, *36*(1), 169–182.

Yeganeh, M., Afyuni, M., Khoshgoftarmanesh, A., Khodakarami, L., Amini, M., Sofftanian, A., & Schulin, R. (2013). Mapping of human health risks arising from soil nickel and mercury contamination. *Journal of Hazardous Materials, 244–245*, 225–239.

Yenugadhati, N., Birkett, N.J., Momoli, F., & Krewski, D. (2009). Industries and lung cancer: A population-based case-control study in British Columbia. *Toxicological and Environmental Chemistry, 91*(3), 451–484.

Yilmaz, H.H., Yazihan, N., Tunca, D., Sevinc, A., Olcayto, E.Ö., Ozgul, N., & Tuncer, M. (2010). Cancer trends and incidence and mortality patterns in Turkey. *Japanese Journal of Clinical Oncology, 41*(1), 10–16.

Yomralioglu, T. (2008). *Production and geostatistical examination of cancer cases—risk maps by geographical information systems in the Eastern Black Sea Region of Turkey* [article in Turkish]. Trabzon, Turkey: The Scientific and Technological Research Council of Turkey (TUBITAK).

Yomralioglu, T., Colak, H.E., & Aydinoglu, A.C. (2009). Geo-relationship between cancer cases and the environment by GIS: A case study of Trabzon in Turkey. *International Journal of Environmental Research and Public Health, 6*(12), 3190–3204.

You, W.H., Harvey, C.M., & Harvey, C.F. (2003). Arsenic in groundwater in Bangladesh: A geostatistical and epidemiological framework for evaluating health effects and potential remedies. *Water Resources Research, 39*(6), 1146.

Did You Know?

The U.S. Environmental Protection Agency has designated January as National Radon Action Month. Learn more about the national effort to take action against radon at www.epa.gov/radon/nram/.

Thank You

for Supporting the NEHA/AAS Scholarship Fund

American Public University
Manassas, VA

Vickie L. Church
San Diego, CA

Bruce Clabaugh, RS
Greenwood Village, CO

Amer El-Ahraf
Huntington Beach, CA

Dion L. Lerman
Philadelphia, PA

Gloria T. Mackie
Pueblo, CO

COL Wendell A. Moore
Davidsonville, MD

George A. Morris, RS
Dousman, WI

Welford C. Roberts, PhD, RS, REHS, DAAS
South Riding, VA

James M. Speckhart, MS
Norfolk, VA

Ned Therien
Olympia, WA

Clayton Tolson
Baltimore, MD

Dale H. Truesdell
Yakima, WA

Lisa A. Windross
Port Saint Lucie, FL

INTERNATIONAL PERSPECTIVES

Prepublished online June 2014,
National Environmental Health Association.

Needs Assessment Survey for Master's of Science Training in Environmental Health Science in Swaziland

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 25 countries worldwide, are addressed. Our goal is to raise diverse issues of interest to all our readers, irrespective of origin.*

Ababu Teklemariam Tiruneh, PhD
William N. Ndlela
T.H. Gadaga, MSc, PhD
Stanley J. Nkambule, MSc
Sabelo V. Dlamini, MSc, PhD
Department of Environmental Health Science
University of Swaziland

Abstract **A needs assessment survey research was carried out for Master's of Science training in environmental health in Swaziland. The objective of the survey was to acquire information on training needs, gaps, options of specializations, program structure, courses, topics, and research areas that are relevant to the needs of the stakeholders and sector organizations related to environmental health. A document study, focus group discussion with key informants, stakeholder forum workshop, and needs assessment questionnaire to the wider stakeholders were used for the study described here. The findings of the authors' study point to a shortage of qualified personnel in environmental health; lack of capacity in strategy planning and project management; and lack of capacity in research, data collection, and environmental monitoring skills, among other things. A program structure that takes into account the multidisciplinary nature of environmental health with provisions for specialization was favored. Suggestions on course content, mode of delivery, and research topics to be addressed were also given.**

Introduction

According to the World Health Organization (WHO, 2012), environmental health addresses all the physical, chemical, and biological factors external to a person, and all the related factors impacting behaviors. It encompasses the assessment and control of those environmental factors that can potentially affect health. It is targeted towards preventing disease and creating health-supportive environments. The African Academy for Environmental Health (AAEH, 2010) stated that environmental health is the assessment and management of environmental influences (e.g., chemical, physical, biological, social, and psychosocial factors) on human health. This entails the study of food safety and hygiene (including production, distribution, and fitness for human consumption), occupational health and safety (including investigation and control of work-related ill health), community health (communicable and noncommunicable disease control and prevention, disaster management, health promotion, and education), the built environment (including homes, workplaces, and public spaces), and pollution control (including the control of air, land, and water). Environmental health is about taking a preventative approach to tackling disease and ill health rather than a curative approach.

Master's of Science (MSc) training programs in environmental health are specifically designed to take into account the diversity of society and culture, the diversity of the environmental problems that affect the health of citizens, and the integrity of the ecosystem. This is achieved by adapting the MSc programs so as to have a holistic view through cross sectoral analysis and a multidisciplinary approach (American University of Beirut, 2012). The programs are structured to display diversity while retaining integration of cross sectoral issues in environmental health and core courses that address the most salient environmental health issues, covering technical as well as policy perspectives. Specialized electives further upgrade the graduates to be high-level specialists.

At the training institution level, each institution offering an MSc program in environmental health has unique requirements and constraints that may dictate the depth and

breadth of the curriculum. These can be taken as constraints to which the environmental health curriculum may have to adapt. Taking into account diversity, the multidisciplinary nature of the environmental health field, and existing constraints, accreditation bodies in recognition of such constraints and uniqueness allow for variation in environmental health curricula (National Environmental Health Science and Protection Accreditation Council, 2012). Innovative programs that come up with optimum programs taking into account resources, constraining factors, and regional needs are, therefore, encouraged.

Status of the Trained Workforce in Environmental Health in Swaziland and Africa

An assessment by Africa Health Workforce Observatory (2009) revealed that Swaziland still falls short of WHO standards for the ratio of health service providers per capita. Environmental and occupational health workers were among the health workers identified in that study. At the time of the survey, 116 workers fell into this category and their contribution to the proposed target of 4.1 health service providers and support staff per 1,000 people by 2015 was a mere 0.11. The majority of these workers are holders of diplomas or bachelor's degrees in environmental health from the University of Swaziland. With more graduates being produced from the University of Swaziland program, this ratio will definitely improve. Most of these workers will not have an opportunity, however, to improve their qualifications. To alleviate this problem an additional training at the MSc level in environmental health is required.

At a regional level, a WHO study (2005) in Angola, Botswana, Cameroon, Kenya, Mali, and Zambia revealed that the environmental health personnel per capita was inadequate. In addition, that study concluded that environmental health training is often allied with other professions (nursing, public health, community health, etc.). Curricula lack sufficient skills, knowledge, and proficiency, leading to training of inadequate personnel and resulting in inadequate environmental health practice. The requirement for additional emphasis on training in environmental health is highlighted further by the African Region of WHO (1998), which stressed the need to strengthen the capacities of the ministries of health in Africa to promote environmental health as a precondition for any sustainable human development. The South African Development Community *Health Protocol* (1999) also reaffirms the importance of improving the environmental health conditions of communities especially in rural and underdeveloped areas.

Overview of Existing Environmental Health Curricula and Training Practice

Research on environmental health trainings' relevance to actual practice pointed in the past to a number of challenging issues (Association of Schools and Programs of Public Health [ASPPH], 2000). Training shortcomings pointed to lack of communication, leadership, and management skills. Students do not learn to think creatively and solve problems. Too much orientation towards theory and too little on practice occurs. Training programs operate on limited budgetary support due to poor appreciation of the needs for the training program in environmental health (Public Health Services, Gelderland, 2011).

Further observations are reported in relation to the drawbacks of existing curricula in environmental health. Teaching staff often have difficulty keeping up-to-date with progress in the field. Evaluation of environmental health curricula for employment is dubious and often done through informal contacts. Accreditation bodies are seen as formal establishments and sometimes too numerous, with less impact in ensuring proper professional practice and more in collecting revenues through accreditation fees (ASPPH, 2001). A low demand exists for environmental health professionals, leading to low intake rates for training in universities while the reality of environmental health problems indicates a high need does exist for trained professionals (Public Health Services, Gelderland, 2011).

A WHO project that aimed to develop and test an approach for human resources planning in Cuba, Mexico, and South Africa (WHO, 1997) pointed to a number of drawbacks in the training of environmental health professionals. The report pointed to the requirement for carrying out a needs assessment survey, the need for specialty training (such as in epidemiology, hazardous waste management, etc.), failure to incorporate the priority environmental health problems of the country, lack of outreach and publication of curricula, and lack of locally produced publication and training materials.

Objective of the Needs Assessment

The objective of the needs assessment survey was to identify the training needs for professionals in the field of environmental health at the graduate (MSc) level in Swaziland. The needs assessment survey was specifically directed towards acquiring practical information on the training needs, options of specializations, courses, topics, and research areas that are relevant to the needs of stakeholders and sector organizations that require the services of environmental health professionals. Furthermore, the participation of stakeholders in a needs assessment contributes towards ensuring accountability of the MSc program to employer organizations' needs and developing an inclusive partnership with stakeholders starting from curriculum design and continuing through the assessment, monitoring, and evaluation of the training program in the future. Such an approach is considered a right-track approach for the success of a demand-driven training program in environmental health.

Methods

A document study, focus group discussion with key informants, and needs assessment questionnaire to the wider stakeholders were used for our study. Although document studies such as strategic plans of ministries and organizations offer indicators of training requirements, the major part of our study was in the form of focus group discussion with key informants and the needs assessment questionnaire.

The focus group discussion with key informants and the needs assessment questionnaire employed for the needs assessment study are by and large a *felt need analysis*, which is essentially opinion based. Felt needs analysis investigates shortcomings and assesses the need for further training as felt by professionals in the context of their daily practice (Institut National de Sante Publique du Quebec, 2008). A felt need analysis essentially tries to collect viewpoints and information concerning task performance at hand (Rossett, 1987).

Key informants for the focus group discussion were selected from ministries and

organizations in Swaziland including the Ministry of Health, the Swaziland Environmental Authority, municipal councils, the Swaziland Agricultural Development Enterprise, Swaziland Standards Authority, and the Federation of Employers. The informants were selected on the basis of their respective field of specialization in addition to their qualification, experience, and their current occupation and responsibility. A checklist for the focus group discussion was prepared that included scoping of the organizational situation with respect to trained manpower in environmental health, perceived gaps in job performance and skill, the need for an environmental health MSc training program, and suggestions for the structure of the program.

The questionnaire designed for the needs assessment survey included a request for information about the respondents' area of specialization, their qualifications, years of experience, and the organizations in which they are currently working. The questions asked in the questionnaire included the need for an MSc program, if the respondents' respective organizations would benefit from the proposed MSc training in environmental health, questions about the program structure and options, courses to be included as electives and as parts of the common and specialization options of the program, and mode of delivery and length (time period) of the MSc program for both the full-time and part-time modes.

In addition, information on issues that need to be addressed through research, information on new and emerging/challenging issues to be addressed within the program, additional skills needed to be introduced to increase the employability of the graduates, and other useful suggestions the respondents would like to make were also included in the questionnaire.

The objective of the needs assessment survey was explained in detail in the cover letters accompanying the questionnaire. In addition, and as a matter of ethics, the cover letter explained that the individuals' participation and responses would be confidential and only aggregated data and results would be released anonymously. The questionnaire was pretested through responses obtained from a number of professionals before being distributed to the wider participants.

The questionnaires were distributed to professionals in technical as well as senior positions of management in various organizations in Swaziland whose activities require the services of environmental health professionals. The list of participants in the study was prepared after careful consideration of the diversity in occupation that is apparent within the field of environmental health, taking into account the years of experience of the respondents and the current areas of responsibilities of the respondents including personnel in senior management positions. A sample size of 60 respondents was initially chosen and out of the 60 questionnaires distributed, 39 questionnaires were filled out and returned by the respondents, thus giving a response rate of around 65%.

Results

Points Raised During the Focus Group Discussion With Key Informants

Highest Qualification and Field of Specialization in the Participating Organizations

Concerning the highest qualification of manpower available in the respective organizations, the participants of the focus group discussion revealed that most of the employee staff in technical and management positions have bachelor's degrees in environmental health but also a few staff with master's degrees in fields other than environmental health (such as an MBA degree). The participants were of the view that this situation is inadequate and that heads of departments dealing with environmental health activities should have an MSc degree in environmental health while their deputies should hold a minimum of a bachelor's degree in environmental health. A perception existed among some participants that some senior officers in environmental health tasks are running their organizations without the necessary qualifications at a technical level. Although they may have an MBA, they lack technical skills concerning environmental issues.

Need for MSc Degree Qualification in Environmental Health

The participants felt that a need existed for MSc degree qualified personnel in the field of environmental health in their respective organizations. Organizations that require an MSc degree for the positions of heads of departments would require personnel with MSc degrees in environmental health where appropriate. Some organizations have specialized areas such as waste management that need the service of environmental health specialists but currently no one is available with an MSc in environmental health to fulfill the planning and decision-making tasks. Several organizations are witnessing expansion in their organizational structure and an upgrading of required qualifications of their personnel. They foresee the need for MSc training in environmental health in order to carry out the tasks required in these specialized positions.

Some participants mentioned that the people who analyze rural water supplies are diploma holders whereas a higher level qualification should be required for such a task. Lack of project management skills was also mentioned as a felt gap. Organizations are entrusted with multimillion dollar projects that require good services in project management. Interacting with international organizations at the project level would require personnel with a higher level (MSc) qualification. The participants mentioned that broad-based training in environmental health at the MSc level including project management would be beneficial.

A point of argument was put forward by participants of the focus group discussion that MSc training should also be considered as a natural and logical progression for an environmental health specialist who would want to aspire to higher achievement in the field. For Swaziland, as a country with increasing needs for addressing environmental health issues, it should be thought of as an in-demand and necessary skill. Those people who hold their first degree but who aspire to study for an MSc degree in environmental health would have to search for opportunities abroad since training opportunities are not available inside Swaziland. Obtaining financial sponsorship for studying abroad is not always easy, as some participants mentioned. A training opportunity in Swaziland would simplify the hardship apart from the constraint of securing financial support.

A question also arose of the competence of personnel with BSc degree qualifications to handle tasks with their lack of adequate skills

in research, planning, and management. The knowledge and caliber of people will help them think better, which can be upgraded through MSc training.

On Structure and Content of the MSc Program in Environmental Health

The participants of the focus group discussions foresee a combination of course work and research as being appropriate for the MSc training in environmental health. Some participants mentioned that the university should take a leading role in laboratory services and a need exists for training in epidemiology and statistics. The current officers in employment lack capacity in addressing emerging environmental issues because of a lack of skill in research. Some other topics to be included in the training program were also suggested such as project management, environmental management, International Organization for Standardization, change management, environmental economics, monitoring, and evaluation. Participants unanimously agreed that the program structure should be general, with options and electives.

Because of the diversity in the structure and courses offered at the MSc level in environmental health, some participants mentioned that local and regional trends should be taken into account in structuring the program. They emphasized that some of the MSc program structures from the UK or the U.S. might not be appropriate for the needs of Swaziland.

The participants suggested that both part-time and full-time modes should be made available as getting a leave of study is difficult and some employers may only allow a day or week of study leave. The part-time lectures can suitably be arranged, such as on weekends or on a block basis. The duration of the program was suggested to be two years for the full-time mode and three years for the part-time mode. A one-year MSc program was considered too short but a program that is too long could be a disadvantage as some employees might have to resign from their jobs to attend the program and therefore would want to finish the training in the shortest time possible. Losing a job affects the family.

The entry requirement was suggested to be a first degree (BSc) in environmental health. Opinion was divided on whether to include practical experience as selection criteria and on whether employees would need to get a recommendation letter from their employers to be admitted to the MSc program. Some participants expressed these as inhibiting constraints for some applicants who are unemployed or whose employers are unwilling to release them for training. Others, however, suggested they should be used as selection criteria.

Some participants suggested a formation or use of a national or regional accreditation body that regulates the professional practices of MSc-trained professionals in environmental health in Swaziland.

Results of the Needs Assessment Questionnaire

Benefits From the Proposed MSc Program

All of the respondents stated that their respective organizations would benefit from the proposed MSc program in environmental health. The provision of innovative solutions was mentioned by some respondents as a result of an MSc qualification in environmental health. With graduates having the capacity for research and providing innovative solutions to environmental health problems, the respondents foresaw change for the better in improving people's lives. Some respondents indicated their organization might help MSc students undertake research by providing facilities and offering field attachments to the students. They also indicated that some of the practical problems existing within their organizations' settings could be tackled in the form of research by MSc students.

Need for and Job Requirements of New MSc Staff in Environmental Health

Ninety-seven percent of the respondents believed that a need exists to employ new staff with MSc training in environmental health. The respondents mentioned skills and knowledge required in specific subject matters that were not captured at the BSc level but can be well acquired at the MSc level. Existing BSc programs in environmental health were said to lean more towards the environment.

Due to lack of qualified MSc graduates, tasks requiring informed decisions and strategic thinking are executed by underqualified personnel largely based on experience and short-term training. MSc-trained personnel are required who can bring in new innovative ideas and carry out strategic planning, environmental planning, and new technological advancement. Research capacity is believed to be strengthened by MSc graduates who can set up and lead research studies in order to come up with solutions to emerging problems in environmental health. MSc graduates who are critical and analytical in their skills and scope are also desirable in the field of environmental health. In addition, personnel with MSc qualifications are believed to bring in new and innovative ideas, carry out strategic and environmental planning, and be acquainted with new technological advancement.

Training Needs of Existing Staff in the Organizations Towards the MSc in Environmental Health

Eighty-nine percent of the respondents believed that a need exists to upgrade the existing staff to the MSc level. Several existing staff in organizations have BSc degrees with theoretical knowledge. Their skill is limited to the operational level and needs to be upgraded for them to operate at the planning, technical decision making, and management levels. Another advantage in training existing staff for MSc qualification was stated to be the long institutional memory of existing staff and their familiarity, which coupled with an MSc degree training, will enable them to be competent and qualified for the tasks to which they are assigned. Moreover, the current problem of getting suitably qualified candidates in the local market with needed work experience makes it appropriate to train existing staff for the MSc degree. Some respondents added that their organizations employ consultants from outside of their organizations on a continuous basis for tasks that could well be routinely handled by permanent employees with MSc degrees. Some problems that are best tackled through research are reported to require the skills and knowledge of MSc-degree level training.

Major Skills the Graduates Are Expected to Have When They Complete the MSc Degree in Environmental Health

Responses were obtained from participants of the needs assessment questionnaire about the major skills that graduates with an MSc degree in environmental health are required to possess. The responses are categorized into

general skills, skills for project management and leadership, food safety and hygiene, water resources management, environmental management, occupational safety and health, general environmental health, and disease and public health.

Program Structure for MSc in Environmental Health

The participants were also requested to suggest a structure for the MSc degree program in environmental health. The responses indicated that 81% of the respondents preferred a program structure that is an MSc in environmental health with common compulsory courses followed by specialization courses according to the options students choose such as occupational safety and health, food safety and hygiene, environmental management, and water resources.

Courses Requirements for the MSc Program

Courses to be included in the MSc program in environmental health were requested to be suggested by the respondents. At the discretion of the respondents, a list of courses was provided to choose from and respondents were also free to include any other courses that they thought should be included within the program.

From the stream of environmental management, the courses suggested by a number of respondents included environmental impact assessment, environmental risk assessment, environmental sampling and analysis, energy use, sustainability, and air pollution control. Courses such as health policy planning and promotion, health management, and epidemiology were favored by the respondents to be included in the program from the stream of public health. From the stream of food quality and control, sanitary microbiology and food safety were important courses for inclusion in the MSc program.

Courses that may be considered as common supporting courses were also suggested by the respondents. The responses indicated that organizational management and leadership, project management, research methods, GIS, and sustainable development are important for the training program.

From the stream of water resources, the respondents suggested solid and hazardous waste management, water and wastewater treatment, water quality management, hydrology, and water resources management as important courses to be included in the program. From the stream of occupational safety and health, courses suggested were occupational health and safety, industrial hygiene, occupational and environmental risk assessment, occupational and environmental law, air pollution and health, occupational health standards, and occupational and environmental risk communication.

Perhaps an important highlight of the responses was the desire for skills such as GIS, project management, organizational leadership, and management and research methods. A large number of the respondents suggested that these were important skills that are needed for the job requirements after graduation.

Requirements of Additional Managerial and Technical Skill Courses

By far the largest number of respondents indicated the following as additional managerial technical skill courses necessary to be included in the MSc program:

1. project management,
2. organizational management and leadership for environmental health,
3. research methods, and
4. environmental health practice and management.

It is noted that most of the courses have also been mentioned in an overlapping manner by the respondents to be included as either elective courses, specializations, or common courses.

Duration of the MSc Degree Program in Environmental Health Science

The full-time and part-time durations for the MSc program determine the time length of study including both course and thesis work. According to the respondents' replies, 71% of the respondents chose a duration of two years for the full-time program while 29% preferred a duration between one and one and a half years. For the part-time mode, 74% of the respondents chose a duration between three and four years while 26% preferred a duration between two and two and a half years. Some respondents suggested a research period of six months while others even suggested that a full year is preferable for practical attachment. It is to be noted, however, that the University of Swaziland has a (binding) regulation regarding the duration of the full-time and part-time modes. The duration of the full-time mode is two years and the duration of the part-time mode is three years, extendable to four years at most. In addition, according to the norm practiced within the University of Swaziland's postgraduate programs, the course work/thesis duration time split for the full-time option is 1:1, i.e., one year duration for course work and one year duration for research.

Emerging or New Topics to Be Addressed at the MSc Level

Emerging or new topics to be addressed at the MSc level were requested to be suggested by the respondents. Within the realms of public health, topics dealing with emerging infections of international health importance, drug resistance and mutating microbes, indoor air pollution, and environmental health in support of global trades were suggested. In the area of environmental management, climate change and its effects, renewable energy resources, a green economy, integrated environmental management system development, and environmental laboratory analysis were suggested. Topics suggested in water resources management included pollution control, environmental flows, shared water resources, and transboundary water agreements. Hazardous waste management, structural design of water facilities, and water and food security were also suggested. Other topics suggested from the various categories included governance, project management, monitoring and evaluation, International Organization for Standardization, GIS, housing and sanitation in industrial settlements, land use and environmental planning, emergence of street food, and sustainable development.

Problem Areas/Challenges That Need to Be Addressed Through Research Endeavors at the MSc Level

Problem areas and challenges to be addressed through research at the MSc level were suggested by respondents. These included issues concerning impacts of improved environmental health services, problems of communicable diseases in relation to the provision of water and sanitation services, effects of climate change, long-term effects of pollutants, trend analysis in environmental monitoring, bioaccumulation and risk assessment, water demand management, water conservation, water recy-

cling, baseline data on water and sanitation, work safety management, low-income housing, baseline data on foodborne diseases, and quality assurance in the food industry.

Interpersonal/Community Engagement Skills Training That May Be Required by the Graduates

Interpersonal and community engagement skills that may be required by the graduates and were suggested by the respondents include understanding social factors related to community and environmental health and understanding of politics and laws dealing with environment and health.

Organizational management skills that were suggested by the respondents include leadership, communication, negotiation, listening, conflict management, time management, and assertiveness. Community development and facilitation skills suggested included participatory approaches, participatory rural appraisal, communication and facilitation skills, public education, and mass communication.

Additional Remarks in Relation to the Proposed MSc Program in Environmental Health

While the majority of the respondents believed that the proposed MSc program will be useful and even long overdue, some of the respondents pointed out that initially less interest in the program and less recognition of the value of the graduates might occur. Nonetheless, the training program was suggested to be started anyway. The production of the graduates must match with the absorption capacity and a strong advocacy for the program must be conducted to recruit students for the program.

The program should include course work and a thesis and should be in some way geared towards producing research specialists that focus on future environmental health problems and develop careers to solve those problems such as in consultancies. The courses offered should be relevant to the African conditions so that the graduates can work anywhere in Africa.

The MSc training in environmental health should incorporate social studies, environmental studies, and economic studies as well and should make or prepare the graduates to generate thinking with a self-driven approach and provide information for decisions to the next level of the structure of the organization. The respondents suggested that they be provided with continuous feedback on progress and that other similar institutions of higher learning should be fully involved and responsible for constant review of the environmental health programs and that the program be flexible to change. It was also suggested to benchmark the program with others provided in the region and beyond to assure credibility of the program.

Conclusion

The trained personnel ratio for environmental health in Africa in general and in Swaziland in particular is assessed to be inadequate. A need exists for MSc training in Swaziland since the majority of the trained personnel are BSc or diploma holders. MSc-trained personnel are required who can bring in new and innovative ideas, carry out strategic planning, environmental planning, and new technological advancement. In addition, several organizations and ministries targeted in our study are expanding their organizational structure with the anticipated increase in the human resources requirement in the field of environmental health at MSc level in the future. The preferred structure for the MSc program is a set of common courses followed by specialization into the four fields of food safety and hygiene, occupational safety and health, environmental management, and water resources. The core skill requirements that were brought up by the needs assessment study include emphasis on practical skill, ability to carry out research studies and surveys, skills in a number of training areas in environmental health, project management and entrepreneurial skills, advanced analytical laboratory skills, and computer skills. New challenges such as climate change and emerging diseases have been raised as topics to be incorporated in the training program. The study also pointed to the need to have both full-time and part-time modes for the training and a requirement for adapting the curriculum to the local (Swaziland) and regional conditions.

Corresponding Author: Ababu Teklemariam Tiruneh, Faculty of Health Sciences, University of Swaziland, P.O. Box 369, Mbabane H100, Swaziland. E-mail: ababute@yahoo.com.

References

African Health Workforce Observatory. (2009). *Human resources in health fact sheet*. Retrieved from http://www.hrh-observatory.afro.who.int/en/country-monitoring/88-swaziland-.html

American University of Beirut. (2012). *Master of science program in environmental health*. Retrieved from http://www.aub.edu.lb/fhs/fhs_home/degrees_programs/Pages/graduate_programs_mseh.aspx

Association of Schools and Programs of Public Health. (2000). *Improving environmental health curricula and practice at schools of public health*. Washington, DC: Author.

Association of Schools and Programs of Public Health. (2001). *Environmental health conference summary, 2001*. Washington, DC: Author.

Institut National de Sante Publique du Quebec. (2008). *Terms of reference for training needs analysis*. Retrieved from http://www.inspq.qc.ca/pdf/publications/884_Cadre_reference_ang.pdf

National Environmental Health Science and Protection Accreditation Council. (2012). *Graduate guidelines*. Retrieved from http://www.ehacoffice.org/accred-guide/grad-guide.php

Public Health Services, Gelderland. (2011). *Training of professionals in environment and health* (European Commission Directorate General for Health and Consumers, Luxembourg). Retrieved from http://ec.europa.eu/health/healthy_environments/docs/env_training.pdf

Rossett, A. (1987). *Training needs assessment*. Englewood Cliffs, NJ: Educational Technology Publications.

continued on page 100

References *continued from page 99*

Southern African Development Community. (1999). *Health protocol*. Retrieved from http://www.unctadxi.org/Sections/DITC/SADC/docs/SADC%20Regional/SADCHEALTHPROTOCOL.pdf

World Health Organization. (1997). *Guidelines for human resources planning in environmental and occupational health*. Geneva: Author.

World Health Organization. (1998). *Environmental health in Africa role of ministries of health. Regional Committee meeting 48* [Press Release]. Geneva: Author.

World Health Organization. (2005). *National profiles on children's environmental health: Angola—Botswana—Cameroon—Kenya—Mali—Zambia. Regional Office for Africa*. Retrieved from http://s3.amazonaws.com/zanran_storage/www.afro.who.int/ContentPages/4877257.pdf

World Health Organization. (2012). *Health topics: Environmental health*. Retrieved from http://www.who.int/topics/environmental_health/en/

BUILDING CAPACITY

Darryl Booth, MBA

GIS Builds Capacity to Reclaim Brownfields and Respond to Public Requests: Elkhart County, Indiana

Editor's Note: A need exists within environmental health agencies to increase their capacity to perform in an environment of diminishing resources. With limited resources and increasing demands, we need to seek new approaches to the business of environmental health.

Acutely aware of these challenges, NEHA has initiated a partnership with Decade Software Company called *Building Capacity*. *Building Capacity* is a joint effort to educate, reinforce, and build upon successes within the profession, using technology to improve efficiency and extend the impact of environmental health agencies.

The *Journal* is pleased to publish this bimonthly column from Decade Software Company that will provide readers with insight into the *Building Capacity* initiative, as well as be a conduit for fostering the capacity building of environmental health agencies across the country.

The conclusions of this column are those of the author(s) and do not necessarily represent the views of NEHA.

Darryl Booth is president of Decade Software Company and has been monitoring regulatory and data tracking needs of agencies across the U.S. for 18 years. He serves as technical advisor to NEHA's technology section, which includes computers, software, GIS, and management applications.

In our introductory column in November, I spoke of profiling right-minded environmental health projects that address the numerous challenges agencies face today. I know that citizens want more information about the health of their communities. They expect answers (and not just data, but conclusions) faster than ever before. GIS stands out as a tool health agencies must utilize to meet this pressing need. The best application of GIS technology can bring about far-reaching insight and manifest inferences about the relationship between our environment and our health never before imagined.

GIS is software used to view, manage, and analyze data connected with specific locations. Public health data always includes a location component, to which GIS adds a valuable perspective. An Esri® white paper (Esri, 2011) put it succinctly as follows:

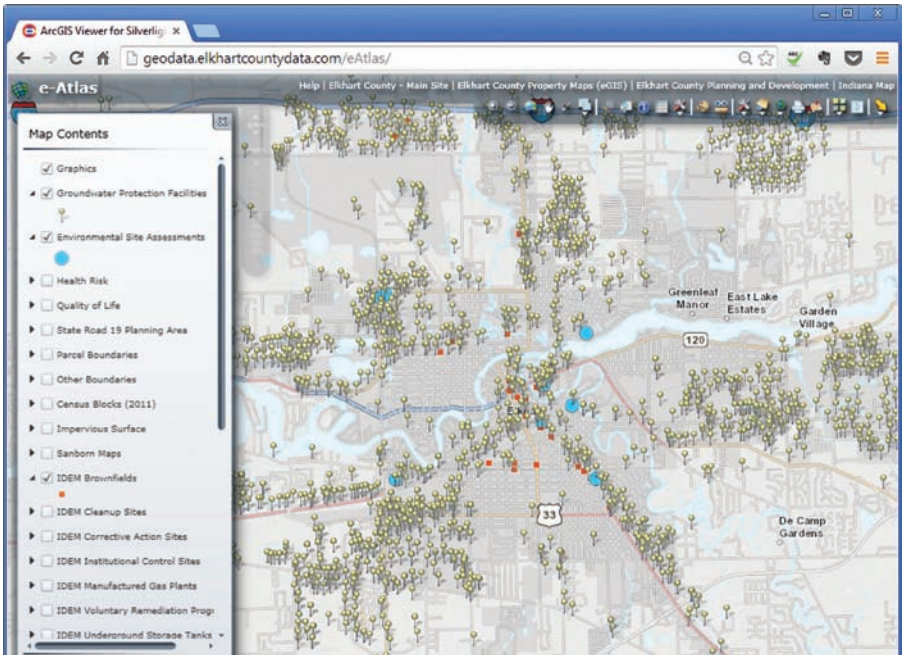
> GIS technology integrates common database operations, such as query and statistical analysis, with the unique visualization and geographic analysis benefits offered by maps. It is valuable to environmental health organizations for explaining events, predicting outcomes, and planning strategies. In this sense, GIS is much more than a computer map; it is a decision support system that integrates spatially referenced data and statistical analyses to address environmental health problems.

The health department in Elkhart County, Indiana, is one such agency that effectively utilizes GIS technology as both a decision support system and to improve customer service. The department developed a custom web application, originally to analyze brownfields (Esri, 2010), and eventually evolving into a resource that citizens can access to identify local health hazards as well as health opportunities.

The project began with the county's groundwater protection program, which monitors over 5,100 groundwater protection sites (facilities that store over 25 gallons of hazardous materials or are on a septic system) as a way to confirm the status of sites that are (or are not) health hazards. This program was born of a critical localized need to protect groundwater resources (Elkhart County Board of Commissioners, 2014).

FIGURE **1**

eAtlas Showing "Groundwater Protection Facilities," "Environmental Site Assessments," and "IDEM Brownfields" Layers



IDEM = Indiana Department of Environmental Management.

Brownfields are properties stigmatized by a real or perceived health threat. Beyond being a health hazard, brownfields are often a visual blight for a community and can lower adjacent property values. Elkhart County has a strong industrial history, but what has been good for the economy now poses a serious threat to community drinking water. "We have a lot of groundwater, but the water tables are high and the soil is sandy, so we are at risk for contamination from spills," says John Hulewicz, former groundwater program supervisor. "We have six Superfund sites, which is extremely rare for a county with a population of less than 200,000."

Aware of their vulnerability, the program works closely with local facilities to monitor their activities and hazardous substances, balancing education with enforcement. But as facilities close down or depart, their environmental footprint remains. A 2006 County Comprehensive Plan (Elkhart County Board of Commissioners, 2006) called for better land use management and prompted the department to reconsider these lots. Having relied on a paper-based filing system for over 20 years, the health department lacked a community wide representation and did not have the capacity to determine the health status of each property. Elkhart thus sought and won a U.S. Environmental Protection Agency (U.S. EPA) brownfield assessment grant to implement a data management system that would empower them to identify and reclaim underused sites in an organized and defendable manner.

The first step was to organize and scan the department's 44 drawers of paper files. Finding the right document management system is crucial, Hulewicz warns. "You have to put time into identifying exactly what you need so you know what to look for. It was vital that whatever system we chose was compatible for our needs and compatible for use with Esri products." The county selected Laserfiche (www.laserfiche.com) for this purpose.

The next step was to take those files (applications, complaints, inspections records) and connect each to an address. The team faced many of the standard challenges of converting paper to digital. Addresses change over time as they are annexed into the city; facilities go out of business; some files (for example, waste tire sites far from any given intersection) did not even have an address. Records were filed by business name, not location, so properties that had hosted several businesses over time were split across multiple files. "Ultimately, though, we were able to take all the groundwater files and associate them with a point on a map, even when numerous facilities had occupied that space."

Elkhart County's GIS team partnered with Symbiont, an engineering and consulting firm based in Wisconsin, to develop the map-based data management system. Utilizing Esri ArcGIS technology, the project team created eAtlas (Figure 1), available at http://geodata.elkhartcountydata.com/eAtlas/. Elkhart's documents were scanned using optical character recognition, which allows the system to search scanned text. Each linked document can be viewed within eAtlas (Figure 2).

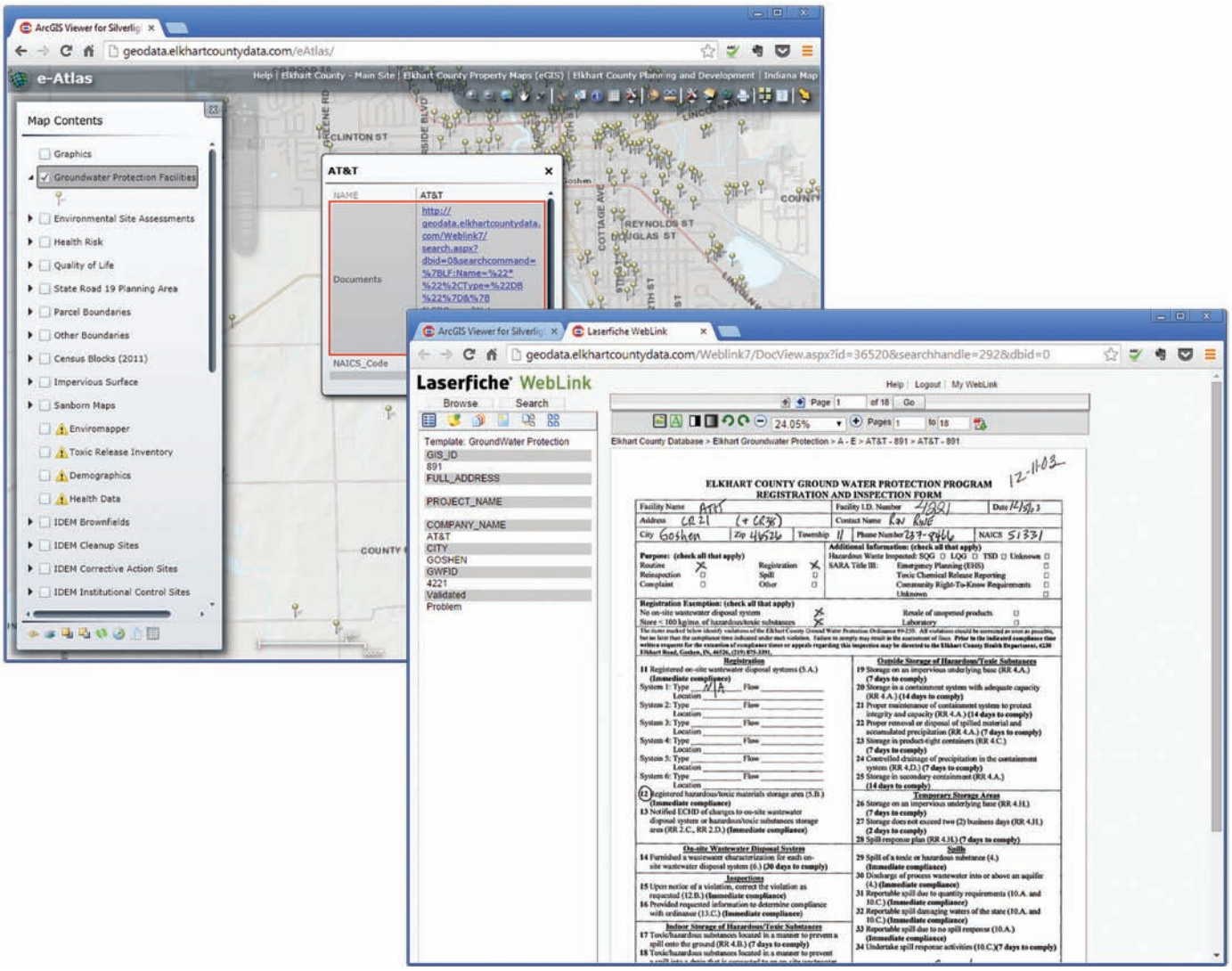
This project resonates with me for a number of reasons. I'm primarily impressed by the seamless marriage of regulatory needs with public interest. Originally, two sites were created, eAtlas and another called What's In My Backyard (WIMBY). WIMBY was born from Not In My Backyard (NIMBY), the characterization of a community's opposition to new, traditionally industrial, development.

"We wanted to be more positive," Hulewicz told me. "We could show the detrimental things, but we also wanted to show the quality of life things that people are interested in—'What schools or churches are near me, are there any bike trails or golf courses?'" Incorporating groundwater protection data and other environmental datasets from organizations such as U.S. EPA, the state of Indiana, and neighboring regions and departments, eAtlas and WIMBY were eventually combined into a single, public-facing Web site. Users can choose from many different data layers, from more regulatory focused "groundwater protection facilities" and "tire waste sites" to quality of life layers such as "cleaned up" and "uncleaned" meth lab locations, hospitals, libraries, and parks. Viewers can choose from several base maps, including aerial photos or "topographic" (Figure 3).

Not only is this system a positive, transparent resource for the community, but it has

FIGURE **2**

Clicking the "Documents" Link for a Selected "Groundwater Protection Facilities" Site Layer Displays Linked Documents via Laserfiche



increased the agency's capacity. They save dozens of hours every month by directing record requests to this site and have been able to steer their own activities based on the conclusions that this application provides. In part because of this resource, several former brownfields have been redeveloped into neighborhood parks and other treasured communal areas.

The county intends to develop this tool further to create a scoring model by which the program can rate a facility's risk utilizing parameters such as number of spills, hazardous material storage methods, and type of chemicals. The division could easily enhance the system with other environmental health layers. The state of Florida Department of Health is using GIS to create a parcel-based drinking water and wastewater inventory to identify the drinking water source and the method of wastewater disposal for every built parcel in the state. Calculate the time your office would save and the positive image you'd cultivate if all this valued information were immediately and automatically available to constituents! If the records are already considered "public," make them obtainable.

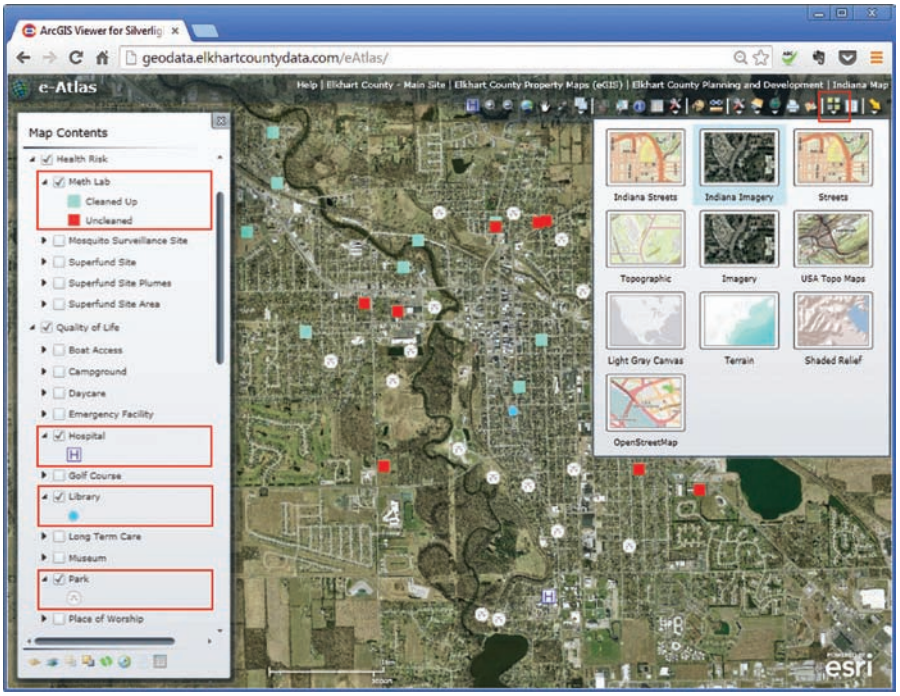
If you are interested in pursuing a project like this, find more resources at www.decadesoftware.com/column.

Acknowledgement: Kelly Delaney, marketing communications manager for Decade Software Company, provided the research for this column.

Corresponding Author: Darryl Booth, President, Decade Software Company, 1195 W. Shaw, Fresno, CA 93711.
E-mail: darrylbooth@decadesoftware.com.

FIGURE **3**

Several Selected Quality of Life Layers and Base Map Options



References

Elkhart County Board of Commissioners. (2006). *County comprehensive land use plan.* Retrieved from http://www.elkhartcountyindiana.com/Elkhart%20County%202006-15%20land%20use%20plan.pdf

Elkhart County Board of Commissioners. (2014). *Groundwater protection ordinance.* Retrieved from http://www.elkhartcountyhealth.org/environmentalhealth/water.html

Esri. (2010). *County health department makes brownfield environmental data accessible.* Retrieved from http://www.esri.com/news/arcnews/winter1011articles/elkhart-brownfields.html

Esri. (2011). *Geographic information systems and environmental health: Incorporating Esri technology and services.* Retrieved from http://www.esri.com/library/whitepapers/pdfs/gis_and_env_health.pdf

DIRECT FROM CDC ENVIRONMENTAL HEALTH SERVICES BRANCH

LaToria Whitehead, MPH, PhD

The Road Towards Environmental Justice From a Multifaceted Lens

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.

LaToria Whitehead currently serves as the environmental justice officer of the Division of Emergency and Environmental Health Services at CDC's National Center for Environmental Health and is an adjunct professor in the political science department at Clark Atlanta University and Spelman College.

Social Determinants of Health and Environmental Justice

The intersection of social justice and environmental stewardship has become a catalyst for environmental justice (EJ). Economic, social, and cultural factors impact health outcomes and the exposure to environmental hazards. Housing deficiencies, exposure to pollutants, and other environmental risks are distributed unequally by race and socioeconomic status. Although no individual is exempt from environmental exposures, low-income and minority populations are more likely to live in counties with particulate matter and ozone levels that exceed air quality standards. They are more likely to live in older homes and impoverished areas and have the highest odds of living in inadequate housing that contains toxic substances (Centers for Disease Control and Prevention [CDC], 2014a). Populations more likely to be affected by environmental degradation are also more likely to be disproportionately afflicted with chronic diseases, including asthma, obesity, and cancer (CDC, 2014b).

EJ, which is a paradigm that has become a major part of the environmental discourse, works to address and reduce the imbalance of exposure to environmental hazards and the disparate aftereffects. EJ has a goal to ensure fair treatment and to ensure that no individual—irrespective of race, color, culture, national origin, income, and educational level—has an unequal share of harmful environmental exposures (U.S. Environmental Protection Agency, 2014). The EJ framework serves as a conduit for everyone to be part of a democratic decision making process. A mechanism for addressing issues of environmental hazards as a result of concentrated poverty and geographical inequities, the narrative of EJ has allowed us to view environmental disparities and quality of life issues through a multidimensional lens.

A Multifaceted Approach

The Centers for Disease Control and Prevention's (CDC's) National Center for Environmental Health and Agency for Toxic Substances and Disease Registry (NCEH/ATSDR) support EJ and continue to address environmental health–related disparities through tools, collaborations, and public health programs (see Tables 1 and 2). In essence, as federal agencies have been called to address these issues, an increasing utilization of methods beyond traditional public health interventions has occurred (Executive Order No. 12898, 1994). The multiple elements that comprise EJ compel us to confront inequalities through a multidimensional lens. For example, facets of EJ include accessibility to nutritional food and health care, safe and affordable transportation and housing, politi-

TABLE **1**

National Center for Environmental Health/Agency for Toxic Substances and Disease Registry (NCEH/ATSDR) Environmental Justice Tools for the Public

Tool	Web Site	Description
Community environmental health presentations	www.atsdr.cdc.gov/emes/public/health_presentations.html	Information about specific types of exposures to hazardous substances, exposure routes and pathways, health effects, and how to prevent and minimize exposures.
Environmental health WebMaps	www.atsdr.cdc.gov/webmaps/index.asp	Interactive map that displays environmental health information from NCEH/ATSDR, NCEH/ATSDR-funded programs, and other federal and state agencies.
Hazardous waste sites	www.atsdr.cdc.gov/hazardouswastesites.html	Information about current activities at focus waste sites, including public health assessments and lists of sites by state, by contaminant, or by site ownership.
Healthy community design tool kit	www.cdc.gov/healthyplaces/toolkit/default.htm	Tool kit to help planners, public health professionals, and the general public include health in the community planning process.
Protocol for Assessing Community Excellence in Environmental Health (PACE EH)	www.cdc.gov/nceh/ehs/CEHA/PACE_EH.htm	Methodology to guide communities and local health officials in conducting community-based environmental health assessments.
Toxic substances portal	www.atsdr.cdc.gov/substances/index.asp	Interface to guide users to information about specific toxic substances.
ToxFAQs™	www.atsdr.cdc.gov/toxfaqs/index.asp	Answers to the most frequently asked questions about exposure to hazardous substances found around hazardous waste sites and the effects of exposure on human health.
Toxicology curriculum for communities trainer's manual	www.atsdr.cdc.gov/training/toxmanual/	Training modules for lectures or seminars for communities on the topic of toxicology and issues surrounding environmental exposures.
ToxZine	www.atsdr.cdc.gov/sites/toxzine/	Summary of health effects, exposure, and recommendations in an easy-to-read magazine format.

Note. NCEH/ATSDR is in phase one of creating a tool that will be publicly available to investigate environmental justice. Phase two will involve linking the environmental burden index with the existing social vulnerability index to identify areas at risk for environmental injustice. The final tool will be an interactive mapping product that will also include access to the raw cleaned data.

cal engagement, economic investment in vulnerable communities, favorable neighborhoods, green jobs, collaborative partnerships, and inclusiveness.

Public health practitioners designing studies that not only reduce and mitigate disparities for all populations, but support communities in "owning" these interventions, create empowerment and applicable methods for community design, response to disasters, and healthy medical management for low-income and minority populations. Community knowledge and a consistent discourse between policy makers and vulnerable populations may potentially lead to sustainability for disparate neighborhoods. Practitioners designing culturally appropriate initiatives within the health sector could have a positive effect outside of the health sector as well. Connecting quality of life discrepancies will yield robust approaches in confronting environmental injustices.

Creating an Atmosphere of Justice

NCEH/ATSDR tools contribute to confronting environmental inequalities from a multifaceted lens. These tools include pediatric health training, the assessment of chemical exposures and toxicological profiles, healthy community design methods, emergency response for vulnerable populations, community education, and geographical mapping around EJ communities. The approaches put forward to address environmental disparities are not restricted to public health professionals. NCEH/ATSDR tools lend themselves to creating geographical knowledge for urban planners in the public and private sectors while designing transportation, land use, and sustainable development strategies for the community. Medical professionals are able to utilize the tool kits to help guide their understanding of various environmental health issues during patient visits. Environmental health maps assist business, law, political, sociology, and public health students and professionals in learning about the health of their community while creating sustainable environmental initiatives for vulnerable populations.

The extension of scientific knowledge coupled with successful community design models are available for governmental agencies, policy makers, and industry professionals to make efficient decisions and assist in creating a sustainable society. A sustainable and healthy environment will contribute to the economic vitality of impoverished neighborhoods and business owners. Notably, the communities are empowered and equipped to tackle and confront environmental injustices by use of tools and other processes.

The various roads to EJ have finally met each other in a congruent fashion. Continuing to challenge and devote ourselves to vulnerable communities with passion and endurance from a multidimensional perspective may set

TABLE **2**

National Center for Environmental Health/Agency for Toxic Substances and Disease Registry (NCEH/ATSDR) Environmental Justice Tools for Health Professionals

Tool	Web Site	Description
Case studies in environmental medicine	www.atsdr.cdc.gov/csem/csem.html	Self-instructional publications to increase primary care providers' knowledge of a hazardous substance in the environment and to aid in the evaluation of potentially exposed patients.
Grand rounds in environmental medicine	www.atsdr.cdc.gov/emes/health_professionals/grem.html	One-hour continuing-education seminars to increase primary care providers' knowledge of hazardous substances in the environment and to aid in the evaluation of potentially exposed patients.
Patient education and care instruction sheets	www.atsdr.cdc.gov/emes/health_professionals/instruction_sheets.html	General information on various environmental medicine topics to give health-care providers quick, ready-to-use materials to aid in patient care and instruction.
Pediatric environmental health tool kit training module	www.atsdr.cdc.gov/emes/health_professionals/pediatrics.html	Tool kit with detailed examples for health-care providers about how to best deliver anticipatory guidance on a range of environmental health issues, especially during well-child visits.
Managing hazardous materials incidents	www.atsdr.cdc.gov/MHMI/index.asp	Three-volume set with recommendations for on-scene (prehospital) and hospital medical management of patients exposed during a hazardous materials incident.
Medical management guidelines for acute chemical exposure	www.atsdr.cdc.gov/mmg/index.asp	Publication to aid emergency department physicians and other emergency health care professionals who manage acute exposures.
Priority list of hazardous substances	www.atsdr.cdc.gov/spl/index.html	List of hazardous substances based on a combination of the frequency, toxicity, and potential for human exposure at National Priorities List sites.
Scientific assessments and consultations	www.atsdr.cdc.gov/consultations/index.html	Chemical-specific technical information for scientists and public health and medical professionals.
Social vulnerability index*	http://svi.cdc.gov/	Tool to help emergency response planners and public health officials identify and map the communities that will most likely need support before, during, and after a hazardous event.
Toxic substances portal	www.atsdr.cdc.gov/substances/index.asp	Interface to guide users to information about specific toxic substances.
ToxGuides™	www.atsdr.cdc.gov/toxguides/index.asp	Quick reference guide for information such as chemical and physical properties, sources of exposure, routes of exposure, minimal risk levels, children's health, and health effects for a substance.
Toxicological profiles	www.atsdr.cdc.gov/toxprofiles/index.asp	Comprehensive information on the toxicological and adverse health effects of a hazardous substance.

*NCEH/ATSDR is in phase one of creating a tool that will be publicly available to investigate environmental justice. Phase two will involve linking the environmental burden index with the existing social vulnerability index to identify areas at risk for environmental injustice. The final tool will be an interactive mapping product that will also include access to the raw cleaned data.

a precedent for reducing environmental disparities. Despite our victories, we still have a considerable amount of work to accomplish. Moreover, as we continue to collaborate and integrate the EJ framework as an operating principle through public health programs, we may be one step closer to achieving what we all call environmental justice.

Corresponding Author: LaToria Whitehead, Environmental Justice Officer, Division of Emergency and Environmental Health Services, National Center for Environmental Health, CDC, 4770 Buford Highway NE, Mailstop F-58, Atlanta, GA 30341.
E-mail: lwhitehead1@cdc.gov.

References

Centers for Disease Control and Prevention. (2014a). *National Center for Environmental Health*. Retrieved from http://www.cdc.gov/nceh/

Centers for Disease Control and Prevention. (2014b). *Minority health and health equity*. Retrieved from http://www.cdc.gov/MinorityHealth/index.html

Executive Order No. 12898, 59 FR 7629. (1994). *Federal actions to address environmental justice in minority populations and low-income populations*. Retrieved from http://www.archives.gov/federal-register/executive-orders/pdf/12898.pdf

U.S. Environmental Protection Agency, Office of Environmental Justice. (2014). *Environmental justice*. Retrieved from http://www.epa.gov/environmentaljustice/

2015 Walter F. Snyder Award

Call for Nominations

Nomination deadline is April 30, 2015.

Given in honor of NSF International's co-founder and first executive director, the *Walter F. Snyder Award* recognizes outstanding leadership in public health and environmental health protection. The annual award is presented jointly by NSF International and the National Environmental Health Association.

❖ ❖ ❖

Nominations for the 2015 *Walter F. Snyder Award* are being accepted for professionals achieving peer recognition for:

- outstanding accomplishments in environmental and public health protection,
- notable contributions to protection of environment and quality of life,
- demonstrated capacity to work with all interests in solving environmental health challenges,
- participation in development and use of voluntary consensus standards for public health and safety, and
- leadership in securing action on behalf of environmental and public health goals.

❖ ❖ ❖

Past recipients of the *Walter F. Snyder Award* include:

2014 – Priscilla Oliver
2013 - Vincent J. Radke
2012 - Harry E. Grenawitzke
2011 - Gary P. Noonan
2010 - James Balsamo, Jr.
2009 - Terrance B. Gratton
2008 - CAPT. Craig A. Shepherd
2007 - Wilfried Kreisel
2006 - Arthur L. Banks
2005 - John B. Conway
2004 - Peter D. Thornton
2002 - Gayle J. Smith
2001 - Robert W. Powitz
2000 - Friedrich K. Kaeferstein
1999 - Khalil H. Mancy
1998 - Chris J. Wiant
1997 - J. Roy Hickman
1996 - Robert M. Brown
1995 - Leonard F. Rice
1994 - Nelson E. Fabian
1993 - Amer El-Ahraf
1992 - Robert Galvan
1991 - Trenton G. Davis
1990 - Harvey F. Collins
1989 - Boyd T. Marsh
1988 - Mark D. Hollis
1987 - George A. Kupfer
1986 - Albert H. Brunwasser
1985 - William G. Walter
1984 - William Nix Anderson
1983 - John R. Bagby, Jr.
1982 - Emil T. Chanlett
1981 - Charles H. Gillham
1980 - Ray B. Watts
1979 - John G. Todd
1978 - Larry J. Gordon
1977 - Charles C. Johnson, Jr.
1975 - Charles L. Senn
1974 - James J. Jump
1973 - William A. Broadway
1972 - Ralph C. Pickard
1971 - Callis A. Atkins

The 2015 Walter F. Snyder Award will be presented during NEHA's 79th Annual Educational Conference (AEC) & Exhibition to be held in Orlando, Florida, July 13 - 15, 2015.

For more information or to download nomination forms, please visit www.nsf.org or www.neha.org or contact Stan Hazan at NSF at 734-769-5105 or hazan@nsf.org.

CAREER **OPPORTUNITIES**

Food Safety Inspector

UL Everclean Services is the leader in the restaurant inspections market. We offer opportunities throughout the country. We currently have openings for professionals to conduct Q.A. audits of restaurants. Past or current food safety inspecting is required.

U.S. Listings
Alaska
Albany, NY
Billings, MT
Bismarck, ND
Boise, ID
Buffalo, NY
Butte, MT
Chattanooga, TN
Cleveland, OH
Colorado Springs, CO
Grand Junction, CO
Hartford, CT
Jackson, MS
Jacksonville, FL
Knoxville, TN
Little Rock, AR
McAllen, TX
Milwaukee, WI
Minneapolis, MN
New Orleans, LA
Owatonna, MN
Pittsburgh, PA
Pocatello, ID
Puerto Rico
Rapid City, SD
Roanoke, VA
Rochester, NY
San Francisco, CA
San Jose, CA
Shreveport, LA
Sioux Falls, SD
Spearfish, SD
St. Louis, MO
St. Paul, MN
Syracuse, NY
Tulsa, OK
Washington, DC
Yuma, AZ

Canada Listings
Edmonton, AB
Kamloops, BC
Mississauga, ON
Ottawa, ON

Interested applicants can send their resume to: Bill Flynn at Fax: 818-865-0465. E-mail: Bill.Flynn@ul.com.

Find a Job | Fill a Job

Where the "best of the best" consult...

NEHA's Career Center

First job listing **FREE** for city, county, and state health departments with a NEHA member, and for Educational and Sustaining members.

For more information, please visit neha.org/job_center.html

NEHA SABBATICAL 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, or in Canada, in cooperation with the Canadian Institute of Public Health Inspectors. The sabbatical can be from two to four weeks, as determined by the recipient. If selected, the sabbatical ambassador receives 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 2, 2015.

Winners will be announced at the NEHA 2015 Annual Educational Conference (AEC) & Exhibition in Orlando, Florida, in July 2015. Recipients will complete the sabbatical between August 1, 2015, and June 1, 2016. The sabbatical ambassador will give a required report of their experience at the 2016 AEC in San Antonio, Texas.

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

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

EH CALENDAR

UPCOMING NEHA CONFERENCE

July 13–15, 2015: NEHA's 79th Annual Educational Conference & Exhibition, Renaissance Orlando at SeaWorld, Orlando, FL. For more information, visit www.neha2015aec.org.

NEHA AFFILIATE AND REGIONAL LISTINGS

Arizona
March 11–12, 2015: Annual Spring Conference, hosted by the Arizona Environmental Health Association, Phoenix, AZ. For more information, visit www.azeha.org/Conferences.html.

California
April 13–16, 2015: Annual Educational Symposium, hosted by the California Environmental Health Association, San Diego, CA. For more information, visit www.ceha.org.

Idaho
March 18–19, 2015: Annual Education Conference, hosted by the Idaho Environmental Health Association, Boise, ID. For more information, visit www.ieha.wildapricot.org.

Indiana
April 16, 2015: Annual Spring Educational Conference, hosted by the Indiana Environmental Health Association, Indianapolis, IN. For more information, visit www.iehaind.org.

Michigan
March 17–20, 2015: Annual Educational Conference, hosted by the Michigan Environmental Health Association, Traverse City, MI. For more information, visit www.meha.net.

Minnesota
January 29, 2015: Winter Conference, hosted by the Minnesota Environmental Health Association, St. Paul, MN. For more information, visit www.mehaonline.org/events.

Ohio
April 22–24, 2015: Annual Education Conference, hosted by the Ohio Environmental Health Association, Dublin, OH. For more information, visit www.ohioeha.org.

Utah
May 13–15, 2015: Spring Conference, hosted by the Utah Environmental Health Association, Bicknell, UT. For more information, visit www.ueha.org/events.html.

Virginia
April 17, 2015: Spring Educational Session, hosted by the Virginia Environmental Health Association, Daleville, VA. For more information, visit http://virginiaeha.org/educational-sessions/.

Wisconsin
April 21, 2015: Spring Education Conference, hosted by the Wisconsin Environmental Health Association, Oshkosh, WI. For more information, visit www.weha.net.

TOPICAL LISTINGS

Children's Environmental Health
February 4–6, 2015: 2015 Research Conference—Children: Food and Environment, hosted by the Children's Environmental Health Network, Austin, TX. For more information, visit www.cehn.org/2015_research_conference.

Onsite Wastewater
January 15–16, 2015: 33rd Annual Onsite Wastewater Treatment Conference, hosted by the Illinois Association of Local Environmental Health Administrators, East Peoria, IL. For more information, visit http://ieha.coffeecup.com/calendar.html.

Smart Growth
January 29–31, 2015: 14th Annual New Partners for Smart Growth Conference, presented by The Local Government Commission, Baltimore, MD. For more information, visit www.newpartners.org.

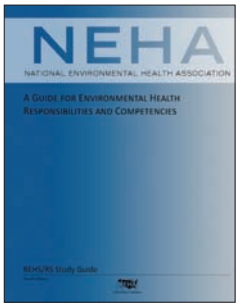
RESOURCE CORNER

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!

NEHA BOOKSTORE
www.neha.org/store

REHS/RS Study Guide (Fourth Edition)

National Environmental Health Association (2014)



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

308 pages / Paperback / Catalog #EZ3010
Member: $149 / Nonmember: $179

Certified Professional-Food Safety Manual (Third Edition)

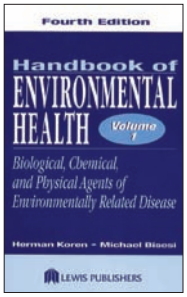
National Environmental Health Association (2014)

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

358 pages / Spiral-bound paperback / Catalog #EZ9020
Member: $179 / Nonmember: $209

Handbook of Environmental Health, Volume 1: Biological, Chemical, and Physical Agents of Environmentally Related Disease (Fourth Edition)

Herman Koren and Michael Bisesi (2003)

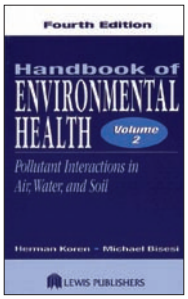


A must for the reference library of anyone with environmental health concerns, this book focuses on factors that are generally associated with the internal environment. It was written by experts in the field and co-published with the National Environmental Health Association. A variety of environmental issues are covered such as food safety, food technology, insect and rodent control, indoor air quality, hospital environment, home environment, injury control, pesticides, industrial hygiene, instrumentation, and much more. New environmental issues, energy, practical microbiology and chemistry, risk assessment, emerging infectious diseases, laws, toxicology, epidemiology, human physiology, and the effects of the environment on humans are also covered. Study reference for NEHA's REHS/RS exam.

790 pages / Hardback / Catalog #215A

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 co-published with the National Environmental Health Association. 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
Volume 1 OR Volume 2: Member: $195 / Nonmember: $215
Two-Volume Set: Member: $349 / Nonmember: $379

JEH QUIZ

FEATURED ARTICLE QUIZ #4

Hazardous Metals in Vintage Plastic Toys Measured by a Handheld X-ray Fluorescence Spectrometer

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

1. Read the featured article carefully.
2. Select the correct answer to each *JEH* Quiz question.
3. a) Complete the online quiz at www.neha.org (click on "Continuing Education"),
   b) Fax the quiz to (303) 691-9490, or
   c) Mail the completed quiz to
   JEH Quiz, NEHA
   720 S. Colorado Blvd., Suite 1000-N
   Denver, CO 80246.
   Be sure to include your name and membership number!
4. One CE credit will be applied to your account with an effective date of January 1, 2015 (first day of issue).
5. Check your continuing education account online at www.neha.org.
6. You're on your way to earning CE hours!

Quiz Registration

Name

NEHA Member No.

Home phone

Work phone

E-mail

Quiz deadline: April 1, 2015

1. The Consumer Product Safety Improvement Act restricted total lead in children's products to __ in 2011.
   a. 100 ppm
   b. 200 ppm
   c. 300 ppm
   d. 600 ppm

2. The developing brains and bodies of infants and young children are vulnerable to toxic exposures because they
   a. are exposed to contaminated dust particles by playing close to the floor.
   b. chew on, mouth, and occasionally swallow items.
   c. absorb and retain lead more efficiently than do adults.
   d. all of the above.

3. Cadmium appears to impact brain development and is also known to damage renal function.
   a. True.
   b. False.

4. In this study, __ of the vintage plastic toys analyzed contained either cadmium or lead.
   a. 54%
   b. 60%
   c. 67%
   d. 75%

5. The percentage of vintage non-polyvinyl chloride (PVC) toys containing barium was __ the percentage of vintage PVC toys containing barium.
   a. less than
   b. the same as
   c. more than

6. Cadmium, lead, or arsenic was detectable in some of the contemporary PVC toys analyzed in this study.
   a. True.
   b. False.

7. __ of vintage non-PVC toys had detectable lead levels greater than 90 ppm.
   a. Twenty-three percent
   b. Thirty-four percent
   c. Fifty-seven percent
   d. Sixty-six percent

8. Lead and cadmium in various chemical forms are added to PVC to function as
   a. plasticizers.
   b. pigments.
   c. stabilizers.
   d. all of the above.

9. In the 1970s and 1980s vinyl toys tested, lead and cadmium are most likely part of the __ compounds added to the toys.
   a. pigment
   b. plasticizer
   c. stabilizer

10. Darker colored vintage vinyl toys had the __ levels of lead or cadmium.
    a. lowest
    b. highest

11. __ of recent PVC toys contained barium levels greater than 250 ppm.
    a. Twenty-two percent
    b. Thirty-six percent
    c. Forty-one percent
    d. Sixty-nine percent

12. The highest concentrations of both cadmium and lead were found in __ toy parts.
    a. white
    b. black
    c. blue
    d. yellow

JEH Quiz #2 Answers
October 2014

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

SUPPORT THE NEHA ENDOWMENT FOUNDATION

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

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

Thank you.

DELEGATE CLUB ($25–$99)

Name in the Journal *for one year and endowment pin.*

Freda W. Bredy
Alexandria, VA

HONORARY MEMBERS CLUB ($100–$499)

Letter from the NEHA president, name in the Journal *for one year, and endowment pin.*

Michele R. DiMaggio
Martinez, CA

James M. Speckhart, MS
Norfolk, VA

21st CENTURY CLUB ($500–$999)

Name in AEC program book, name submitted in drawing for a free one-year NEHA membership, name in the Journal *for one year, and endowment pin.*

Bette J. Packer
Ham Lake, MN

Peter M. Schmitt
Shakopee, MN

Dr. Bailus Walker, Jr.
Arlington, VA

SUSTAINING MEMBERS CLUB ($1,000–$2,499)

Name in AEC program book, name submitted in drawing for a free two-year NEHA membership, name in the Journal *for one year, and endowment pin.*

James J. Balsamo, Jr., MS, MPH, MHA, RS, CP-FS
Metairie, LA

George A. Morris, RS
Dousman, WI

Welford C. Roberts, PhD, RS, REHS, DAAS
South Riding, VA

AFFILIATES CLUB ($2,500–$4,999)

Name in AEC program book, name submitted in drawing for a free AEC registration, name in the Journal *for one year, and endowment pin.*

EXECUTIVE CLUB AND ABOVE ($5,000–$100,000)

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

NEHA ENDOWMENT FOUNDATION PLEDGE CARD

I pledge to be a NEHA Endowment Foundation Contributor in the following category:

❍ Delegate Club ($25)
❍ Honorary Members Club ($100)
❍ 21st Century Club ($500)
❍ Sustaining Members Club ($1,000)
❍ Affiliates Club ($2,500)
❍ Executive Club ($5,000)
❍ President's Club ($10,000)
❍ Endowment Trustee Society ($25,000)
❍ Visionary Society ($50,000)
❍ Futurists Society ($100,000)
❍ **You have my permission to disclose the fact and amount (by category) of my contribution and pledge.**

I plan to make annual contributions to attain the club level of _____ over the next _____ years.

Signature _____ Print Name _____

Organization _____ Phone _____

Street Address _____ City _____ State _____ Zip _____

❍ Enclosed is my check in the amount of $_____ payable to **NEHA Endowment Foundation**.

❍ Please bill my: MasterCard/Visa Card #_____ Exp. Date _____

Signature _____

MAIL TO: NEHA, 720 S. Colorado Blvd., Suite 1000-N, Denver, CO 80246, or FAX to: 303.691.9490. 1501JEHEND

SPECIAL NEHA MEMBERS

Sustaining Members

Advanced Drainage Systems
www.ads-pipe.com

Advanced Fresh Concepts Corp.
www.afcsushi.com

AIB International
www.aibonline.org

Albuquerque Environmental Health Department
www.cabq.gov/environmentalhealth

Allegheny County Health Department
www.county.allegheny.pa.us

American Academy of Sanitarians (AAS)
Gary P. Noonan
www.sanitarians.org

American Chemistry Council
www.americanchemistry.com

Anua
www.anua-us.com

Ashland-Boyd County Health
hollyj.west@ky.gov

Association of Environmental Health Academic Programs
www.aehap.org

ATSDR/DCHI
www.atsdr.cdc.gov/hac

Camelot International Health Organization
www.camelot.gr

CDP, Inc.
www.cdpehs.com

Chemstar Corporation
www.chemstarcorp.com

City of Bloomington
www.ci.bloomington.mn.us

City of Fall River Health & Human Services
(508) 324-2410

City of Houston Environmental Health
www.houstontx.gov/health/environmental-health

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

City of San Diego Environmental Services Department
www.sandiego.gov/environmental-services

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

Coconino County Public Health
www.coconino.az.gov

Colorado Department of Public Health and Environment, Division of Environmental Health, Delegated Programs Unit
Therese Pilonetti
therese.pilonetti@state.co.us

Decade Software Company, LLC
Darryl Booth
www.decadesoftware.com

DEH Child Care
www.denvergov.org/DEH

DeltaTrak, Inc.
Vallierie Cureton
www.deltatrak.com

Digital Health Department, Inc.
www.dhdinspections.com

Diversey, Inc.
Steve Hails
www.diversey.com

DuPage County Health Department
www.dupagehealth.org

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

Ecobeco
www.ecobeco.com

Ecolab
robert.casey@ecolab.com
www.ecolab.com

EcoSure
charlesa.arnold@ecolab.com

Elite Food Safety Training
www.elitefoodsafety.com

English Sewage Disposal, Inc.
(756) 358-4771

Florida Department of Health
www.doh.state.fl.us

Gila River Indian Community, Environmental Health Services
www.gilariver.org

GLO GERM/Food Safety First
Joe D. Kingsley
www.glogerm.com

HealthSpace USA Inc.
Joseph Willmott
www.healthspace.com

Industrial Test Systems, Inc.
www.sensafe.com

Inspect2Go
www.inspect2go.com

InspekPro LLC
www.inspekpro.com

International Association of Plumbing and Mechanical Officials
www.iapmo.org

Jefferson County Health Department (Missouri)
Joe Hainline
www.jeffcohealth.org

Jefferson County Public Health (Colorado)
csanders@jeffco.us
http://jeffco.us/health

Kansas Department of Health & Environmental
jrhoads@kdheks.gov

Linn County Public Health
health@linncounty.org

Maricopa County Environmental Services
jkolman@mail.maricopa.gov

Mars Air Doors
www.marsair.com

Merced County Public Health, Division of Environmental Health
rrowe@co.merced.ca.us

Mesothelioma Lawyer Center
www.mesotheliomalawyercenter.org

Mid-Iowa Community Action
www.micaonline.org

Mid-Ohio Valley Health Department
tim.l.miller@wv.gov
www.movhd.com

Mitchell Humphrey
www.mitchellhumphrey.com

Mycometer
www.mycometer.com

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

National Registry of Food Safety Professionals
Lawrence Lynch
www.nrfsp.com

National Restaurant Association
www.restaurant.org

National Swimming Pool Foundation
Michelle Kavanaugh
www.nspf.org

Neogen Corporation
www.neogen.com

New Mexico Environment Department
www.nmenv.state.nm.us

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

North Bay Parry Sound District Health Unit
www.healthunit.biz

Nova Scotia Department of Agriculture
www.gov.ns.ca

NSF International
Stan Hazan
www.nsf.org

Oneida Indian Tribe of Wisconsin
www.oneidanation.org

Orkin
Zia Siddiqi
www.orkincommercial.com

Ozark River Hygienic Hand-Wash Station
www.ozarkriver.com

PerkinElmer, Inc.
www.perkinelmer.com

Polk County Public Works
www.polkcountyiowa.gov/publicworks

Presby Environmental, Inc.
www.presbyenvironmental.com

Prometric
www.prometric.com

Racine City Department of Health
www.cityofracine.org/Health.aspx

Remco Products
www.remcoproducts.com

Sacramento County Environmental Management Department
www.emd.saccounty.net

San Jamar
www.sanjamar.com

Seattle & King County Public Health
Michelle Pederson
michelle.pederson@kingcounty.gov

Shat-R-Shield Inc.
Anita Yost
www.shat-r-shield.com

Skillsoft
www.skillsoft.com

Sonoma County Permit and Resource Management Department, Wells and Septic Section
www.sonoma-county.org/prmd

Starbucks Coffee Company
www.starbucks.com

StateFoodSafety.com
www.StateFoodSafety.com

Stater Brothers Market
www.staterbros.com

Sweeps Software, Inc.
Kevin Thrasher
www.sweepssoftware.com

Target Corp.
www.target.com

Taylor Technologies, Inc.
www.taylortechnologies.com

Texas Roadhouse
www.texasroadhouse.com

The Steritech Group, Inc.
www.steritech.com

Tri-County Health Department
www.tchd.org

Underwriters Laboratories, Inc.
www.ul.com

Waco-McLennan County Public Health District
http://waco-texas/cms-healthdepartment/

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

Waukesha County Public Health Division
sward@waukeshacounty.gov

Educational Institution Members

American Public University
Tatiana Sehring
www.StudyatAPU.com/NEHA

East Tennessee State University, DEH
Phillip Scheuerman
www.etsu.edu

Eastern Kentucky University
worley.johnson@eku.edu
http://eh.eku.edu

Georgia State University
Christine Stauber
cstauber@gsu.edu

Michigan State University, Online Master of Science in Food Safety
www.online.foodsafety.msu.edu

Ponce School of Medicine, Public Health Program
www.psm.edu/php

The University of Findlay
www.findlay.edu

University of Illinois Springfield
Sharron LaFollette
www.uis.edu/publichealth

University of Wisconsin–Stout, College of Science, Technology, Engineering, and Mathematics
www.uwstout.edu

SPECIAL **LISTING**

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

Ned Therien, MPH
Region 1
Vice President

Marcy A. Barnett, MA, MS, REHS
Region 2
Vice President

National Officers

President—Carolyn Hester Harvey, PhD, CIH, RS, DAAS, CHMM, Professor, Director of MPH Program, Department of Environmental Health, Eastern Kentucky University, Dizney 220, 521 Lancaster Avenue, Richmond, KY 40475.
Phone: (859) 622-6342
carolyn.harvey@eku.edu

President Elect—Bob Custard, REHS, CP-FS, 29 Hammond Drive, Lovettsville, VA 20180. Phone: (571) 221-7086
BobCustard@comcast.net

First Vice President—David E. Riggs, REHS/RS, MS, 2535 Hickory Avenue, Longview, WA 98632. Phone: (360) 430-0241
davideriggs@comcast.net

Second Vice President—Adam London, RS, MPA, Environmental Health Director, Kent County Health Department, 700 Fuller NE, Grand Rapids, MI 49503.
Phone: (616) 632-7266
adam.london@kentcountymi.gov

Immediate Past President—Alicia Enriquez Collins, REHS
enriqueza@comcast.net

Regional Vice Presidents

Region 1—Ned Therien, MPH,
Olympia, WA.
nedinoly@juno.com
Alaska, Idaho, Oregon, and Washington.
Term expires 2017.

Region 2—Marcy A. Barnett, MA, MS, REHS, Emergency Preparedness Liaison, California Department of Public Health, Center for Environmental Health, Sacramento, CA. Phone: (916) 449-5686
marcy.barnett@cdph.ca.gov
Arizona, California, Hawaii, and Nevada.
Term expires 2015.

Region 3—Roy Kroeger, REHS,
Environmental Health Supervisor, Cheyenne/Laramie County Health Department, 100 Central Avenue, Cheyenne, WY 82008.
Phone: (307) 633-4090
roykehs@laramiecounty.com
Colorado, Montana, Utah, Wyoming, and members residing outside of the U.S. (except members of the U.S. armed forces).
Term expires 2015.

Region 4—Keith Johnson, RS, Administrator, Custer Health, 210 2nd Avenue NW, Mandan, ND 58554.
Phone: (701) 667-3370
keith.johnson@custerhealth.com
Iowa, Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin.
Term expires 2016.

Region 5—Sandra Long, REHS, RS, Inspection Services Supervisor, City of Plano Health Department, 1520 K Avenue, Suite 210, Plano, TX 75074. Phone: (972) 941-7143 ext. 5282; Cell: (214) 500-8884
sandral@plano.gov
Arkansas, Kansas, Louisiana, Missouri, New Mexico, Oklahoma, and Texas.
Term expires 2017.

Region 6—Lynne Madison, RS,
Environmental Health Division Director, Western UP Health Department, 540 Depot Street, Hancock, MI 49930.
Phone: (906) 482-7382, ext. 107
lmadison@hline.org
Illinois, Indiana, Kentucky, Michigan, and Ohio. Term expires 2016.

Region 7—Tim Hatch, MPA, REHS,
Environmental Programs, Planning, and Logistics Director, Center for Emergency Preparedness, Alabama Department of Public Health, 201 Monroe Street, Suite 1310, Montgomery, AL 36104.
Phone: (334) 206-7935
tim.hatch@adph.state.al.us
Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, and Tennessee. Term expires 2017.

Region 8—LCDR James Speckhart, MS, USPHS, Health and Safety Officer, FDA, CDRH-Health and Safety Office, WO62 G103, 10903 New Hampshire Avenue, Silver Spring, MD 20993. Phone: (301) 796-3366
jamesmspeckhart@gmail.com
Delaware, Maryland, Pennsylvania, Virginia, Washington, DC, West Virginia, and members of the U.S. armed forces residing outside of the U.S. Term expires 2015.

Region 9—Edward L. Briggs, MPH, MS, REHS, Director of Health, Town of Ridgefield Department of Health, 66 Prospect Street, Ridgefield, CT 06877.
Phone: (203) 431-2745
eb.health@ridgefieldct.org
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. Term expires 2016.

Affiliate Presidents

Alabama—Haskey Bryant, MPH, MPA, Environmental Health Specialist, Jefferson County Dept. of Health, Birmingham, AL.
haskey.bryant@jcdh.org

Alaska—Ryan Autenrieth, REHS, Environmental Health Officer, Yukon-Kuskokwim Health Corporation, Bethel, AK.
aeha.net@gmail.com

Arizona—Michelle Chester, REHS, RS, Training Officer, Maricopa County Environmental Services Dept., Phoenix, AZ.
mchester@mail.maricopa.gov

Arkansas—Jeff Jackson, Camden, AR.
jeff.jackson@arkansas.gov

California—Sarah Crossman, REHS, Environmental Health Specialist IV, Riverside County Dept. of Environmental Health, Riverside, CA.
president@ceha.org

Colorado—Lane Drager, Consumer Protection Coordinator, Boulder County Public Health, Boulder, CO.
ldrager@bouldercounty.org

Connecticut—Stephen Civitelli, RS, Town of Wallingford, Wallingford, CT.
wlfdsan@yahoo.com

Florida—Jill Wallace, Winter Haven, FL.
kninetrainer@aol.com

Georgia—Chris Rustin, MS, DrPH, REHS, Environmental Health Section Director, Georgia Dept. of Public Health, Atlanta, GA.
chris.rustin@dph.ga.gov

Hawaii—John Nakashima, Sanitarian IV, Food Safety Education Program, Hawaii Dept. of Health, Hilo, HI.
john.nakashima@doh.hawaii.gov

Idaho—Patrick Guzzle, MA, MPH, REHS, Food Protection Program Manager, Idaho Dept. of Health and Welfare, Boise, ID.
guzzlep@dhw.idaho.gov

Illinois—Lenore Killam, Clinical Instructor, University of Illinois Springfield, Springfield, IL.
lkill2@is.edu

Indiana—Michael Mettler, Indiana State Dept. of Health, Indianapolis, IN.
mmettler@isdh.in.gov

Iowa—Sandy Heinen, Environmental Health Officer, Black Hawk County Health Dept., Waterloo, IA.
sheinen@co.black-hawk.ia.us

Jamaica—Steve Morris, Chief Public Health Inspector, Ministry of Health, St. Catherine, Jamaica.
president@japhi.org.jm

Kansas—Bronson Farmer, RS, HHS, Salina-Saline County Health Dept., Salina, KS.
farmerduo@hotmail.com

Kentucky—Leslie Cobb, Technical Consultant, Kentucky Food Safety Branch, Frankfort, KY.
leslie.cobb@ky.gov

Louisiana—Bill Schramm, Louisiana Dept. of Environmental Quality, Baton Rouge, LA.
bill.schramm@la.gov

Maryland—James Lewis, Westminster, MD.
jlewis@mde.state.md.us

Massachusetts—Alan Perry, REHS/RS, Health Agent, City of Attleboro, Attleboro, MA.
healthagent@cityofattleboro.us

Michigan—Carolyn Kreiger, REHS, Environmental Quality Analyst, Michigan Dept. of Environmental Quality, Kalamazoo, MI.
chobbs@meha.net

Minnesota—Jim Topie, REHS, Planner Principal, Minnesota Dept. of Health, Duluth, MN.
james.topie@state.mn.us

Mississippi—Queen Swayze, Food Program Specialist, Mississippi State Dept. of Health, Jackson, MS.
elizabeth.swayze@msdh.state.ms.us

Missouri—Paul Taylor, Environmental Representative, St. Louis County Health Dept., Berkeley, MO.
ptaylor@stlouisco.com

Montana—Erik Leigh, RS, Public Health Sanitarian, State of Montana DPHHS, Helena, MT.
eleigh@mt.gov

National Capitol Area—Shannon McKeon, Environmental Health Specialist, Fairfax, VA.
smckeon@ncaeha.com

Nebraska—Allen Brown, REHS, Environmental Health Inspector, Douglas County, Omaha, NE.
allen.brown@douglascounty-ne.gov

Nevada—Tamara Giannini, Environmental Health Supervisor, Southern Nevada Health District, Las Vegas, NV.
giannini@snhdmail.org

New Jersey—Robert Uhrik, Senior REHS, South Brunswick Township Health Dept., Township of South Brunswick, NJ.
ruhrik@sbtnj.net

New Mexico—Michael Broussard, CP-FS, Program Specialist, NMED, Santa Fe, NM.
michael.broussard@state.nm.us

New York—Contact Region 9 Vice President Edward L. Briggs.
eb.health@ridgefieldct.org

North Carolina—Jesse Dail, Environmental Health Specialist, Morehead City, NC.
jessed@carteretcountygov.org

North Dakota—Jane Kangas, Environmental Scientist II, North Dakota Dept. of Health, Fargo, ND.
jkangas@nd.gov

Northern New England Environmental Health Association—Co-president Brian Lockard, Health Officer, Town of Salem Health Dept., Salem, NH.
blockard@ci.salem.nh.us
Co-president Thomas Sloan, RS, Agricultural Specialist, New Hampshire Dept. of Agriculture, Concord, NH.
tsloan@agr.state.nh.us

Ohio—Eric J. Zgodzinski, MPH, RS, CPH, Director of Community and Environmental Health, Toledo-Lucas County Health Dept., Toledo, OH.
zgodzinski@co.lucas.oh.us

Oklahoma—James Splawn, RPS, RPES, Sanitarian, Tulsa City-County Health Dept.,

Tulsa, OK.
tsplawn@tulsa-health.org

Oregon—Delbert Bell, Klamath Falls, OR.
Dbell541@charter.net

Past Presidents—Mel Knight, REHS, Folsom, CA.
melknight@sbcglobal.net

Pennsylvania—TBD

Rhode Island—Dottie LeBeau, CP-FS, Food Safety Consultant and Educator, Dottie LeBeau Group, Hope, RI.
deejaylebeau@verizon.net

Saudi Arabia—Zubair M. Azizkhan, Environmental Scientist, Saudi Arabian Oil Company, Saudi Arabia.
Zubair.azizkhan@aramco.com.sa

South Carolina—Trey Reed, Regional Environmental Health Director, South Carolina Dept. of Health and Environmental Control, Aiken, SC.
reedhm@dhec.sc.gov

South Dakota—John Osburn, Pierre, SD.
john.osburn@state.sd.us

Tennessee—David Garner, Nashville, TN.
david.garner@tnenvironmentalhealth.org

Texas—Joanna Meyer, RS, Regional QA Manager, MBM, Ft. Worth, TX.
jmeyer@mbmfoodservice.com

Uniformed Services—MAJ Joseph Hout, MSPH, PhD, REHS, CPH, Industrial Hygiene Chief, Academy of the Health Sciences, Ft. Sam Houston, TX.
joseph.j.hout.mil@mail.mil

Utah—Michelle Cooke, LEHS, Program Manager, Weber-Morgan Health Dept., Ogden, UT.
mcooke@co.weber.ut.us

Virginia—Mark Cranford, REHS, CP-FS, Environmental Health Specialist, Virginia Dept. of Health, Charlottesville, VA.
mark.cranford@vdh.virginia.gov

Washington—Michael Baker, MS, PhD, Dept. of Environmental Health Director, Whitman County Public Health, Pullman, WA.
michael.baker@whitmancounty.net

West Virginia—Ronald Dellinger, REHS/RS, WVDHHR/BPH/OEHS/PHS, Beckley, WV.
jarod.r.dellinger@wv.gov

Wisconsin—Laura Temke, REHS, CP-FS, HHS, Environmentalist, City of West Allis Health Dept., West Allis, WI.
ltemke@westalliswi.gov

Wyoming—Tiffany Gaertner, REHS, CP-FS, EHS II, Cheyenne-Laramie County Health Dept., Cheyenne, WY.
tgaertner@laramiecounty.com

NEHA Historian

Dick Pantages, NEHA Past President, Fremont, CA.
dickpantages@comcast.net

Technical Advisors

Air Quality—David Gilkey, PhD, Associate Professor, Colorado State University, Ft. Collins, CO.
dgilkey@colostate.edu

Aquatic Venues/Recreational Health—Tracynda Davis, MPH, President, Davis Strategic Consulting, LLC, Colorado Springs, CO.
tracynda@gmail.com

Aquatic Venues/Recreational Health—Colleen Maitoza, REHS, CPO, Supervising Environmental Specialist, Sacramento County Environmental Management Dept., Sacramento, CA.
maitozac@gmail.com

Children's Environmental Health—Anna Jeng, MS, ScD, Associate Professor and Graduate Program Director, Old Dominion University, Norfolk, VA.
hjeng@odu.edu

Drinking Water/Environmental Water Quality—Sharon Smith, REHS/RS, Sanitarian Supervisor, Minnesota Dept. of Health, Fergus Falls, MN.
sharon.l.smith@state.mn.us

Emergency Preparedness and Response—Martin Kalis, Public Health Advisor, CDC, Atlanta, GA.
mkalis@cdc.gov

Emergency Preparedness and Response—Vince Radke, MPH, RS, CP-FS, DAAS, CPH, Sanitarian, CDC, Atlanta, GA.
vradke@cdc.gov

Emerging Pathogens—Lois Maisel, RN, CP-FS, Environmental Health Specialist, Fairfax County Health Dept., Fairfax, VA.
lois.maisel@fairfaxcounty.gov

Environmental Justice—Welford Roberts, PhD, DAAS, RS, REHS, Subject Matter Expert, Office of the Air Force Surgeon General and ERP International, LLC, South Riding, VA.
welford@erols.com

Food (including Safety and Defense)—Eric Bradley, MPH, REHS, CP-FS, DAAS, Environmental Health Specialist, Scott County Health Dept., Davenport, IA.
eric.bradley@scottcountyiowa.com

Food (including Safety and Defense)—John Marcello, CP-FS, REHS, Regional Retail Food Specialist, FDA, Tempe, AZ.
john.marcello@fda.hhs.gov

General Environmental Health—Ron de Burger, CPHI(C), Retired Director, Toronto Public Health, Toronto, ON, Canada.
rdeburger@gmail.com

General Environmental Health—ML Tanner, HHS, Program Manager, South Carolina Dept. of Health and Environmental Control, Columbia, SC.
tannerml@dhec.sc.gov

Global Climate Change and Health—Norbert Campbell, Lecturer, University of the West Indies, Kingston, Jamaica.
norbert.campbell02@uwimona.edu.jm

Hazardous Materials/Toxic Substances—Priscilla Oliver, PhD, Life Scientist/Regional Program Manager, U.S. EPA, Atlanta, GA.
POliverMSM@aol.com

Hazardous Materials/Toxic Substances—Sarah Keyes, MS, Health, Safety, and Environmental Manager, Peter Cremer North America, LP, Cold Spring, KY.
skeyes@petercremerna.com

Healthy Homes and Healthy Communities—Sandra Whitehead, MPA, PhD, Director of Healthy Community Design, National Association of County and City Health Officials, Washington, DC.
whitehead.sandra.1@gmail.com

Injury Prevention—Alan Dellapenna, RS, Branch Head, Injury and Violence Prevention Branch, North Carolina Division of Public Health, Raleigh, NC.
alan.dellapenna@dhhs.nc.gov

International Environmental Health—Sylvanus Thompson, PhD, CPHI(C), Associate Director, Toronto Public Health, Toronto, ON, Canada.
sthomps@toronto.ca

Land Use Planning/Design—Felix Zemel, MCP, MPH, REHS/RS, CEHT, HHS, DAAS, Health Agent, Cohasset Board of Health, Cohasset, MA.
felix.zemel@gmail.com

Legal—TBD

Occupational Health/Safety—D. Gary Brown, DrPH, CIH, RS, DAAS, Professor and Graduate Program Coordinator, Eastern Kentucky University, Richmond, KY.
gary.brown@eku.edu

Onsite Wastewater—Samendra Sherchan, PhD, Assistant Professor, California State University-Fresno, Fresno, CA.
ssherchan@csufresno.edu

Onsite Wastewater—Joelle Wirth, RS, Program Manager III, Environmental Quality Division, Coconino County Health Dept., Flagstaff, AZ.
jwirth@coconino.az.gov

Radiation/Radon—Tara Gurge, MS, RS, Environmental Health Agent, Town of Needham Public Health Dept., Needham, MA.
tgurge@needhamma.gov

Risk Assessment—Jason Marion, PhD, Assistant Professor, Eastern Kentucky University, Richmond, KY.
jason.marion@eku.edu

Schools/Institutions—Stephan Ruckman, Environmental Health Manager, Worthington City Schools, Dublin, OH.
mphosu@yahoo.com

Sustainability—Tom Gonzales, MPH, REHS, Environmental Health Director, El Paso County Public Health, Colorado Springs, CO.
tomgonzales@elpasoco.com

Sustainability—Timothy Murphy, PhD, REHS/RS, DAAS, Associate Professor and Dept. Chair, The University of Findlay, Findlay, OH.
murphy@findlay.edu

Technology (including Computers, Software, GIS, and Management Applications)—Darryl Booth, MPA, President, Decade Software Company, Fresno, CA.
darrylbooth@decadesoftware.com

Vector Control & Zoonotic Diseases—Zia Siddiqi, PhD, BCE, Director of Quality Systems, Orkin/Rollins Pest Control, Atlanta, GA.
zsiddiqi@rollins.com

Workforce Development, Management, and Leadership—CAPT Michael Herring, MPH, REHS, Senior Environmental Health Specialist/Training and Technical Assistance Team Leader, CDC, Atlanta, GA.
mherring@cdc.gov

Workforce Development, Management, and Leadership—George Nakamura, MPA, REHS, RS, CP-FS, DAAS, CEO, Nakamura Leasing, Sunnyvale, CA.
gmlnaka@comcast.net

NEHA Staff: (303) 756-9090

Rance Baker, Program Administrator, NEHA Entrepreneurial Zone (EZ), ext. 306, rbaker@neha.org

Trisha Bramwell, Customer & Member Services Specialist, ext. 336, tbramwell@neha.org

Laura Brister, Customer & Member Services Specialist, AEC Registration Coordinator, ext. 309, lbrister@neha.org

Patricia Churpakovich, Credentialing Coordinator, ext. 317, pchurpakovich@neha.org

Brian Collins, Interim Executive Director, ext. 301, bcollins@neha.org

Ginny Coyle, Grants/Projects Specialist, Research and Development (R&D), ext. 346, gcoyle@neha.org

Vanessa DeArman, Project Coordinator, R&D, ext. 311, vdearman@neha.org

Cindy Dimmitt, Receptionist, Customer & Member Services Specialist, ext. 300, cdimmitt@neha.org

Elizabeth Donoghue-Armstrong, Copy Editor, *Journal of Environmental Health,* nehasmtp@gmail.com

Eric Fife, Learning Content Producer, NEHA EZ, ext. 344, efife@neha.org

Soni Fink, Strategic Sales Coordinator, ext. 314, sfink@neha.org

Michael Gallagher, IFSS Logistics and Training Coordinator, NEHA EZ, ext. 343, mgallagher@neha.org

TJay Gerber, Credentialing Specialist, ext. 328, tgerber@neha.org

Dawn Jordan, Customer Service Manager, Office Coordinator, HR and IT Liaison, ext. 312, djordan@neha.org

Erik Kosnar, Learning Content Production Assistant, NEHA EZ, ext. 318, ekosnar@neha.org

Elizabeth Landeen, Assistant Manager, R&D, (702) 802-3924, elandeen@neha.org

Matt Lieber, Marketing and Communications Assistant, ext. 338, mlieber@neha.org

Marissa Mills, Project Assistant, R&D, ext. 304, mmills@neha.org

Eileen Neison, Credential Department Customer Service Representative, ext. 310, eneison@neha.org

Carol Newlin, Credentialing Specialist, ext. 337, cnewlin@neha.org

Terry Osner, Administrative Coordinator, ext. 302, tosner@neha.org

Barry Porter, Financial Coordinator, ext. 308, bporter@neha.org

Kristen Ruby-Cisneros, Managing Editor, *Journal of Environmental Health*, ext. 341, kruby@neha.org

Michael Salgado, Assistant Manager, NEHA EZ, ext. 315, msalgado@neha.org

Jill Schnipke, Education Coordinator, ext. 313, jschnipke@neha.org

Joshua Schrader, Sales & Training Support, NEHA EZ, ext. 340, jschrader@neha.org

Clare Sinacori, Marketing and Communications Manager, ext. 319, csinacori@neha.org

Christl Tate, Project Coordinator, R&D, ext. 305, ctate@neha.org

To update information, contact Terry Osner at tosner@neha.org.

ENVIRONMENTAL HEALTH ADVANCEMENT

ENVIRONMENTAL HEALTH EDUCATION & TRAINING

ENVIRONMENTAL HEALTH NETWORKING

ENVIRONMENTAL HEALTH POLICY INVOLVEMENT

AEC

JULY 13–15, 2015

79TH NEHA ANNUAL EDUCATIONAL CONFERENCE & EXHIBITION

IMAGINE THE NEW NEHA

Tools for Success Today and
Making a Difference for Tomorrow

REGISTER NOW

neha2015aec.org

NATIONAL ENVIRONMENTAL HEALTH ASSOCIATION

ORLANDO

So Much to Explore!

NEHA AEC DESIGNATED HOTEL

Renaissance Orlando at SeaWorld
Room rate: $129 per night + taxes and fees.
AEC attendees will not have to pay the hotel's resort or Internet fees.

For more information, visit neha2015aec.org and click the "Travel/Hotel" tab.

With dozens of theme parks and attractions, world-class golf courses, and miles of ocean and gulf beaches a short drive away, you will want to plan an extended stay in Orlando before or after (or both!) the conference. Cool off at a water park, visit an orange grove, take an airboat ride, or drive a NASCAR race car!

- SeaWorld Orlando
- Disney's Magic Kingdom, Animal Kingdom, Hollywood Studios, Epcot
- Kennedy Space Center and Visitor Complex
- Discovery Cove
- Legoland
- Universal Studios Florida including the Wizarding World of Harry Potter
- Richard Petty Driving Experience
- Busch Gardens Tampa
- Gatorland and Wild Florida Gator Park

GO AHEAD GIVE IN

VISIT THE ORLANDO ATTRACTIONS YOU'VE ALWAYS WANTED TO SEE!

SO MUCH MORE THAN A CONFERENCE

GAIN A FRESH PERSPECTIVE AND BE INSPIRED

120 EDUCATIONAL SESSIONS

24 HOURS OF NEHA CONTINUING EDUCATION

12 ENVIRONMENTAL HEALTH TRACKS

80–100 EXHIBITORS FOCUSED ON ENVIRONMENTAL HEALTH SOLUTIONS

The AEC is the nexus for environmental health training, education, networking, and advancement. It is the event environmental health professionals attend to acquire practical and real-world information and expertise. After attending the AEC, environmental health professionals leave trained, motivated, inspired, and empowered to further advance their organizations and themselves.

SHARE YOUR SUCCESSES AND LESSONS LEARNED

PRELIMINARY SCHEDULE

Schedule Subject to Change

Saturday, July 11

Review Courses: REHS/RS, CP-FS, CCFS, HACCP

Sunday, July 12

Review Courses: REHS/RS, CP-FS, CCFS
Exam: HACCP
Events:

- Community Event
- First Time Attendee Workshop
- Social Networking Event

Monday, July 13

Review Course: REHS/RS
Exams: REHS/RS, CP-FS, CCFS
Events:

- Education Sessions
- Keynote
- Networking Lunch
- Awards
- Exhibit Hall Grand Opening Party

Tuesday, July 14

Events:

- Education Sessions
- Exhibit Hall
- Lunch in Exhibit Hall

Wednesday, July 15

Events:

- Breakfast & Town Hall
- Education Sessions
- President's Banquet

REGISTRATION

	Member	Non-Member
Early Registration Full Conference: Includes admission for one person to: Networking Lunch, Exhibit Hall Grand Opening Party, and President's Banquet.	$575	$735
Early Registration Retired/Student: Does not include any food functions – tickets must be purchased separately.	$155	$230
Early One-Day Registration: Does not include any food functions – tickets must be purchased separately.	$310	$365

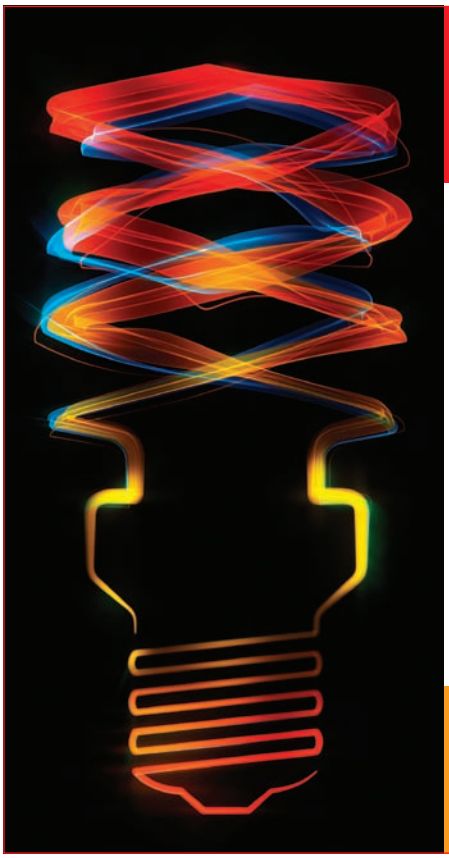
Registration information is available at neha2015aec.org. For personal assistance, contact Customer Service toll free at 866.956.2258 (303.756.9090 local), extension 0.

2015 Educational Contribution Award

This award was established to recognize NEHA members, teams, or organizations for an outstanding educational contribution within the field of environmental health. This award provides a pathway for the sharing of creative methods and tools to educate one another and the public about environmental health principles and practices. Don't miss this opportunity to submit a nomination to highlight the great works of your colleagues!

Nominations are due in the NEHA office by March 16, 2015.

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**.



2015 Nelson E. Fabian Environmental Health Innovation Award

This award recognizes 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.

Named in honor of former NEHA Executive Director Nelson Fabian, 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 16, 2015.

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**.

UL PUTS SAFETY AT THE TOP OF THE FOOD CHAIN

Full Service Solution Provider for the Food Service Industry

UL Everclean

For more than a century UL has employed exacting scientific processes and the highest ethical principles to deliver trusted results. Today, we continue to focus on the next generation of food safety challenges and more, helping the food service industry and stakeholders achieve safer living and work environments.

Learn about our many food service and food safety resources below:

FOOD SERVICE EQUIPMENT
UL.COM/APPLIANCES

FOOD SAFETY & BRAND PROTECTION
UL.COM/FOOD

RETAIL FOOD SAFETY TRAINING
ULEDUNEERING.COM/FOODSAFETY