Health Hazards:
Metals in Tattoo Inks and Hair Dyes

ABOUT THE COVER

In this month's cover feature, "Safety Evaluation of Metal Exposure From Commonly Used Hair Dyes and Tattoo Inks in Nigeria," the authors found that tattoo ink samples contained allergenic metals such as nickel, chromium, and cobalt at concentrations above the suggested limit of 1 µg/g, while metals in the hair dyes were below their respective specified limits in the majority of the samples. To guard against health hazards as a result of exposure to tattoo inks and hair dyes, the authors recommend the establishment of regulatory guidelines for metals in cosmetic products.

See page 26.

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New feature to the *Journal*—the E-*Journal* Bonus Article! You will find in this issue the first E-*Journal* bonus article. This article will only be found in the E-*Journal* and replaces the online prepublished article that NEHA used to publish with every issue. These online prepublished articles were made available to NEHA members via the Bookstore and My NEHA and were subsequently published in the January/February issue. Now members can access these articles through their E-*Journal* issues and NEHA will no longer publish the large compendium issue. The E-*Journal* gives NEHA the ability to provide you with another peer-reviewed article in a timely and convenient manner while eliminating the costs related to publishing the large compendium issue. It is our hope that authors and readers alike will see the benefits of the E-*Journal* bonus article.

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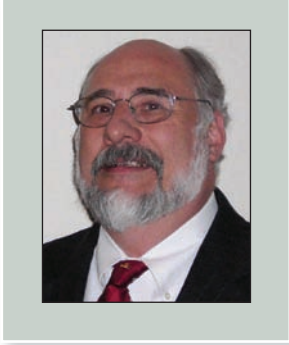
Building the Future Environmental Health Workforce

Bob Custard,
REHS, CP-FS

The baby boomers (those born between 1946 and 1964) are retiring. This is the generation that in 1970 sponsored the first Earth Day and gave birth to the environmental movement. This is the generation that initially populated the U.S. Environmental Protection Agency's workforce and similar state-level agencies across the country with responsibility for air quality, water quality, solid waste, and hazardous materials.

Over the next 20 years the retiring baby boom generation will take many years of environmental health experience and a lot of hard-won wisdom out of public health agencies, environmental protection agencies, and private companies. As this generational change occurs, there will be numerous environmental health positions left vacant by retirement that will need to be filled. Educating and training new environmental health professionals should be a national public health goal.

What Is NEHA Doing?

NEHA is committed to helping develop the environmental health workforce of the future. To learn how to better serve students, NEHA surveyed the Association of Environmental Health Academic Programs (AEHAP) and the National Environmental Health Science and Protection Accreditation Council (EHAC) members in attendance at the NEHA Annual Educational Conference (AEC) & Exhibition last July. As a result of the input gained from those surveys, NEHA is taking the following steps to help students jump start their environmental health careers:

- NEHA officers and regional vice presidents are being encouraged to visit the EHAC-

The professional legacy each of us leaves will not be in the programs we created or the awards we were honored with, but in the young professionals we trained, mentored, encouraged, and inspired.

accredited environmental health academic programs around the country and speak to students about environmental health career paths. For example, I will be speaking to the students at Eastern Kentucky University in mid-February.

- The NEHA board of directors has asked its membership committee to help interested parties form a new Student National Environmental Health Association (SNEHA).

- NEHA will more actively encourage employers to advertise environmental health jobs through the NEHA Web site.

- NEHA will encourage more educational institutions, in particular those institutions that offer an environmental health program, to join NEHA as educational institution members.

- At future AECs, a student registration will now include tickets for all the food func-

tions that are included in a regular conference registration such as the Exhibition Grand Opening & Party.

- The student AEC registration fee for 2016 will be only $180 (a 69% savings off the cost of regular member registration).

- Student AEC registration will now include a one-year, E-*Journal*-only NEHA student membership.

- To make NEHA's AEC more relevant to the millennial generation (those born between 1982 and 2004), the 2016 AEC will include a conference session that will be designed, arranged, and managed by recent college graduates. AEHAP will oversee development of this conference track.

- The deadline for students to submit to present at the AEC Student Poster Session will be extended until later in the year so that more students can present their research.

- NEHA participated in the American Public Health Association's 2015 Annual Conference panel session to shine a light on the emerging environmental health workforce, its needs, and opportunities for the future.

- NEHA has secured initial funding to conduct a national needs assessment of the existing environmental public health workforce. This assessment will provide greater insight into the needs and opportunities of the incoming workforce.

NEHA will also continue to assist students as follows:

- Providing deeply discounted memberships to students. The $15 student membership dues is an 84% savings compared to the cost of regular membership.

- Sponsoring a special session for student research presentations at the AEC.
- Recognizing outstanding student research through awards at the AEC.
- Together with the American Academy of Sanitarians, sponsoring academic scholarships for environmental health students.
- Working with the Centers for Disease Control and Prevention's National Center for Environmental Health to award summer internship opportunities to deserving environmental health students.

What Can NEHA's Affiliates Do?

Many NEHA affiliates are actively engaged in helping students through their scholarship programs. For example, the Michigan Environmental Health Association (MEHA) has grown its endowment fund to more than $100,000 by earmarking a small portion of each member's dues for the endowment fund and by hosting fundraising events such as clay shoots, raffles, and golf outings. The earnings from the MEHA endowment fund are used to fund scholarships and special projects each year.

Most NEHA affiliates offer students highly discounted memberships. For example, student membership in the National Capitol Area Environmental Health Association is just $5.00.

Similarly, many affiliates offer students greatly reduced prices on registrations for their annual educational conference. The Texas Environmental Health Association, for example, charges students just $25.00 to attend their three-day AEC. (Regular members pay $300.)

Some affiliates partner with the environmental health programs at universities in their state by locating their conferences on or near campus so that it is easy for students to attend. Several years ago, for example, the Virginia Environmental Health Association held their Spring Educational Conference at Old Dominion University. Several professors were invited as speakers.

Going forward, we would like to encourage our affiliates to help develop the future environmental health workforce in the following ways:
- Reaching out to environmental health students to get them involved in meaningful ways in their NEHA affiliate;
- Expanding their student scholarship programs;

- Creating educational conferences that are conveniently located and affordable for students;
- Sending outstanding environmental health professionals to universities to speak about career opportunities in environmental health; and
- Sponsoring SNEHA affiliates at the universities in their state that have environmental health academic programs.

What Can Employers Do?

Employers in both government and private industry can also play an important role in helping develop the future environmental health workforce. Specifically they can do the following:
- Provide internship and volunteer opportunities for students to gain hands-on experience applying their environmental health knowledge;
- Encourage their outstanding staff members to mentor young environmental health professionals; and
- Advertise their job openings on NEHA's Web site and in publications like the *JEH* so that more graduating students become aware of the opportunities open to them.

What Can Universities Do?

The de Beaumont Foundation recently published researched suggesting that the ninth most popular undergraduate degree in the U.S. is public health. Universities with strong environmental health programs are one of the prime sources of qualified candidates for the future environmental health workforce. Many of today's environmental health leaders came from these programs.

Most of these universities have strong practicum or internship programs. For example, Western Carolina University has an outstanding program for placing their students in North Carolina state and local environmental health, emergency preparedness, and industrial hygiene agencies. They also collaborate with the U.S. Public Health Service internship program.

Some environmental health academic programs like Eastern Kentucky University pay for each of their students to take the Registered Environmental Health Specialist/Registered Sanitarian (REHS/RS) exam immediately after graduation. This credentialing provides a significant advantage to these

students as they look for their first full-time environmental health job.

Going forward, we would like to encourage environmental health academic programs as follows:
- Continue expanding their internship and practicum programs. A job applicant's practical experience is a significant factor in the hiring decisions of environmental health managers.
- Ensure that each of their students has the opportunity to take the REHS/RS exam immediately after graduation.
- Create a SNEHA affiliate chapter on their campus that will enrich the professional experience of their students.
- Synergistically collaborate with their state or regional NEHA affiliate to create events or educational conferences that benefit both students and environmental health professionals in the field.

What Can You Do?

Successful environmental health practice is as much about the values we bring to the job as it is about the scientific knowledge we apply. It has often been said that "values are caught, not taught." What values are our colleagues "catching" from us? Are our actions teaching integrity, patience, persistence, and dependability? Are we relentless learners that strive for professional excellence?

The professional legacy each of us leaves will not be in the programs we created or the awards we were honored with, but in the young professionals we trained, mentored, encouraged, and inspired. I encourage you to do three things:
- Bring your best to work each day and model the values for which you wish to be remembered. Help your colleagues "catch" your positive attitudes and passion for environmental health.
- Be a mentor to your younger colleagues. Leave a legacy of excellence and kindness by teaching those who follow you the skills of our profession.
- Invest in a student with a generous donation to the NEHA Scholarship Fund. To donate to NEHA's Scholarship Fund go to www.neha.org/donate.

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Gender Differences in Respiratory Health of School Children Exposed to Rail Yard–Generated Air Pollution: The ENRRICH Study

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Abstract **Studies about environmental burdens often explore overall community risk. Increasing evidence suggests, however, differential burdens by gender and age. The purpose of the authors' research was to determine if gender-related difference exists among children in a region plagued with poor air quality and if increased exposure to pollutants from a major goods movement rail yard influences the relationship. Using a cross-sectional study design, the authors provided respiratory screening for children at two elementary schools. Compared to females, males were at significantly greater odds of exhibiting elevated fractional exhaled nitric oxide (FeNO) but less likely to exhibit reduced lung volume. Even in an area of overall poor air quality, the authors found that male children were a vulnerable subpopulation for greater elevated FeNO, while females were at increased risk for reduced lung capacity. Understanding differential burdens in vulnerable subpopulations is critical to providing timely and responsive strategies targeted towards health-based prevention and intervention activities.**

Introduction

Interest is increasing in studying gender-related differences associated with air pollution studies (Hwang, Chen, Lin, Wu, & Leo Lee, 2015). While it is well established that younger age is a risk factor for poorer respiratory health (Pope, 2000; Schwartz, 2004), recent epidemiological evidence suggests differing effects by gender; however, the results are far from consistent (Clougherty, 2010). Also, most studies have focused on the effects of traffic-related air pollution exposure, but limited consideration has been given to emissions from major transportation goods movement facilities, such as rail yards (Castaneda et al., 2008; Gehring et al., 2002; Spencer-Hwang et al., 2014).

Risk may stem both from pollutants emitted as well as the characteristics of the individual pollutants and ultimately result in different adverse health impacts depending on the gender of the exposed. Since some locations are burdened by several sources of pollution, research is also needed to assess the cumulative health impact on residents living in close proximity to these local sources (Fox, 2002). Indeed, no research exists on the potential adverse health impacts on children living in close proximity to a major rail yard located in an already polluted area and if effects differ by gender.

Gender-related air pollution studies have reported mixed findings (Clougherty, 2010). Many studies have linked chronic exposure to air pollution with a wide range of respiratory health outcomes, including retarded lung function and growth, asthma onset and exacerbation, wheezing, respiratory infections, cough, and other related symptoms among children aged 0–18 years of age. In a study conducted by Peters and co-authors (1999), researchers identified gender-influenced differences among children in grades 4, 7, and 10 across 12 communities in Southern California and found stronger relationships between ambient air pollutants (nitrogen dioxide, ozone, and particulate matter 2.5 µm in diameter or less) and reduced lung volume among girls. In that study, an association was identified for boys, but not as strong as the association found for girls. In a Canadian study of children aged 0–14 years of age, girls were more likely to be hospitalized with a respiratory ailment with increased exposure to ambient air pollutants such as carbon monoxide and nitrogen dioxide (Luginaah, Fung, Gorey, Webster, & Wills, 2005).

In contrast to these findings indicating an increased risk for females, a number of researchers have found stronger and significant adverse respiratory health outcomes for males (Delfino et al., 2004; Gehring et

FIGURE **1**

Map of the Study Area

This map illustrates the location of the exposure elementary school (EES) and the control elementary school (CES), relative to the San Bernardino Railyard and in relation to the transportation infrastructure (railroads and roadways). The dashed circles identify the areas where two-thirds (approximately 67%) of the participating students at each school reside.

al., 2002), while researchers in a study conducted in Mexico City found no clear gender differences (Rojas-Martinez et al., 2007).

The inland region of Southern California may provide a unique opportunity for health research examining this issue, given the perennially poor air quality experienced by San Bernardino County's residents, combined with the existence of several local major freight rail yards. The air quality problem is exacerbated in the inland community of San Bernardino as the prevailing winds transport air pollutants eastward from Los Angeles. Air pollution becomes trapped by the mountains surrounding the inland region, which leads to high concentrations of pollutants when coupled with the routinely stagnant air flow and temperature inversions. Thus San Bernardino is regularly at or near the bottom of U.S. air quality rankings for ozone and fine particulate air pollution in the U.S. according to the U.S. Environmental Protection Agency and the American Lung Association (ALA).

In this article, we utilize data collected as part of the Environmental Railyard Research Impacting Community Health (ENRRICH) Project, a community health outcomes study designed to better understand the health risks among local residents living in close proximity to the San Bernardino Railyard (SBR). A series of health risk assessments conducted by the California Air Resource Board (CARB) across the 18 major rail yards indicates that SBR may pose the greatest health risk to its surrounding communities as it is the largest source of air pollution immediately adjacent to densely populated areas (Castaneda et al., 2008). The purpose of this investigation was to determine if a gender-related difference exists for adverse respiratory health outcomes among children living and attending school in close proximity to SBR compared with children living in the same region but farther away from the rail yard.

Materials and Methods

Study Location
SBR is located in a densely populated area in inland Southern California, characterized by poor air quality for ozone and fine particulate matter air pollution. This region has experienced an increase in population growth while facing severe social challenges and a weakened economy. It is home to predominantly young, low-income, Hispanic populations.

Air pollution emission sources at this 24/7 rail yard facility include diesel locomotives, on-road and off-road loading equipment and associated machinery, and typical roadway vehicles. Diesel particulate matter (DPM) is the dominant air pollutant, although air toxics (e.g., benzene and 1,3-butadiene) are also emitted in small amounts (Castaneda et al., 2008). CARB has estimated the SBR's combined DPM emissions and other significant non-rail-yard (mobile and stationary) sources within a one-mile radius of the facility at 33 tons per year (Castaneda et al., 2008).

Study Design
We used a cross-sectional design to compare two sociodemographically similar schools (Figure 1) matched by a GIS-derived sociodemographic profile: one located 500 m downwind from SBR, the exposure elementary school (EES); and the second, the control elementary school (CES), located seven miles west of SBR.

After obtaining Loma Linda University institutional review board and school district approval, an explanatory letter, consent form, and a short questionnaire were sent to the parents of the children. An assembly in the form of a theatrical play with an air quality theme was conducted to encourage students to tell their parents/guardians about the study and return active parental permission slips and a parent-completed child health questionnaire, resulting in 74% of children screened. School-based respiratory health screenings were conducted during late February 2012, with students from grades K–5 screened throughout the school day.

Screening Clinics
Trained technicians using standardized methods collected peak expiratory flow (PEF) and fractional exhaled nitric oxide (FeNO), along with height and weight to determine each child's body mass index (BMI) (CDC, 2011). Screenings were conducted in partnership with the San Bernardino County Breathmobile Program (SCBP), a no-cost mobile pediatric asthma disease management program staffed by a physician, a licensed vocational nurse, a clinic assistant, and a respiratory therapist specially trained in asthma case management. Children who exhibited respiratory values outside normal PEF range, or per the parental survey had asthma, received additional spirometry testing by the SCBP staff and were offered free follow-up medical care.

PEF

PEF was assessed using a peak flow meter. The highest of three readings was used in analyses after having been transformed into the percentage of the predicted PEF according to the child's height based on manufacturer's guidelines.

FeNO Determination

Nitric oxide in exhaled breath reflects the redox state of the airway and has been proposed as a biomarker of lung tissue injury and inflammation (Dweik et al., 2010). FeNO was measured once with the child in a sitting position using a NIOX MINO instrument.

Potential Confounders

Potential confounders included the following variables:

1) *From the parental questionnaire.* Sociodemographic, residential, and health history information was collected including gender (male/female), age (years), grade (kindergarten, 1st, 2nd, 3rd, 4th, 5th), race (non-Hispanic white, non-Hispanic black, Hispanic, other), furry pets in the home (yes/no), time spent outdoors (<12 hrs. per week, 12–24 hrs. per week, >24 hrs. per week), exposure to environmental tobacco smoke (ETS) (yes/no), type of home heating system (gas, wood burning stove/fireplace, coal/oil, other), length of time at current address (months), physician diagnosis of asthma for their child (yes/no), use of asthma inhaler medication (yes/no), and lack of access to medical care (yes/no).

2) *Census-derived neighborhood characteristics.* Using GIS, we created several variables to characterize population density, housing indicators, and median household income at the census block group (BG) level using 2010 census figures and definitions. These neighborhood-level indicators were assigned to study subjects from both schools according to their residential BG.

3) *Traffic-related air pollution exposures.* We modeled proximity to major roadways as a proxy for residential exposure and school exposure to traffic emissions. Distance from the subjects' residence to nearest major roads (freeway, highway, and arterials) was estimated through GIS mapping methods described previously (McConnell et al., 2006; Newcomb & Li, 2008; Rioux,

Gute, Brugge, Peterson, & Parmenter, 2010; Wilhelm et al., 2008).

4) *DPM exposure variables.* To account for exposures to DPM emissions from local sources, we used data from the Multiple Air Toxics Exposure Study III (MATES-III), a regional emissions gridded inventory of air toxics emissions developed by the South Coast Air Quality Management District (Ospital, Cassmassi, & Chico, 2008). A GIS raster data set replicated the spatial coverage and resolution of the MATES-III inventory and the combined DPM (kg/day) air emissions from local stationary, on-road, and off-road sources were computed for each 2-km x 2-km grid cell and linked to participant geocoded residential addresses to assign total DPM emission. Background, non-rail-yard-related DPM emissions (both stationary and mobile sources) were found to be similar for EES and CES sites.

Statistical Analysis

Descriptive and summary estimates (i.e., percentages, means, medians, and standard deviations/variances) were assessed with Chi-square tests and t-tests. The association of gender with respiratory health measures, PEF and FeNO, was assessed using logistic regression models that facilitated the calculation of the odds ratios (*OR*) and 95% confidence intervals (95% *CI*). FeNO values were dichotomized into elevated inflammation (≥20 parts per billion) versus normal, based on cutpoints previously identified (Dweik et al., 2011). PEF values were dichotomized into decreased lung function (<80% of predicted value) versus normal, based on cutpoints previously described by ALA. The dichotomized respiratory health endpoints (PEF and FeNO) were assessed individually as outcomes of interest within the logistic regression models. The final model for independent variables included gender, school, age, race, exposure to ETS, time spent outdoors, median household income, total diesel pollution, and proximity to nearest major road. Health endpoints were the dependent variables. For the intraschool comparison, males were compared with females within school. For the interschool comparison, males were compared with males and females with females between the two schools. An additional sensitivity analysis was conducted to exclude the students from the model who had not lived at

their current address for at least six months. All statistical analyses were conducted using SAS version 9.4.

Results

General Characteristics and Distribution of Respiratory Outcomes of Participants

A total of 1,066 children (561 females and 505 males) participated in our study. The majority of the children screened were Hispanic (81%) (Table 1), and most lived fewer than two miles from their school (Figure 1). No significant differences were identified between males and females for most of the potential confounding factors including age, race, BMI, time spent outdoors, exposure to ETS, neighborhood median household income, and background (non-rail-yard-related) diesel exposure. Significant differences were identified for parent-reported doctor asthma diagnosis, use of asthma inhaler medications, and PEF and FeNO breath test results. Approximately 42% (*n* = 452, 43% males and 42% females) of the children screened were identified as having respiratory health issues. Children were identified with a respiratory health issue based on prior asthma diagnosis, use of asthma inhaler medication, or poor PEF or FeNO results. The proportion of children identified as having a respiratory health issue did not significantly differ by gender for all schools combined. When both schools were compared, however, 48% of the EES females compared to 35% of CES females (Chi-square *p*-value < .01) were identified as having respiratory challenges while no significant difference was found for males (EES = 47% and CES = 40%, Chi-square *p*-value > .10).

Associations Between Rail-Yard-Related Exposures and Respiratory Outcomes

Logistic regression results (Tables 2–4) for both schools combined showed that males had significantly greater odds (*OR*: 1.74, 95% *CI*: 1.20–2.54) of exhibiting elevated FeNO values than females. Males had significantly lower odds (*OR*: 0.69, 95% *CI*: 0.49–0.96), however, for exhibiting low PEF values (Table 2). In comparing the respiratory outcomes among the male students by school, students at the EES were at greater odds of elevated FeNO values and low PEF compared to the males at the CES; however, the results were not statistically significant (Table 3).

Demographics and Baseline Characteristics of Children Participating in the Environmental Railyard Research Impacting Community Health Study

Demographic	All Subjects (*N* = 1,066) # (%)	Control Elementary School (*n* = 531)		Exposure Elementary School (*n* = 535)	
		Males (*n* = 249) # (%)	Females (*n* = 282) # (%)	Males (*n* = 256) # (%)	Females (*n* = 279) # (%)
Age, years (mean ± *SD*)	8.00±1.8	8.03±1.8	7.99±1.8	7.99±1.8	7.98±1.8
Race/ethnicity					
White	50 (4.7)	13 (5.2)	13 (4.6)	12 (4.7)	12 (4.3)
Hispanic	865 (81.1)	199 (79.9)	224 (79.4)	211 (82.4)	231 (82.8)
African-American	54 (5.1)	13 (5.2)	24 (8.5)	10 (3.9)	7 (2.5)
Other	95 (9.0)	23(9.2)	20 (7.1)	23 (9.0)	29 (10.4)
Grade					
Kindergarten	146 (13.7)	41 (16.5)	43 (15.2)	27 (10.5)	35 (12.5)
1st	175 (16.4)	28 (11.2)	37 (13.1)	59 (23.0)	51 (18.3)
2nd	196 (18.4)	40 (16.1)	54 (19.1)	49 (19.1)	53 (19.0)
3rd	175 (16.4)	46 (18.5)	49 (17.4)	35 (13.7)	45 (16.1)
4th	193 (18.1)	58 (23.3)	46 (16.3)	44 (17.2)	45 (16.1)
5th	181 (17.0)	36 (14.5)	53 (18.8)	42 (16.4)	50 (17.9)
Body mass index (kg/m^2)					
Underweight (<18.5 kg/m^2)	43 (4.0)	18 (7.2)	12 (4.3)	2 (0.8)	11 (3.9)
Normal (18.5–24.9 kg/m^2)	590 (55.4)	132 (53.0)	155 (55.0)	139 (54.3)	164 (58.8)
Overweight (25.0–29.9 kg/m^2)	174 (16.3)	35 (14.1)	52 (18.4)	41 (16.0)	46 (16.5)
Obese (>30 kg/m^2)	259 (24.3)	64 (25.7)	63 (22.3)	74 (28.9)	58 (20.8)
Time spent outdoors					
<12 hours per week	399 (37.4)	85 (34.1)	113 (40.1)	88 (34.4)	113 (40.5)
12–24 hours per week	399 (37.4)	100 (40.2)	108 (38.3)	105 (41.0)	86 (30.8)
>24 hours per week	172 (16.1)	33 (13.3)	41 (14.5)	45 (17.6)	53 (19.0)
Lived with smoker					
Yes	209 (19.6)	60 (24.1)	54 (19.1)	45 (17.6)	50 (17.9)
Medical services needed but couldn't access					
Yes	12 (1.2)	3 (1.2)	4 (1.4)	2 (0.8)	3 (1.1)
Parent-reported doctor-diagnosed asthma					
Yes	136 (12.8)	34 (13.7)	43 (15.2)*	38 (14.8)	21 (7.5)
Use of asthma inhaler					
Yes	130 (13.5)	36 (14.5)	37 (13.1)*	40 (15.6)	17 (6.1)
PEF[a]					
<80% of predicted mean ± *SD* (L/min)	225 (21.1) 208±61.1	48 (19.3) 211±59.8	88 (31.2) 192±57.7**	40 (15.6) 226±66.4	49 (17.6)* 204±56.1**
NIOX (FeNO[a])					
FeNO ≥20 parts per billion (ppb) Mean ± *SD* (ppb)	174 (16.3) 13.3±14.9	57 (22.9) 14.7±15.6	32 (11.3) 11.9±14.7	48 (18.8) 14.2±16.1	37 (13.3)** 12.5±13.2
Median household income					
Mean ± *SD*	43,779±13,620	38,415±12,448	39,030±12,675	48,821±12,910	48,856±12,628
Non-rail-yard-related diesel exposure (mobile and stationary sources)					
Mean ± *SD* (kg/day)	6.51±1.33	6.11±1.34	6.23±1.91	6.85±0.81	6.83±0.68

Note. Some columns do not add to 100% because of missing data. For continuous outcomes, comparison by Student's *t*-test. For categorical outcomes, comparison by Chi-square test.
[a]PEF = peak expiratory flow; FeNO = fractional exhaled nitric oxide.
*p < .01.
**p < .001.

TABLE **2**

Logistic Regression Modeling Results of Children Experiencing Adverse Respiratory Related Health Outcomes: Overall Males Compared to Females

Result			All Subjects		Sensitivity Analysis[c]		
			Crude	Adjusted[d]			Adjusted[d]
Health outcomes	n	Events	OR[b] (95% CI[b])	OR (95% CI)	n	Events	OR (95% CI)
PEF[a] <80%	1,065	225	0.65 (0.48–0.88)	0.69 (0.49–0.96)	853	164	0.76 (0.53–1.08)
FeNO[a] ≥20 parts per billion	1,052	174	1.87 (1.34–2.61)	1.74 (1.20–2.54)	843	133	1.73 (1.17–2.54)

[a]PEF = peak expiratory flow; FeNO = fractional exhaled nitric oxide.
[b]OR = odds ratio; 95% CI = 95% confidence interval.
[c]Sensitivity analysis included only subjects residing more than six months at their current address.
[d]Model = sex (1 = males, 0 = females), school, age, race, environmental tobacco smoke, time spent outdoors, median household income, total diesel pollution, and proximity to nearest major road.

TABLE **3**

Logistic Regression Modeling Results of Children Experiencing Adverse Respiratory Related Health Outcomes: Gender-Specific Interschool Comparison

Variables					All Subjects		Sensitivity Analysis[e]		
					Crude	Adjusted[d]			Adjusted[d]
Gender	School	Health Outcomes	n	Events	OR[c] (95% CI[c])	OR (95% CI)	n	Events	OR (95% CI)
Males only	EES[a] with CES[a]	PEF[b] <80%	504	88	1.29 (0.81–2.05)	1.59 (0.80–3.17)	403	69	1.42 (0.66–3.04)
		FeNO[b] ≥20 parts per billion (ppb)	497	105	1.29 (0.84–1.98)	1.44 (0.75–2.77)	399	78	1.55 (0.77–3.12)
Females only	EES with CES	PEF <80%	561	137	2.13 (1.43–3.17)	2.24 (1.30–3.85)	451	95	1.73 (0.93–3.23)
		FeNO ≥20 ppb	554	69	0.84 (0.51–1.39)	1.37 (0.73–2.58)	451	55	1.35 (0.70–2.59)

[a]EES = exposure elementary school; CES = control elementary school.
[b]PEF = peak expiratory flow; FeNO = fractional exhaled nitric oxide.
[c]OR = odds ratio; 95% CI = 95% confidence interval.
[d]Model = school (1 = EES, 0 = CES), age, race, environmental tobacco smoke, time spent outdoors, median household income, total diesel pollution, and proximity to nearest major road.
[e]Sensitivity analysis included only subjects residing more than six months at their current address.

When comparing only the females between the two schools, we found that the students at the EES had greater odds for elevated FeNO values and significantly greater odds for low PEF (OR: 2.24, 95% CI: 1.30–3.85). A within-school analysis comparing males with females was performed to assess the effect of increased proximity to the rail yard on the potential gender-related adverse respiratory health outcomes. At both schools, males had greater odds than females of exhibiting elevated FeNO values, within the adjusted models (Table 4). Males were less likely than females, however, to exhibit low PEF. These gender-related adverse respiratory health outcomes were magnified at the EES. For males, elevated FeNO values of increased odds of 1.66 vs. 1.93 were observed, as was a decrease in odds for low PEF from 0.83 to a significantly protective effect of 0.59.

Discussion

In our study, we observed differing adverse respiratory health endpoints by gender. Moreover, in a region characterized by poor background-level air quality, both genders were at risk for experiencing adverse respiratory health outcomes. Compared to females, males were significantly more likely to exhibit elevated FeNO values, indicative of airway inflammation, but significantly less likely to experience low PEF. While males in both schools had greater odds of exhibiting elevated FeNO values, the gender-related differences in adverse respiratory health endpoints were enhanced for the school next to the rail yard; males were significantly more likely to exhibit elevation in FeNO values and females were more likely to exhibit reduced lung vol-

Logistic Regression Modeling Results of Children Experiencing Adverse Respiratory Related Health Outcomes: Gender-Specific Intraschool Comparison

Variables					All Subjects		Sensitivity Analysis[e]		
					Crude	Adjusted[d]			Adjusted[d]
Gender	School	Health Outcomes	n	Events	OR[c] (95% CI[c])	OR (95% CI)	n	Events	OR (95% CI)
Males with females	CES[a] only	PEF[b] <80%	535	89	0.87 (0.55–1.37)	0.83 (0.50–1.38)	437	72	0.87 (0.51–1.47)
		FeNO[b] ≥20 parts per billion (ppb)	527	85	1.51 (0.95–2.41)	1.66 (0.95–2.89)	432	61	1.58 (0.89–2.80)
Males with females	EES[a] only	PEF <80%	531	136	0.53 (0.35–0.79)	0.59 (0.37–0.92)	417	92	0.64 (0.39–1.04)
		FeNO ≥20 ppb	525	89	2.32 (1.45–3.72)	1.93 (1.14–3.26)	411	72	1.92 (1.12–3.32)

[a]EES = exposure elementary school; CES = control elementary school.
[b]PEF = peak expiratory flow; FeNO = fractional exhaled nitric oxide.
[c]OR = odds ratio; 95% CI = 95% confidence interval.
[d]Model = sex (1 = males, 0 = females), age, race, environmental tobacco smoke, time spent outdoors, median household income, total diesel pollution, and proximity to nearest major road.
[e]Sensitivity analysis included only subjects residing more than six months at their current address.

ume. Since previous studies lacked consistent results on gender-related adverse health outcomes associated with air pollutants, our study provides further support for the studies supporting the existence of gender-related differences in adverse respiratory outcomes associated with air pollutants.

Unique Exposure Environment/Setting
Our data suggest that the unique setting of the San Bernardino area, with the air pollutants transported from the Los Angeles basin by the prevailing winds, along with exposure to a major local rail yard source, could enhance potential gender differences in respiratory health outcomes. Recent evidence indicates that the concentration of quinones, the key agents in the toxicity of polycyclic aromatic hydrocarbons (PAHs), increases significantly in an eastward direction from Santa Monica/Long Beach toward the inland valleys of Southern California, and that 90% of these organic compounds measure at receptor sites inland are generated photolytically during atmospheric transport (Eiguren-Fernandez et al., 2008). Both the EES and CES schools are exposed to the toxically enhanced organic species as they travel inland, which our data suggest indeed impact the respiratory health of students. In addition, students at the EES are exposed to a local source of air pollution

from this major freight rail yard, thus further exacerbating the respiratory health impacts experienced by inland area students.

Of note, the constituents in the rail yard–related emissions are likely to differ from those in traffic-related air pollution. Railyard emissions are associated with combustion from diesel engines as well as other emission sources associated with the specific daily functions of the rail yard (e.g., arriving and departing trains, fueling of equipment and trains, maintenance) (ENVIRON International, 2007). It has been shown that the diesel engines emit large quantities of fine particulate matter, PAHs, volatile organic carbons, carbon dioxide, carbon monoxide, and nitrogen oxides. Diesel exhaust also contains other carcinogens including benzene, formaldehyde, and arsenic. It's therefore possible that EES pollutants may differ in their chemical composition from those associated with roadway traffic. The arrival and departure of trains may produce shavings of tiny metal particles as metal-to-metal friction is taking place. Indeed, a study conducted of the subway system in New York City has identified a microenvironment for heavy metal exposures with higher iron, manganese, and chromium in airway samples due to steel dust exposure (Chillrud et al., 2005). Additionally, another study has found gender-related differences

in adverse health responses linked to heavy metal exposures (Llop, Lopez-Espinosa, Rebagliato, & Ballester, 2013; Vahter, Akesson, Liden, Ceccatelli, & Berglund, 2007).

Implications of Study Findings
The findings from our study have a number of implications especially for school and local health professionals in areas with air quality issues, but also for key government officials and local institutions. Local health professionals should be aware of the potential impact on the respiratory health of residents living in regions with high background levels of air pollutants, especially with the added burden of exposure to rail-yard-associated emissions and that these adverse respiratory health endpoints may differ by gender.

Given the fact that air pollution has been shown to promote initial development of asthma in children, routine asthma screening should be offered to all children attending schools in areas burdened with complex air pollution (McConnell et al., 2010). Health professionals have a responsibility to consider the impact of these environmental conditions on growing children, especially on children from low-income minority households who often already live stressful lives and are, according to emerging evidence, at even greater risk of adverse respiratory health

effects (Islam et al., 2011; Shankardass et al., 2009). Chen and co-authors (2008) have reported that chronic traffic-related air pollution and stress interact to predict biologic and clinical outcomes in asthma that are stronger than either factor alone. Proximity to a major air emissions source like the rail yard may further increase difficulty in asthma management for children complicated by differential gender presentation. A better understanding of the gender-related difference in response to different types of air pollutant exposure may lead to novel prevention and treatment strategies for children residing in areas with multisource air pollution.

In addition to implications for school and health officials, implications also exist for government officials and institutional agencies serving these high-impact areas. Indeed, the needs of these types of affected communities should be addressed by taking a Health in All Policies (HiAP) approach (National Association of County and City Health Officials, 2013; Spencer-Hwang et al., 2014). Coordinated efforts should focus on responsive policy development and implementation to ensure beneficial effects moving toward prevention, as well as delivery of health services to address already emerging needs within the community. As imports into the U.S. continue to grow and expansion of inland ports is a reality, results of this study should provide caution toward protecting children who are among the most vulnerable of the affected communities and allow them a chance at an environment where they can live and thrive (Landrigan & Etzel, 2014).

Strengths and Limitations

Our study has a number of strengths that merit discussion. Rather than merely relying on the self-reporting of individuals participating in the study, biological measurements were obtained, including tests on airway inflammation (FeNO) as well as lung function (PEF). The comparison school was sociodemographically matched to the exposure school to allow for a robust comparison. The schools were in close proximity to each other and therefore subject to virtually the same levels of regional air pollution, allowing us to assess the additional rail-yard-related risk in an environment already burdened by poor background-level air quality. Finally, a high overall study participation rate (74%) allowed us to obtain a large sample of participants for whom we had complete data.

Our research also had some limitations. One, school location, rather than actual personal exposure measurements, was used as a surrogate of exposure. Additionally, due to the cross-sectional design of our study, a causal association between FeNO and PEF outcomes and exposure to DPM between CES and EES students cannot be established. Future research studies should attempt to collect individual longitudinal exposures on children as has been done in adults (Spira-Cohen, Chen, Kendall, Lall, & Thurston, 2011; van Roosbroeck et al., 2006), such as having participants carry personal monitoring equipment for an extended period of time. Another limitation was the difficulty of isolating the exposures to rail-yard-related (on-site) emissions given the presence of other (off-site) local sources of pollution. The 2008 CARB report has documented, however, that the SBR accounts for 66% of the combined on-site and off-site DPM emissions and adjustments were made to take that into account in our model.

Conclusion

In summary, emerging epidemiological evidence indicating the existence of gender-related differences in adverse respiratory health outcomes is supported by the findings from this research study (Brunekreef et al., 1997; Delfino et al., 2004; Llop et al., 2013; Vahter et al., 2007). We also found that increased exposure to air pollution from a major goods movement rail yard additionally contributes (adversely) to enhancing gender-related respiratory health outcomes, even in an area plagued with poor background air quality. Further research is warranted to better understand the impact of air pollution on the gender-related respiratory differences and for potential development of novel prevention and treatment strategies.

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‣ **INTERNATIONAL PERSPECTIVES**

A Step Towards Improving Food Safety in India: Determining Baseline Knowledge and Behaviors Among Restaurant Food Handlers in Chennai

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Abstract **With the establishment of the Food Safety and Standards Authority of India (FSSAI) and new food safety regulations, a precedent has been set to prevent foodborne illness in India. The objective of the authors' study was to identify knowledge gaps among food handlers in Chennai, Tamil Nadu, to establish priorities for future intervention. A 44-question survey was administered to 156 food handlers at 36 restaurants in Chennai between April and June of 2011. The overall mean knowledge score was 49% and knowledge gaps related to hand hygiene, proper food cooking and holding temperatures, and cross contamination were identified. Food handlers with a Medical Fitness Certificate scored significantly higher than those without a certificate, after controlling for food safety training and level of education ($p < .05$). As the FSSAI standards now require a medical certificate for restaurant licensure and registration, consideration should be given to include an educational component to this certification with an explanation of expected food safety behavior.**

Introduction

Foodborne diseases are a growing public health problem worldwide. The World Health Organization estimates that foodborne and waterborne illnesses account for 1.8 million childhood deaths annually, predominantly in developing countries (World Health Organization, 2005). In India, a substantial amount of illness and death can be attributed to diarrheal disease, but the burden of foodborne illness is not fully recognized or understood. A review conducted by the Food and Drug Toxicology Research Center in Hyderabad, India, found 37 foodborne disease outbreaks from 1980 to 2009. Researchers concluded that foodborne disease in India is highly underreported and that a national surveillance system would improve effective detection and prevention of outbreaks (Sudershan, Naveen Kumar, & Polasa, 2012).

Increasingly, food is consumed outside the home with the potential for exposure to poor hygiene in commercial food service settings (World Health Organization, 2008). A 2007 food safety study of knowledge, attitudes, and practices reported that mothers in southern India consider home-cooked meals to be safer than prepared meals bought outside the home and they were even reluctant to eat meals prepared by "reputed hotels or eateries (Subba Rao, Sudershan, Pratima Rao, Vishnu Vardhan Rao, & Polasa, 2007)."

In the U.S., working while ill, failing to properly wash hands, inadequately cleaning equipment, cross contamination, and temperature abuse are known risk factors associated with foodborne illness outbreaks (Food and Drug Administration, 2011; Todd, Greig, Bartleson, & Michaels, 2007). A lack of food safety knowledge can lead to these unsafe food handling behaviors that increase risk for food poisoning. Limited research has been published assessing food handler knowledge and behaviors in developing regions, such as India (Al-Khatib & Al-Mitwalli, 2009; Malhotra, Lal, Prakash, Daga, & Kishore, 2008; Onyeneho & Hedberg, 2013; Sangole, Lanjewar, Zodpey, & Doifode, 2001; Singh, 2004; Udgiri & Yadavnavar, 2006). Given that behavior may change as a result of several factors including knowledge, an assessment of food handler knowledge of safe food handling practices is necessary and can be useful in designing educational interventions that target these knowledge gaps and related behaviors (DeBess, Pippert, Angulo, & Cieslak, 2009; Dworkin, Panchal, & Liu, 2012; Manes, Liu, Burke, & Dworkin, 2014; Manes, Liu, & Dworkin, 2013; Panchal, Liu, & Dworkin, 2012).

The Indian Parliament, with the Food Safety and Standards Act (2006) and the Food Safety and Standards Authority of India (FSSAI), is taking action to reduce foodborne illness in India. Food safety in restaurants

Characteristics of Restaurants Participating in a Knowledge Survey in Chennai, India, 2011 (*N* = 36) and Score Out of 23 Food Safety Knowledge Questions

Characteristic	Frequencies		Bivariate Analysis	
	Restaurant *n* (%)	Food Handler *n* (%)	Mean Score (%)	*p*-Value
Restaurant size				.3225
Small (≤10 tables)	5 (14)	22 (14)	12.0 (52)	
Medium (>10 tables but <30 tables)	20 (56)	94 (60)	11.0 (48)	
Large (≥30 tables)	11 (30)	40 (26)	11.2 (49)	
Food service style				.0007
Fast food	6 (17)	23 (15)	13.3 (58)	
Informal (casual)	25 (69)	114 (73)	10.8 (47)	
Formal	5 (14)	19 (12)	10.9 (47)	
Food specialization				.1263
Vegetarian	12 (33)	46 (29)	10.6 (46)	
Nonvegetarian	24 (67)	110 (71)	11.4 (50)	
Chain or independent				.0231
Chain	19 (53)	69 (44)	11.8 (51)	
Independent	17 (47)	87 (56)	10.7 (46)	
Average entrée price				.0244
≤100 Indian rupees	20 (56)	93 (57)	10.8 (47)	
>100 Indian rupees	16 (44)	63 (39)	11.8 (51)	

and other food service establishments is one area of regulatory focus. The purpose of our study was to assess knowledge gaps among food handlers in restaurants in Chennai, Tamil Nadu, India, in order to use that information to guide the development of future interventions in restaurant food safety.

Materials and Methods

Sample and Participants
From April through June 2011, a survey of restaurant food handlers in Chennai, Tamil Nadu, was administered by the local health department, known as the Corporation of Chennai. Restaurants of varying sizes, food prices, food types, and cuisines were selected using purposive sampling methodology. Health inspectors selected two to three restaurants within their normally assigned geographic zone to approach for the study (Corporation of Chennai, 2008).

Restaurant managers were approached in person by trained Corporation of Chennai sanitarians for approval to conduct inter-views with the staff at each restaurant. A signed consent was obtained that required participants be 18 years or older. Eligible participants were food handlers defined as restaurant employees who prepare food (washing, cutting, cooking, or placing food onto a plate) to be consumed by patrons. Surveys were administered in either Tamil or English and completed discreetly at the restaurants. Approval from the Corporation of Chennai ethics board and the University of Illinois at Chicago institutional review board was received prior to survey initiation.

Instrument Development and Data Collection
A 44-question survey instrument was developed to determine baseline knowledge and to collect self-reported behaviors among the food handlers. The survey was adapted from one used to assess baseline knowledge of food handlers in the suburbs of Chicago (Manes et al., 2013). Survey modifications and language translations were provided by staff from the Corporation of Chennai. The survey

included 23 food safety knowledge questions and tested knowledge of germs, appropriate temperatures for heating and cooling of foods, handling of raw and ready-to-eat food, and cross contamination. Participants were also asked about behavior practices including hand hygiene and working while ill. Food handler demographic information was collected and included history of food safety training and certification, restaurant job type, frequency of specific food handling tasks, and typhoid vaccination. Restaurant characteristics including size, service style, food type, and average entrée price were also obtained.

Statistical Analysis
Statistical analysis was performed using SAS version 9.3 for Windows with data from all participating food handlers. An overall knowledge score was determined by the proportion of correctly answered knowledge questions of the 23 from the survey. An overall vegetarian knowledge score was determined by the proportion of correctly answered knowledge questions of the 15 vegetarian-only questions by removing all questions involving meat temperatures or preparation.

Bivariate analyses were performed to identify food handler or restaurant variables associated with knowledge score. Analysis of variance models with Tukey's pairwise comparisons were employed to compare the mean knowledge scores for categorical variables. To identify factors associated with the food handler knowledge score, multivariable analysis was performed using mixed-effects regression models. A multilevel random restaurant and geographic zone effect was used to account for the potential correlations between food handlers from the same restaurant and zone. Variables that had a statistically significant association ($p < .1$) with the knowledge score were included in the multivariate analysis. A backward elimination method with a probability of Type I Error of $\alpha = .10$ was used to determine the significant variables to remain in the final regression model.

Results
From April through June 2011, 36 restaurants from six of the 15 geographical zones in Chennai, Tamil Nadu, were approached and participated in the study. Among the 36 restaurants, 56% (20) were medium-sized, 69% (25) had informal/casual dining, and 56%

(20) had an average entrée price of Indian rupees (INR) 100 or less (INR 100 was equivalent to U.S. $2.25 at the time of this study) (Table 1). Approximately half were chain restaurants (19, 53%) and two-thirds (24, 67%) served nonvegetarian meal options.

Among the 156 food handlers interviewed, the mean age was 29.3 years (range: 19–51 years) and 92% (144) were male (Table 2). Seventy-one percent (111) of the food handlers had no more than a high school education. The average time spent working as a food handler was 2.4 years (range: 0.2–40 years). Forty-four percent of the food handlers worked as the restaurant chef or cook, 21% maintained a supervisory role, and 21% served as other restaurant staff. Many (60, 38%) of the participating food handlers reported not obtaining the Corporation of Chennai required Medical Fitness Certificate (a health exam administered by a Chennai clinic certifying the food handler healthy enough to work with food served to the public) or not receiving food safety training at their current job (87, 56%). A history of college education and of receiving food safety training was more common among food handlers reporting a medical certificate than those without a certificate (38% vs. 13%, $p = .008$ and 59% vs. 20%, $p < .001$, respectively). Of the 156 food handlers, only 17% (27) reported ever hearing about India's Food and Safety Standards (2006) regulation.

Identifying Knowledge Gaps

The overall mean knowledge score was 49% (11.2/23, $SD = 2.9$) and the overall mean knowledge score for vegetarian-only questions was 38% (5.7/15, $SD = 2.1$). Most food handlers were knowledgeable of how the spread of germs can be related to personal hygiene. The following responses highlight this awareness: "unhygienic behavior causes germs and bacteria in hands and body" and "germs are live bacteria and can cause some disease." Food handlers performed poorly, however, when asked to identify the danger zone for pathogen growth (14, 9%), the proper temperature to cook meat (1, 0.6%), and the proper holding temperatures for hot and cold foods (1, 0.6% and 4, 3%, respectively) (Table 3). Only 21% (33) and 53% (83) of the food handlers knew that cooked rice and uncooked eggs can have germs that can make people sick, respectively. By contrast, a much greater proportion of partici-

pants were aware that uncooked chicken and beef can have germs that can make people sick (145, 93% and 141, 90%, respectively) and that uncooked meat can cause serious conditions, like bloody diarrhea (127, 81%). A substantial proportion of food handlers was aware that storing raw eggs and meat above ready-to-serve food is an unsafe food storage practice (121, 78% and 126, 81%, respectively); however, only 57% correctly identified that "vegetables for a salad splashed with raw chicken juice should not be rinsed, but instead must be thrown away," as true. For the hand hygiene questions, 72% (113) of the food handlers correctly answered true that "you need to thoroughly

wash hands when using single-use gloves to handle food." Approximately half knew to use warm water when washing hands and to use a clean paper towel to dry hands (71, 46% and 77, 49%, respectively). The majority of food handlers, however, stated that using bare hands or clothing to turn off the water after washing hands was acceptable (59, 38% and 29, 19%), rather than the recommended method of using a paper towel.

Important unsafe behaviors were also identified, particularly with regard to hand hygiene and working while ill. Twenty-three percent of the participants stated that they would come to work with a sore throat and cough and 14% would come to work with

TABLE **2**

Characteristics of Food Handlers Participating in a Knowledge Survey in Chennai, India, 2011 *(N* = 156) and Score Out of 23 Knowledge Questions

Characteristic	Frequencies	Bivariate Analysis	
	n (%)	Score (%)	*p*-Value
Age			.006
18–29 years	93 (59)	11.8 (51)	
30–39 years	43 (28)	10.3 (45)	
≥40 years	20 (13)	10.2 (44)	
Gender			.1188
Male	144 (92)	11.3 (49)	
Female	12 (8)	9.9 (43)	
Education			.0003
Attended or completed primary	38 (24)	10.2 (44)	
Attended or completed high school	73 (47)	10.8 (47)	
Attended or completed college	45 (29)	12.6 (55)	
Medical Fitness Certificate			.0009
Self-reported certificate	96 (62)	11.8 (51)	
No certificate	60 (38)	10.2 (44)	
Food safety training from restaurant			.0001
Self-reported training	69 (44)	12.3 (53)	
No training received	87 (56)	10.3 (48)	
Current position at restaurant			.0239
Manager/supervisor	32 (21)	12.2 (53)	
Chef/cook	70 (44)	10.5 (46)	
Other restaurant staff	32 (21)	11.9 (52)	
Unknown position	22 (14)	10.8 (47)	
Time working as a food handler			.0465
<1 year	36 (23)	11.2 (49)	
1–5 years	54 (35)	11.9 (52)	
6–10 years	38 (24)	10.2 (44)	
≥11 years	28 (18)	11.1 (48)	

TABLE **2** *continued*

Characteristics of Food Handlers Participating in a Knowledge Survey in Chennai, India, 2011 *(N = 156)* **and Score Out of 23 Knowledge Questions**

Characteristic	Frequencies	Bivariate Analysis	
	n (%)	Score (%)	*p*-Value
Meat food handling task			.0112
Handles meat	80 (51)	11.8 (51)	
Does not handle meat	76 (49)	10.6 (46)	
Seafood food handling task			.0250
Handles seafood	76 (49)	11.7 (51)	
Does not handle seafood	80 (51)	10.7 (47)	
Egg food handling task			.2201
Handles eggs	78 (50)	11.4 (50)	
Does not handle eggs	78 (50)	10.9 (47)	
Vegetable/fruit food handling task			.7558
Handles vegetables/fruit	135 (4)	11.2 (49)	
Does not handle vegetables/fruit	21 (25)	11.0 (48)	
Personal dietary restrictions			.0249
No restrictions	103 (66)	11.6 (50)	
Vegetarian diet only	35 (22)	10.3 (45)	
Other diet restrictions	18 (12)	10.3 (45)	
Typhoid vaccination (self-reported)			.1676
Vaccinated	51 (33)	11.6 (50)	
Unvaccinated	74 (47)	11.2 (49)	
Unknown vaccination status	31 (20)	10.4 (45)	
Previous diarrhea- or vomiting-associated hospitalization			.0613
Previously hospitalized	17 (11)	10.5 (46)	
Not hospitalized	124 (79)	11.5 (50)	
Unknown	15 (10)	9.7 (42)	

diarrhea. Eighty-seven percent (135) of the food handlers stated that they always washed their hands after using the restroom at work, whereas 42% (65) answered the question "If you only urinated and did not have a bowel movement, you do not need to wash your hands" incorrectly as true.

Factors Associated With the Knowledge Score

Bivariate analysis revealed restaurant characteristics significantly associated with the knowledge score. The mean knowledge score for fast-food-style restaurants was significantly greater compared to informal (casual) and formal restaurants (58%, 47%, and 47%, respectively, $p = .0007$) (Table 1). Similarly, the mean knowledge score for chain restaurants was significantly but not substantially greater compared to nonchain restaurants (51% and 46%, respectively, $p = .02$) and for restaurants serving less expensive meals compared to those serving more expensive meals (51% and 47%, respectively, $p = .02$).

Food handler characteristics significantly associated with the knowledge score were also identified. Food handlers ages 18 to 29 years had a greater mean knowledge score compared to those in the age ranges of 30 to 39 years and 40 years and older (51%, 45%, and 44%, respectively, $p = .006$) and those with at least some college education scored higher than those with less education (55% vs. 47% and 44%, respectively; $p = .0003$) (Table 2). Managers/supervisors and "other restaurant staff" scored higher than chefs/cooks (53% and 52% vs. 46%, respectively; $p = .023$). The mean knowledge score for food

handlers who reported having the Chennai-required Medical Fitness Certificate or those having received food safety training at the restaurant was greater than for those who did not have the certificate or received training (51% vs. 44%, respectively; $p = .0009$ and 53% vs. 48%, respectively; $p = .0001$).

In the final mixed-effects regression model predicting knowledge, a significant covariance between knowledge scores of food handlers from the same restaurants was detected (random restaurant effect, $\sigma = 3.35$ [$SE = 1.09$, $p = .001$]). The random zone effect was not significant and removed from the final model. No restaurant characteristics were significant in the final model. Food handlers with only primary or secondary education scored significantly lower compared to persons who had at least some college education (1.23 points lower, $p = .046$ and 1.18 points lower, $p = .019$, respectively) (Table 4). Food handlers who reported receiving food safety training in the participating restaurant had higher knowledge scores than those without training ($p = .022$) and having reported a Medical Fitness Certificate was associated with a slight increase of 1.04 points in knowledge score ($p = .02$).

Discussion

The Food Safety and Standards set by FSSAI have established a new precedent of higher standards for food safety in restaurants in India (Ministry of Health and Family Welfare, 2011). Our study provides a rare look into baseline conditions related to food safety in a large urban Indian area. The food handlers in our study had an average overall food safety knowledge score of 49%, demonstrating substantial gaps that need to be addressed. The main areas in need of improvement involved hand hygiene practices, temperatures for cooking and holding foods, and cross contamination.

Inadequate hand hygiene knowledge and behavior among restaurant food handlers has contributed to many foodborne illness outbreaks (Angelillo, Viggiani, Rizzo, & Bianco, 2000; Clayton, Griffith, Price, & Peters, 2002; Green et al., 2007; Guzewich & Ross, 1999; Lynch, Painter, Woodruff, & Braden, 2006; Scallan, Griffin, Angulo, Tauxe, & Hoekstra, 2011). Although many food handlers in our study understood how the spread of germs can be related to personal hygiene, hand hygiene knowledge was poor. More

TABLE **3**

Frequencies of Correct Responses to Knowledge Questions Asked of Chennai Restaurant Food Handlers, 2011 (_N_ = 156)

Questions _(Answers)_	Question Type	_n_ (%)
Temperature		
Germs that make people sick grow well within which temperature rage? _(5°C–57°C)_	Fill-in-the-blank	8 (5)
What is the temperature of the "Danger Zone"? _(5°C–57°C)_	Fill-in-the-blank	14 (9)
Hot foods, such as biryani at a buffet table, should be held at what temperature or above? _(57°C)_	Fill-in-the-blank	1 (0.6)
Cold foods, such as yogurt, should be stored at what temperature or lower? _(5°C)_	Fill-in-the-blank	4 (3)
Cooked meat, for example chicken, should be cooked to at least what internal temperature? _(70°C)_	Fill-in-the-blank	1 (0.6)
Where should a meat thermometer be inserted to accurately check the temperature? _(The thickest part of the meat)_	Multiple choice	29 (24)
It is safe to put frozen chicken breast on the counter to thaw? _(False)_	True/False	88 (56)
Cross contamination		
In the refrigerator, it is safe to store raw eggs in shells above ready-to-serve raw vegetables? _(False)_	True/False	121 (78)
Raw meat can be stored above ready-to-serve food. _(False)_	True/False	126 (81)
Gloves used to handle ready-to-eat food should be thrown in the trash when interruptions occur in operations. _(True)_	True/False	82 (53)
Vegetables for a salad splashed with a few drops of raw chicken juice should not be rinsed, but instead must be thrown away? _(True)_	True/False	89 (57)
Cleaning and sanitizing mean the same thing? _(False)_	True/False	39 (25)
Germs		
Did you know that eating cooked rice could cause you to become ill enough to need to go to the hospital? _(Yes)_	Yes/No	33 (21)
Did you know that eating uncooked eggs could cause you to become ill enough to need to go to the hospital? _(Yes)_	Yes/No	83 (53)
Did you know that eating uncooked chicken could cause you to become ill enough to need to go to the hospital? _(Yes)_	Yes/No	145 (93)
Did you know that eating uncooked meat could cause you to become ill enough to need to go to the hospital? _(Yes)_	Yes/No	141 (90)
Eating ground meat that is not completely cooked can cause bloody diarrhea? _(Yes)_	Yes/No	127 (81)
A food handler who has a small infected cut on his or her finger prepares food that is kept warm but not hot. The person who eats the food could become ill with vomiting and diarrhea? _(True)_	True/False	128 (82)
Hand hygiene		
At work if you only urinated, and did not have a bowel movement, you do not need to wash your hands before returning to food handling? _(False)_	True/False	91 (58)
Do you need to have thoroughly washed hands if you use single-use gloves to handle food? _(Yes)_	Yes/No	113 (72)
When you wash your hands at work should you use cold or warm water? _(Warm/hot water)_	Multiple choice	71 (46)
When you wash your hands at work, what do you use to dry your hands? _(Clean paper towel)_	Multiple choice	77 (49)
After you wash your hands at work, how should you turn off the water? _(Using the paper towel used to dry hands or automatic tap)_	Multiple choice	36 (23)

than one in 10 reported not always washing their hands after using the restroom at work, and just over half (58%) knew that hands should be washed after urination. Compared to data reported in a study of food handlers working in a medical college in Delhi, India, restaurant food handler knowledge of proper hand washing was low. Malhotra and co-authors (2008) reported that 98.5% of food handlers knew that hands should be washed after micturition (urination) although only 82% reported actually washing their hands after urination. Discordance between food handler knowledge and proper hand washing behavior is important and has also been reported from studies in the U.S. and Wales.

This discordance highlights the importance of addressing both knowledge and behavior (Clayton et al., 2002; Green et al., 2007).

Our study also identified knowledge gaps related to proper temperatures for cooking and holding food. The questions about the range of the temperature danger zone, the internal temperature to cook chicken, and the proper holding temperatures for hot and cold foods were answered correctly by fewer than 10% of the food handlers. Similarly poor results have been reported among food handlers in Illinois and Switzerland, suggesting that such lack of knowledge is a widespread problem (Dworkin et al., 2012; Manes et al., 2013; Panchal, Bonhote, & Dworkin, 2013; Panchal et al., 2012).

The newly regulated Food Safety and Standards emphasize that local health departments provide a list of food handlers with a Medical Fitness Certificate to FSSAI on an annual basis. Although the certification process is not new, reporting to FSSAI may help to ensure compliance. At the time of our study, food handlers employed in restaurants in Chennai were required to obtain a certificate, but only 38% reported having one. To obtain the certificate, food handlers visit a public health clinic, receive a physical health exam, provide blood or urine samples for testing, and receive a pamphlet listing hygienic practices. The purpose of the Medical Fitness Certificate is to deter-

TABLE 4

Food Handler Characteristics[a] Associated With Knowledge Score, Mixed-Effects Regression Analysis (*N* = 156), 2011

Characteristic	Multivariate Analysis	
	Estimate (*SE*) Scale of 0–23	*p*-Value
Intercept	13.35 (0.88)	<.0001
Medical Fitness Certificate (self-reported)	1.04 (0.48)	.0210
Education		
Attended or completed college	Ref	
Attended or completed high school	-1.18 (0.49)	.0189
Attended or completed primary school	-1.23 (0.61)	.0467
History of food safety training (self-reported)	1.12 (0.37)	.0215

[a]No restaurant characteristics were significant in the final model.

mine if food handlers are free from infectious diseases, like typhoid. Although a food safety educational component isn't included in the certificate, our results showed that the self-reported Medical Fitness Certificate was independently associated with the food safety knowledge score after controlling for food safety training and education. Potential hypotheses for this association are that food handlers already knowledgeable about food safety are those who make the effort to obtain the certificate, and that food handlers who undergo the process of obtaining the certificate may gain an appreciation of the importance of food safety and therefore seek knowledge related to the subject. According to the Theory of Motivated Information Management, the association between Medical Fitness Certificate screening and food safety knowledge is possible through an iterative process consisting of an awareness of the transmission of infectious disease, evaluation of the pursuance of food safety knowledge, and the decision to seek further information regarding the safe handling of food (Afifi & Weiner, 2004). It is also possible that the food handlers working at a restaurant that required the medical certificate are working at restaurants that maintain a culture of food safety (in our study 59% of the food handlers with a medical certificate also reported food safety training).

Food handlers working while ill is another area of concern identified by our study and underscored by foodborne illness outbreaks. For example, in West Bengal, India, a typhoid fever outbreak with 103 suspected cases likely resulted from an infected food handler who did not wash his hands (Bhunia et al., 2007). Although the typhoid vaccine is recommended for adolescents (India Academy of Pediatrics, 2012), our study showed that a substantial proportion of the food handlers were either unvaccinated or of unknown vaccination status (67%). Current Association of Physicians of India (API) guidelines do not recommend routine typhoid immunization of adults and no recommendations have been provided by the group for food service workers in India (API, 2009). Because ill food handlers can shed pathogenic organisms that may be transferred through food, it is critical that they understand the substantial consequences of working while ill and how to prevent the spread of disease.

A limitation of our study was that restaurants were selected using purposive sampling, as the city did not have a list of all Chennai restaurants from which to generate a random sample. Since the study was intended to guide educational intervention, rather than produce a broadly generalizable statistic, this limitation was considered acceptable. Six of 15 geographical zones are represented in these data and geographical zone was examined as a potential confounding factor. Unlike the restaurant level, the zone was not significant in the multilevel random effects regression model. As with any smaller-sized study, the limited number of restaurants and participants may bias results and reduce generalizability.

Conclusion

Substantial food safety knowledge gaps exist among food handlers in Chennai. The main areas in need of improvement involved hand hygiene, cross contamination, and temperatures for cooking and holding foods, common themes for food handler education. To our knowledge this is the first study examining an association between the Indian Medical Fitness Certificate and food safety knowledge. Future research should further evaluate the effectiveness of having this certificate on food safety knowledge and behavior, especially with the new FSSAI standards requiring all food handlers to have it. Consideration should be given to including an educational component to this certification with an explanation of expected food safety behavior. In response to this need, the investigators have created an educational brochure that instructs on the food safety topics prioritized by the knowledge survey and restaurant inspections. The brochure was adapted from educational interventions shown to be effective in improving food safety knowledge among restaurant food handlers in Chicago (Dworkin et al., 2012; Manes et al., 2014).

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Safety Evaluation of Metal Exposure From Commonly Used Hair Dyes and Tattoo Inks in Nigeria

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Abstract **In the study described in this article, the concentrations of metals (cadmium, copper, chromium, aluminum, lead, nickel, zinc, cobalt, manganese, and iron) in samples of some commonly used hair dyes and tattoo inks were determined with a view to providing information on the hazards associated with the use of these products. The concentrations of metals were measured after nitric acid/perchloric acid/hydrogen peroxide digestion by atomic absorption spectrometry. Results indicated that the tattoo ink samples contained allergenic metals such as nickel, chromium, and cobalt at concentrations above the suggested limit of 1 μg/g for greater skin protection, and the toxic metals were below their respective prescribed limits, as impurities in ingredients for use for cosmetics, in the majority of the samples.**

Introduction

Tattoos and dying of hair have been practiced for several centuries worldwide. Tattoos have been used as a simple fashionable body ornament as well as to express membership of a particular sociocultural group (Forte, Petrucci, Cristaudo, & Bocca, 2009).

In permanent tattoos, the pigments are deposited into the dermis by means of a needle, which ensures that pigments are permanent. The person is directly exposed to the ingredients in the tattoo color. Tattoo colors are metal based; for instance, dichromate, cobalt, cadmium, and mercury salts are used as the base for green, blue, yellow and red colors, while iron oxide, titanium dioxide, cobalt, and manganese are prevalent in brown, white, black, and violet (Forte et al., 2009; Kaatz, Elsner, & Bauer, 2008). Organics and metals are sometimes combined to create a different hue, brightness, lightness, and shade of colors (Duke, Urioste, Dover, &

Anderson, 1998). The direct contact of the skin with the metal components of these pigments can cause metal-related skin inflammation such as allergic, eczematous, lichenoides, psudolymphomatous, or granulomatous reactions in sensitized persons.

The assessment of metal concentrations in personal care products is a public health concern since the use of these products could represent a possible source of human exposure to a variety of chemicals (Piccinini, Piecha, & Torrent, 2013). Most of these products are applied directly to human skin. While skin provides a good protective barrier, some of the ingredients in cosmetic products can penetrate the skin and reach vital internal organs via the circulatory system (Gondal, Seddigi, Nasr, & Gondal, 2010) where they can exhibit acute or chronic toxicity.

Exposure to low concentrations of lead can cause disorders such as behavioral abnormalities, decreased learning and hearing,

and permanent neurological damage and can have adverse effects on the reproductive, hepatic, and renal systems. The International Agency for Research on Cancer (IARC) has categorized cadmium as a group 2A carcinogen because it is a cell poison, which causes different types of damage including cell death or increased cell proliferation (World Health Organization, 2004).

Other metals such as nickel, chromium, iron, manganese, zinc, and aluminum are essential to humans since they are involved in many biological processes, even though some controversy still exists surrounding chromium. Despite the importance of these metals to humans and other organisms, the presence of these metals in personal products may constitute a serious health risk, e.g., allergic reactions. Nickel, chromium, and cobalt are well-known allergens, while copper, manganese, and zinc are seen as weak allergens. The objective of our study was to

Hair Dyes and Tattoo Inks Sampled

Brand Name	Color	Country of Origin	Active Ingredients
Hair dyes			
Above Nature	Black	India	Nil
Above Floweriness	Red	India	Nil
Above Violet	Red	India	Nil
Cruset	Deep black	China	Cetearyl alcohol, hydrogen peroxide
Orino	Black	China	Nil
Orino	Wine	China	Nil
Orino	Gold	China	Nil
Orino	Purple	China	Nil
Orino	Coral brown	China	Nil
Orino	Chestnut brown	China	Nil
Orino	Purplish wine	China	Nil
Sabary	Wine red	India	Nil
Sabary	Chestnut brown	India	Nil
Sabary	Grape red	India	Nil
Sabary	Splendid purple	India	Nil
Sabary	Splendid red	India	Nil
Native Dye	Black	Nigeria	Nil
Tattoo inks			
Intenze	Lemon yellow	USA	Nil
Intenze	Bright red	USA	Nil
Intenze	True black	USA	Nil
J.Y.	Red	China	Nil
J.Y.	Black	China	Nil
J.Y.	Blue	China	Nil
J.Y.	Green	China	Nil

Note. Nil = not specified.

evaluate the concentrations of metals (cadmium, copper, chromium, aluminum, lead, nickel, zinc, cobalt, manganese, and iron) in hair dyes and tattoo inks with a view to providing information on the hazards associated with use of these products.

Materials and Methods

Sampling
Samples of commonly used hair dyes and tattoo inks were purchased from markets in Abraka, Warri, Asaba, Benin-City, and Lagos, Nigeria. A total of 24 brands were collected, including some manufactured in Nigeria and some imported from other countries. The choice of brands was carefully made to reflect the brands used by different income classes.

Within each type or brand, a total of three samples with different batch numbers and date of manufacture were collected in order to study the variation in elemental concentrations within a particular brand. All samples collected were within their specified usage periods (shelf life). Information about the brand names, country of origin, and active ingredients of these products is displayed in Table 1.

Reagents
All reagents, nitric acid (69%), hydrogen peroxide (30%), and perchloric acid, were ultrapure quality. The calibration standards were prepared by diluting 1,000 mg/L commercial standards of cadmium, copper, chromium, aluminum, lead, nickel, zinc, cobalt, manganese, and iron with 0.25 mol/L nitric acid.

Sample Preparation
A mass of 1.0 g of each sample was placed in a Teflon vessel, to which 20 mL of concentrated nitric acid, 10 mL of perchloric acid, and 5 mL of hydrogen peroxide were added and the mixture (sample + acids) was left to stand overnight. The following day, the sample was heated on a hotplate to 125°C for two hours. The sample solution was allowed to cool, and was then filtered and made up to 25 mL with 0.25 mol/L nitric acid. Four blanks were prepared in an identical manner, but omitting the samples.

Chemical Analysis
All digested samples were analyzed in triplicate for cadmium, copper, chromium, aluminum, lead, nickel, zinc, cobalt, manganese, and iron by using flame atomic absorption spectrometry. Calibration standards and blank solutions were analyzed in the same way as the samples. In each analysis at least three to four blanks were analyzed. The average blank signal was subtracted from the analytical signal of the sample before statistical analysis.

Quality Control and Statistical Analysis
All glassware used in the study was previously soaked in 10% (v/v) nitric acid solution for 24 hours and rinsed with deionized water. The instrument was calibrated after every 10th run. The accuracy of the analytical procedure was verified by using a spike recovery method. A known amount of the test element was introduced into an already analyzed sample and the sample was reanalyzed. The percentage spike recoveries for metals were between 89.0% and 98.9%. The limits of detection for the metals were 0.05, 0.01, 0.03, 0.01, 0.08, 0.01, 0.01, 0.01, 0.02, and 0.03 µg/g while the limits of quantification were 0.15, 0.03, 0.10, 0.25, 0.03, 0.03, 0.03, 0.03, 0.05, and 0.10 µg/g for cadmium, copper, chromium, aluminum, lead, nickel, zinc, cobalt, manganese, and iron, respectively. Analysis of variance (ANOVA) and Tukey's multiple comparison tests were used to determine whether the concentrations of metals varied significantly within the same brand and among the different brands of hair dyes and tattoo inks.

TABLE **2**

Metal Concentrations (μg/g) in Hair Dyes and Tattoo Inks Purchased in Nigeria

Sample Codes	Cadmium	Copper	Chromium	Aluminum	Lead	Nickel	Zinc	Cobalt	Manganese	Iron
Hair dyes										
HD-1	<0.15	2.00±0.16	7.50±0.45	<0.25	3.00±0.15	0.73±0.04	32.5±4.23	<0.03	22.3±3.34	76.1±13.7
HD-2	<0.15	7.00±1.05	8.00±0.64	<0.25	2.00±0.24	0.95±0.08	32.0±4.80	<0.03	25.8±2.32	105±6.28
HD-3	<0.15	8.50±0.85	7.75±1.40	<0.25	0.50±0.07	0.78±0.05	30.0±1.80	<0.03	24.0±1.20	81.6±4.08
HD-4	<0.15	4.25±0.72	7.75±1.24	<0.25	2.25±0.38	0.78±0.07	30.0±2.40	<0.03	41.5±3.32	188±20.7
HD-5	<0.15	3.25±0.39	8.25±0.83	<0.25	1.25±0.23	0.78±0.11	34.8±3.75	<0.03	26.5±2.39	86.6±12.1
HD-6	<0.15	1.50±0.27	8.25±0.99	<0.25	1.50±0.17	0.20±0.01	20.0±1.70	<0.03	21.3±1.49	76.4±6.11
HD-7	<0.15	3.25±0.24	8.75±1.49	<0.25	<0.03	0.43±0.04	26.8±2.56	<0.03	23.0±4.14	77.2±6.95
HD-8	<0.15	2.00±0.29	8.50±1.11	<0.25	4.50±0.72	0.08±0.02	34.0±3.82	<0.03	25.3±4.04	331±46.4
HD-9	<0.15	9.50±0.57	8.25±1.07	<0.25	1.25±0.19	0.78±0.15	32.0±2.80	<0.03	27.5±2.48	243±26.8
HD-10	<0.15	<0.03	<0.10	<0.25	0.75±0.09	<0.03	<0.03	<0.03	<0.05	<0.10
HD-11	16.8±2.47	7.75±0.93	9.0±1.53	<0.25	2.75±0.36	1.33±0.17	155±24.8	<0.03	<0.05	<0.10
HD-12	<0.15	4.75±0.33	7.25±1.09	<0.25	0.75±0.04	0.75±0.11	62.5±4.38	0.50±0.07	18.8±2.44	286±25.7
HD-13	<0.15	2.25±0.18	8.00±0.48	<0.25	0.25±0.26	0.58±0.06	27.8±3.89	<0.03	26.0±3.38	157±25.1
HD-14	<0.15	2.50±0.20	7.25±0.58	<0.25	1.75±0.21	0.73±0.04	275±19.3	<0.03	20.8±1.87	133±15.9
HD-15	<0.15	4.00±0.68	7.25±0.65	<0.25	3.50±0.42	0.63±0.08	298±17.9	<0.03	26.3±3.64	77.6±3.88
HD-16	<0.15	20.5±2.46	8.25±0.73	<0.25	2.00±0.26	1.05±0.17	133±10.6	<0.03	29.3±3.22	99.2±6.94
HD-17	<0.15	4.25±0.55	8.50±0.94	<0.25	1.25±0.15	0.70±0.05	37.3±4.84	1.00±0.04	18.5±0.93	128±14.1
Tattoo inks										
TT-1	<0.15	775±38.8	16.5±2.64	878±105	0.50±0.08	4.78±0.76	38.5±4.24	1.00±0.17	23.8±1.19	188±22.6
TT-2	<0.15	5.50±0.66	18.0±3.24	42.0±2.52	1.25±0.23	5.28±0.79	31.5±4.41	0.75±0.14	29.8±2.38	136±8.15
TT-3	<0.15	2.25±0.32	14.3±0.86	78.5±7.07	31.8±2.86	3.65±0.33	138±19.3	0.75±0.16	17.8±1.07	168±10.1
TT-4	<0.15	3.00±0.45	8.00±0.48	<0.25	1.50±0.08	0.60±0.03	70.0±10.5	0.50±0.08	30.8±2.77	69.8±5.58
TT-5	<0.15	57.8±6.93	9.50±1.24	<0.25	34.0±5.10	1.73±0.42	110±5.50	0.75±0.09	28.5±3.71	74.7±11.2
TT-6	<0.15	2480±173	27.0±0.02	245±14.7	1.75±0.16	8.40±0.40	85.0±5.95	2.25±0.12	37.3±1.86	454±59.1
TT-7	<0.15	1680±151	14.8±1.18	353±28.2	0.50±0.03	3.25±0.46	60.0±8.40	0.50±0.02	32.5±2.28	113±12.4

Results and Discussion

The concentrations of metals measured in the selected types of hair dyes and tattoo inks are displayed in Table 2. The concentration of the metals varied significantly ($p < 0.05$) among the different types, although the concentrations of chromium in the different types of hair dyes were similar. The metallic concentrations varied from manufacturer to manufacturer and from one color to another, even among like-colored pigments. As a general trend, iron, manganese, and zinc were the dominant metals in the hair dyes, while iron, manganese, zinc, copper, and aluminum were the dominant metals in the tattoo inks.

The concentrations of cadmium in these samples were below the limit of detection except for HD-11 (16.8 μg/g), which is higher than the 3.0 μg/g regulatory limit for cadmium in cosmetic products (Health Canada, 2012). Human exposures to cadmium from the use of these products are very low except in the case of HD-11.

Copper was detected in all samples analyzed except in HD-10. The concentrations of copper in these products ranged from <0.03 to 20.5 and 2.25 to 2,480 μg/g for hair dyes and tattoo inks, respectively. The tattoo inks had higher concentrations of copper than the hair dyes. In our study, HD-16 had a higher concentration of copper than the other hair dyes analyzed, while TT-6 and TT-7 had significantly higher copper levels than the other tattoo inks. The higher concentrations of copper were observed in the blue- and green-colored tattoo inks. The high concentrations of copper in TT-6 and TT-7 may be due to the use of blue pigments from materials such as copper (II) carbonate, calcium copper silicate, and copper

phthalocyanine. Copper phthalocyanine and malachite are used to produce green pigments (Forte et al., 2009). Forte and co-authors (2009) reported similar high concentrations of copper in blue- and green-colored tattoo inks (8,329 and 5,887 µg/g, respectively). The red-colored hair dye had a higher copper concentration than the other colors.

Chromium was found in all samples of the hair dyes and tattoo inks except in HD-10. The concentrations of chromium ranged from <0.10 to 9.00 µg/g and 8.00 to 27.0 µg/g in the hair dyes and tattoo inks, respectively. On average tattoo inks had higher concentrations of chromium than the hair dyes. The highest chromium concentrations were observed in the green-colored tattoo inks, which may be due to the use of dichromate pigments in the manufacture of these products. The concentrations of chromium found in this study were lower than 0.315 to 147.0 µg/g reported for tattoo inks in Italy (Forte et al., 2009).

Nickel concentrations ranging from <0.03 to 1.33 and 0.60 to 8.40 µg/g were found in hair dyes and tattoo inks, respectively. The tattoo inks had elevated levels of nickel when compared with the hair dyes. TT-6 had a higher nickel concentration than the other tattoo inks. The concentrations of nickel found in our samples were higher than those reported in tattoo inks in Italy (Forte et al., 2009), but were lower than nickel concentrations of henna in the Palestinian market (Al-Qutob, Alatrash, & Abol-Ola, 2013).

The concentrations of cobalt in the majority of the hair dye samples were below the limit of detection except in HD-12 and HD-17. The cobalt concentrations in the tattoo inks ranged between 0.50 and 2.25 µg/g. The highest concentration of cobalt was found in a blue tattoo ink, which is due to the presence of cobalt aluminum oxides. Cobalt-based tattoo inks are more toxic than copper-based inks and are linked with urticarial, granulomatous, and pseudolymphomatous reactions (Bagnato et al., 1999; Bjornberg, 1961; Blumental, Okun, & Pontich, 1982; Smith, Odom, & Maibech, 1975). Nickel, chromium, and cobalt are metals of allergological relevance and the levels of nickel, chromium, and cobalt found in our samples can be compared with published maximum levels defined as allergologically safe for consumers exposed to products containing these metals. In this context, Basketter and co-

authors (2003) have shown that the presence of the irritant or following repeated exposures to cobalt, chromium, and nickel, individuals rarely react below 10 µg/g. For this reason, Basketter and co-authors (2003) recommended that consumer products should not contain more than 5 µg/g of cobalt, chromium, or nickel as "good manufacturing practice" while the "target" value to minimize the risk of sensitization in particularly sensitive subjects should be as low as 1 µg/g.

The results of our study indicated that hair dyes and tattoo ink samples contained chromium at concentrations above safe limits while cobalt and nickel were within the safe limit, except for nickel in TT-2 and TT-6. The concentrations of nickel and cobalt found in a henna tattoo mixture ranged from less than 2.5 to 3.96 µg/g and 2.96 to 3.54 µg/g, respectively, while lead and copper were less than their respective detection limits (Kang & Lee, 2006).

Aluminum was found to be less than 0.25 µg/g in all the samples of hair dyes examined, whereas aluminum concentrations of 42 to 878 µg/g were found in five of the tattoo inks examined. The highest aluminum concentration was observed in a yellow-colored tattoo ink. Our samples contained lower concentrations of aluminum than those reported in tattoo ink in Italy (Forte et al., 2009). Al-Qutob and co-authors (2003) reported an aluminum concentration of 142.1 µg/g in henna in the Palestinian market. Aluminum exposure, apart from causing cholinotoxicity, can induce changes in other neurotransmitter levels since neurotransmitter levels are closely related (Al-Ashban, Aslam, & Shan, 2004).

The concentrations of lead in the hair dyes and tattoo inks ranged from <0.03 to 3.50 µg/g and 0.50 to 34.0 µg/g, respectively. Tattoo ink samples TT-3 and TT-5 (black colored) had much higher concentrations of lead than other samples investigated. The United States Food and Drug Administration (FDA) maximum limit for lead in color additives in cosmetics for external use formulated following good manufacturing practice is 20 µg/g, while a 10 µg/g limit for lead in cosmetics was specified by the Canadian Health Authority (Health Canada, 2012). In our study, only TT-3 and TT-5 had lead concentrations above the FDA and Canadian Health specified limits for lead in cosmetics. Apart from these two samples (TT-3 and TT-5), all other samples analyzed had lead con-

centrations in the range reported by Forte and co-authors (2009). Al-Qutob and co-authors (2013) found lead concentrations of 5.35 µg/g in henna from a Palestinian market.

Zinc concentrations of <0.03 to 298 µg/g and 31.5 to 138 µg/g were detected in the hair dyes and tattoo inks, respectively. Higher concentrations of zinc were observed in HD-11, HD-14, HD-15, HD-16, TT-3, and TT-5 than in other samples investigated. Zinc used in anti-dandruff shampoos has been shown to cause allergenic contact dermatitis (Salvador, Pascual-Marti, Arago, Chisvert, & March, 2000) and high levels of exposure to zinc can cause brittle hair and nails, neurological abnormalities, and gastrointestinal disorders and convulsions (Ayenimo, Yusuf, Adekunle, & Makinde, 2010).

The concentrations of manganese in these samples were in the range of <0.05 to 41.5 µg/g and 17.8 to 37.3 µg/g for hair dyes and tattoo inks, respectively. Higher manganese concentrations were found in blue-, green-, and red-colored tattoo inks than in the other colors. The concentrations of manganese observed in our samples were higher than levels reported for tattoo inks in Italy (Forte et al., 2009). Skin diseases associated with manganese seem to be quite rare. Manganese has been reported as a possible cause of swelling and itching, scaling, and cutaneous granuloma in the purple region of a tattoo (Nguyen & Allen, 1979; Schwartz, Mathias, Miller, Rojas-Corona, & Lambert, 1987).

Iron was not detected in two samples of the hair dyes (HD-10 and HD-11), while iron concentrations of 76.1 to 331 µg/g were detected in the other samples of hair dyes. The highest concentration of iron was found in a purple hair dye. Also, the coral brown and wine red hair dyes had significantly higher concentrations of iron than the other colors investigated. Iron concentrations of 69.8 to 454 µg/g were detected in the samples of tattoo inks. High concentrations of iron in a blue tattoo ink may be due to the presence of ferro-ferricyanide (Prussian blue). The lemon yellow, bright red, and black tattoo inks contained high amounts of iron. Iron in a black tattoo ink is associated with the use of magnetite and wüstite (iron oxides) as components of the ink. The concentrations of iron in our samples were higher than concentrations of iron found in tattoo inks in Italy (Forte et al., 2009).

Conclusion

The results of our study revealed that iron, manganese, and zinc are the main components of hair dyes while iron, manganese, zinc, copper, and aluminum are the main components of tattoo inks. Our study indicated that the tattoo ink samples contained allergenic metals such as nickel, chromium, and cobalt at concentrations above the suggested limit of 1 μg/g for greater skin protection in most samples. The toxic metals (cadmium and lead) were below their respective specified limits in cosmetic products in the majority of these samples. The results of our study demonstrate the need for the establishment of regulatory guidelines for metals in these kinds of cosmetic products.

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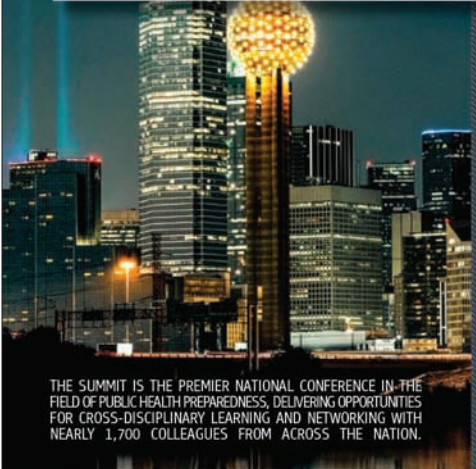
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Knowledge and Food Handling Practices of Nurses in a Tertiary Health Care Hospital in Nigeria

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Abstract **Food safety in hospitals is important to protect patients whose immunity may be compromised by their illness. The safety of food served to patients is dependent on its handling acquisition of raw food items, to preparation, packaging, and distribution. The study described in this article assessed the knowledge and food handling practices of nurses in the food chain to patients in the hospital wards. The mean age of respondents was 33.7±9.3 years and 180 (56.6%) had worked in the hospital for 1–5 years. While respondents had good knowledge scores overall, only 22 (6.5%) knew the correct temperature for maintaining hot, ready-to-eat food. Also, 332 (97.6%) respondents knew the importance of hand washing before handling food while 279 (84.1%) always wash hands before handling food. The study revealed a decline in performance over time, from knowledge and attitudes to practice in food handling. Therefore, regular training on safe food handling procedures should be mainstreamed into the training curriculum of staff nurses in health care institutions.**

Introduction

In our study, a food handler referred to any person who handles food (raw, processed, or packaged), regardless of whether s/he prepares or serves it (Isara & Isah, 2009). Food hygiene involves all sanitary measures taken to ensure food safety in the food chain or the systematic control of environmental conditions during food supply services devoid of contamination by extraneous pathogens and chemicals (Aibor & Oloruntoba, 2006). Food safety is the assurance that food will not harm the consumer when prepared or eaten according to its intended purpose.

In hospitals, a balanced diet is essential for patient recovery, so served food must be safe, nutritious, devoid of pathogens, and served at appropriate times. In many hospitals, meals are cooked and wheeled to the wards (Lund & O'Brien, 2009). Therefore, food handling staff needs to observe hygienic practices at all times. Failure at any point along the food chain can expose patients to the potential for foodborne illnesses (Buccheri et al., 2007).

Foodborne illnesses have been documented globally; the World Health Organization (WHO) has recognized food safety as an essential public health function and it has devel-

oped a global framework to reduce its disease burden (Health and Social Care, 2013). Illnesses from contaminated food contribute to declining socioeconomic productivity (World Health Organization [WHO], 2002). Several studies estimated that about one-third of the population in developed countries experiences foodborne illnesses. In developed countries, the epidemiology and outcome of foodborne illnesses are documented, while in Nigeria, an ineffective surveillance system, self-medication, pharmacy consultations and prescriptions, and the use of local medicinal herbs mask the endemicity and absolute economic burden of foodborne illnesses (Malhotra, Lal, Prakash, Daga, & Kishore, 2008; Ogundipe, Odunjo, Komolafe, & Olatunji, 2013; WHO, 2007).

Foodborne infection is endemic in Nigeria and its direct cost is estimated at $3 billion, approximating 17%–25% of the estimated cost of all illnesses. The 1997 local government health system profile in Nigeria revealed foodborne illnesses as the leading cause of death, accounting for 25% mortality for that year. In 2007, the Federal Ministry of Health reported 90,000 cases of foodborne illness, while WHO has estimated 200,000 deaths from foodborne pathogens in Nigeria (Ebenso, Ekwere, Akpan, & Okon, 2012; Food and Agriculture Organization & WHO, 2002; WHO, 2009).

In Nigeria, the National Policy on Food Safety was approved by the National Council of Health in 1999. The policy provides guidelines on the minimum standards in food safety practice to ensure safety of food and products meant

Map of Nigeria Showing Osun State

Sampling Technique

The approximate number of respondents in each ward was obtained through a proportional sampling method with simple random sampling used to identify respondents in the 26 wards that participated in the study.

Inclusion and Exclusion Criteria

This study was limited to 26 out of the 28 wards at the hospital because of the difficulty in assessing and engaging those in the surgical ward and the intensive care unit of the hospital. In addition, administrative staff nurses were excluded from the study.

Data Collection and Analysis

Our study was conducted between January and March 2013. We utilized a semistructured questionnaire that was adapted from Buccheri and co-authors (2007). The study instrument had sections on sociodemographic information, knowledge, attitudes, and practices on food safety hygiene among nurses at the hospital. The study instrument was self-administered on 420 randomly selected respondents in 26 wards and retrieved within one week. Out of the questionnaires distributed, 340 were retrieved, which was an 81% response rate.

The data were coded, entered, and analyzed using SPSS v. 16.0. The mean, frequency, and percentages were calculated, while bivariate analysis and tests of association showed the relationship among key variables. In addition, the median (interquartile range) for attained score = 30 (27–32). So a score below 30 was considered poor and a score greater than or equal to 30 was good in the determination of a composite score for knowledge variables (Sudeshna & Aparajita, 2012). Similarly, scores of 20 (18–21) and 8 (6–10) were used to stratify attitude and practice scores into good and poor categories, respectively.

Informed Consent

Because the study did not influence patients' management and the issue investigated is a matter of public record, ethical approval for the study was not required (Buccheri et al., 1997). The procedure was approved by the nursing administrative office at the hospital. Participation in the study was voluntary, and respondents gave verbal consent. The respondents were assured of the confidentiality and personal identifiers were removed in the summary data.

for human consumption (Omojokun, 2013). The policy is currently under review, however, aimed at streamlining the roles and responsibilities of stakeholders to avoid overlap.

Food hygiene is important in hospitals as patients are a high-risk population for foodborne illness. To prevent contamination of food supplies, various stakeholders must contribute towards best practices (Shih & Wang, 2011). Our study evaluated the knowledge, attitudes, and prevailing practices of nurses routinely involved in food service functions in wards in a teaching hospital in Nigeria.

Materials and Methods

Description of the Study Location

Our study was conducted in the state of Osun in southwestern Nigeria (Figure 1). Osun State occupies about 9,250 km² and has over 200 towns. The climate is tropical: humid, high temperatures, and marked wet and dry seasons. Osun State has a population of 3,416,959 people comprised of 1,734,149 (50.8%) males and 1,682,810 (49.2%) females (National Population Commission, 2009). Primary and secondary health care facilities in the study area do not serve food to inpatients. Hence, the target group in this study was nursing staff, assigned to wards in a tertiary hospital in Osun State.

Study Design

This study utilized a descriptive cross-sectional design. The sampling frame comprised all nurses in the services of the teaching hospital while those in the randomly selected wards were the study population.

Sample Size Determination

The sample size was determined using Fisher's formula for estimating single proportions (Naing, Winn, & Rusli, 2006) with a standard normal deviation at a 95% confidence level and 50% proportion assumed since true proportion could not be established. The allowable margin of error was 5%, giving a minimum sample size of 384. The sample size was increased to 420 for attrition and to ensure robust analysis.

Theory

The knowledge and attitude of nurses are determinants of their handling practices of food served from wheeled carts to patients in wards of the hospital. Therefore, an understanding of basic and current information on recent advances in food handling is germane to patients' safety.

Results

Sociodemographic Information of Respondents

The mean age of respondents was 33.7±9.3 years, while most respondents (69.6%) were within 20–40 years. The majority of the respondents were females (74.7%), married (62.2%), and were of Yoruba ethnicity (87.2%). The respondents' mean length of service in the hospital was 8.2±7.5 years, though about 50.2% (177) had worked in the hospital 1–5 years. All respondents were registered nurses and had a variety of nursing qualifications, ranging from diploma certificate (180, 56.6%), bachelor of science (125, 39.3%), to master of science (13, 4.1%) (Table 1).

Knowledge of Respondents on Food Safety and Hygiene

The respondents' mean knowledge score was 29.4±4.4, with 8 and 36 as the minimum and maximum scores out of the 37 maximum obtainable score. Sixty-five percent (221) of respondents had good knowledge while 35% (119) had poor knowledge. Seventy percent (239) of respondents had good knowledge on the dangers inherent in food preparation well in advance of consumption for the risk of food contamination while only 43.7% (146) had knowledge that reheating food at inappropriate conditions prior to eating could result in food contamination. Almost 97% of respondents understood the importance of hand washing before handling food while 98% of respondents understood the importance of hand washing after using the toilet. About half of the respondents (51.3%) understood that the use of gloves can reduce the risk of food contamination. Only 40.1% respondents were aware of the hospital's standard operating procedure (SOP) for food handling (Table 2).

Overall, only 27.1% (92) respondents were able to demonstrate proper knowledge of

TABLE **1**

Sociodemographic Information of Respondents (*N* = 340)

Variable	#	%
Age, years (*n* = 339)		
20–30	121	35.7
31–40	115	33.9
41–50	72	21.2
51+	31	9.1
Gender (*N* = 340)		
Male	86	25.3
Female	254	74.7
Religion (*n* = 338)		
Islam	59	17.5
Christianity	279	82.5
Ethnicity (*n* = 335)		
Yoruba	292	87.2
Igbo	43	12.8
Marital status (*n* = 336)		
Single	119	35.4
Married	209	62.2
Divorced	3	0.9
Widowed	5	1.5
Length of service in hospital, years (*n* = 331)		
1–5	166	50.2
6–10	73	22.1
11–15	28	8.5
16–20	30	9.1
21+	34	10.3
Length of service in the current ward, months (*n* = 313)		
0–4	96	30.7
5–9	47	15.0
10–14	54	17.3
15+	116	37.1
Highest educational/professional qualification (*n* = 318)		
Nursing diploma certificate	180	56.6
Bachelor of science	125	39.3
Master of science	13	4.1

temperature controls for food storage. Specifically, only 19.4% (66) could demonstrate knowledge of proper temperature controls for cold, ready-to-eat food and only 6.5% (22) for hot, ready-to-eat food. Respondents had a good understanding of foodborne pathogens and diseases, with a mean score of 86.9±0.9. Almost all of the respondents understood that salmonellosis and cholera could be transmitted through food (96.9% and 98.5%, respectively), while 87.4% knew that hepatitis B is not a foodborne pathogen (Table 3).

Attitude of Respondents on Food Safety and Hygiene

Generally, the composite attitude score revealed that 57.1% (194) of respondents had a good attitude while 42.9% (146) had a poor attitude towards food safety and hygiene. Almost 86% (288) of respondents believed that raw and cooked foods should be separated while only 46.5% (155) understood that defrosted foods should not be refrozen. Most respondents (80.4%, 270) believed the use of food handling personal protective equipment (PPE) would reduce the risk of

TABLE 2

Knowledge of Nurses on Food Safety and Hygiene (*N* = 340)

Variables	Correct Response	Incorrect Response	Don't Know
	# (%)	# (%)	# (%)
Preparation of food in advance could contribute to food poisoning (*n* = 340)	239 (70.3)	76 (22.4)	25 (7.4)
Reheating of food could contribute to food contamination (*n* = 334)	146 (43.7)	154 (46.1)	34 (10.2)
Incorrect application of cleaning/sanitizing procedures on equipment (refrigerator, slicing machine) can increase the risk of foodborne disease to inpatients (*n* = 287)	227 (82.2)	24 (7.1)	36 (10.7)
Hand washing before handling food can reduce the risk of food contamination (*n* = 337)	326 (96.7)	10 (30)	1 (0.3)
Wearing hand gloves while handling food reduces the risk of transmitting foodborne infection to patients' food (*n* = 337)	173 (51.3)	143 (42.4)	21 (6.2)
Awareness about standard operating procedure for food safety and hygiene in this hospital (*n* = 332)	133 (40.1)	155 (46.7)	44 (13.3)
People with skin infections/diseases can contaminate food (*n* = 335)	300 (89.6)	27 (8.1)	8 (2.4)
Nose picking habit is dangerous and can contaminate food (*n* = 337)	326 (96.7)	9 (2.7)	2 (0.6)
Mouth, nose, and hair should be covered before handling food (*n* = 336)	274 (81.5)	49 (14.6)	13 (3.9)
Hands should be washed after defecation and urination (*n* = 339)	332 (97.9)	5 (1.5)	2 (0.6)
Licking fingers could contaminate food during handling (*n* = 332)	279 (82.1)	7 (4.4)	46 (13.6)
Talking to patients and colleagues while serving food could contaminate it (*n* = 335)	315 (94)	16 (4.8)	4 (1.2)
Foodborne diseases could be transmitted through contaminated fruits (*n* = 336)	329 (97.9)	4 (1.2)	3 (0.9)
Proper washing of fruits could reduce transmission of foodborne illnesses (*n* = 332)	323 (97.3)	7 (2.1)	2 (0.6)

TABLE 3

Knowledge of Respondents on Pathogens and Foodborne Infections (*N* = 340)

Disease/Pathogen	Correct	Incorrect
	# (%)	# (%)
Hepatitis A (*n* = 324)	216 (66.6)	108 (33.3)
Hepatitis B (*n* = 326)	285 (87.4)	41 (12.6)
Salmonellosis (*n* = 324)	314 (96.9)	10 (3.1)
Cholera (*n* = 339)	334 (98.5)	5 (1.5)
Botulism (*n* = 327)	288 (88.1)	39 (11.9)
Gastroenteritis (*n* = 338)	335 (99.1)	3 (0.9)

food contamination and that hand washing after toilet use is important to food safety and hygiene. Eighty-nine percent (308) of respondents believed that staff with communicable/infectious health conditions (diarrhea/catarrh/cough) should be excluded from

Current Practices of Respondents on Food Handling, Safety, and Hygiene

Table 5 presents the practices of food safety hygiene while Table 6 shows the test of association among key study variables. The composite practice score revealed that 54.4% (185) of respondents engaged in good food handling practices while 45.6% (155) demonstrated poor food handling practices in the hospital. The results revealed that 83.7% (278) of respondents "always" wash their hands before handling food while only 6.0% (20) "occasionally" do so before handling food in the wards. Surprisingly, 6 out of 10 respondents had "never" worn PPE before handling food while only 7.4% (25) wear PPE "always" prior to food handling. Seventy-one percent (237) of respondents "rarely" confirmed the integrity of food in hospital food carts before packaging and serving to patients. Only 41.7% (138) of respondents "always" checked and certified food from sources external to the hospital as safe before consumption by patients.

Our study showed that 87.7% (291) of respondents gained knowledge on food handing and safety during professional training while only 30.9% (102) had attended short-term postservice training on food safety hygiene. Most respondents (63.9%) were ignorant about the SOP for food handling even though the hospital wards' monitoring committee visits at random and inspects foods as part of their mandate.

The results revealed a significant association between knowledge and (1) religion (*p* = .008), (2) attitude (*p* = .009), and (3) awareness about the SOP for food safety and hygiene in wards (*p* = .003). In addition, a significant association occurred between knowledge and (1) temperature controls for hot, ready-to-eat foods (*p* = .010), (2) avoiding food contamination through saliva contamination when serving food (*p* = .0001), and (3) using PPE (apron, nose and mouth masks, and hand gloves) (*p* = .002) (Table 6).

Discussion

This study measured the knowledge, attitudes, and practices of nurses regarding safe food handling. In the hospital, wheeler-bins

(carts) are used to transport food from the hospital kitchen to wards, where the nursing officer in charge will package and distribute to patients.

Almost 70% of 340 respondents were middle-aged adults (20–40 years) with varying years of service in the hospital. As in other studies, most respondents were females, married, and had been employed by the hospital for at least six months. All of them had professional nursing qualifications and therefore had received safe food handling training as part of their professional education (Buccheri et al., 2007; Oteri & Ekanem, 1989).

The respondents had good composite knowledge scores (29.4±4.4) and were aware of safe handling of food and food preparation, hand washing at critical times, abstinence from food handling services when recovering from illnesses, and absolute silence when packaging food for patients. Although a large percentage (95.6%) of respondents knew that improper storage of foods is a health hazard to patients, only 37.6% knew the correct temperature (1°C–5°C) of food refrigeration. The observed pattern was different compared to the study of Buccheri and co-authors (2007), where 67.1% respondents knew the correct refrigeration temperature.

Respondents had poor knowledge regarding food storage and holding temperature controls. This finding was consistent with the studies of Buccheri and co-authors (2007), Lund and O'Brien (2009), and Abdalla and co-authors (2009), in which respondents also demonstrated a poor understanding of correct temperatures to maintain food under different conditions. According to Richards and co-authors (1993), the information on appropriate temperature for food storage at various conditions has been extensively documented and is the lever for the implementation of hazard analysis and critical control points (HACCP) and in the Nigerian food safety and hygiene policy (Omojokun, 2013).

Respondents had excellent knowledge and high scores (86.9±0.9%) on foodborne illnesses, in contrast to findings by Buccheri and co-authors (2007), except that 41(12.6%) nurses incorrectly classified hepatitis B as a foodborne illness. This demonstrates that respondents in this study are knowledgeable about food safety/hygiene and would refrain from endangering patients through cross contamination (WHO, 2009).

TABLE 4

Attitudes of Respondents on Food Safety and Hygiene

Description of Variables	Agree	Disagree	Uncertain
	# (%)	# (%)	# (%)
Raw foods should be separated from cooked foods (*n* = 336)	288 (85.7)	6 (1.8)	42 (12.5)
Defrosted food should not be refrozen (*n* = 333)	155 (46.5)	100 (29.4)	82 (24.1)
It is necessary to check the refrigerator/freezer operating conditions periodically to reduce the risk of food spoilage (*n* = 334)	250 (73.5)	32 (9.4)	52 (15.3)
The risk of food contamination will reduce if we wear personal protective equipment before handling food (*n* = 336)	270 (80.4)	49 (14.6)	17 (5.1)
Improper storage of foods may cause health hazard to consumers (*n* = 336)	325 (95.6)	6 (1.8)	5 (1.5)
Hand washing at critical times contributes to food safety and hygiene (*n* = 335)	297 (87.4)	25 (7.4)	13 (3.8)
Nurses with respiratory/diarrhea diseases should be excluded from food handling until full recovery (*n* = 337)	308 (89.4)	20 (7.0)	9 (2.7)

TABLE 5

Practice of Respondents on Food Safety and Hygiene (*N* = 340)

Description of Variables	Always	Frequently	Rarely	Never
	# (%)	# (%)	# (%)	# (%)
Hand washing before food handling (*n* = 332)	278 (83.7)	34 (10.3)	19 (5.7)	1 (0.3)
Wear personal protective equipment before handling food (*n* = 336)	25 (7.4)	23 (6.8)	85 (25.3)	203 (60.4)
Check and certify external food items before consumption by patients (*n* = 331)	138 (41.7)	71 (21.5)	94 (28.4)	28 (8.5)
Check integrity of hospital wheeler-bin foods before packaging to patients (*n* = 333)	0 (0)	74 (22.1)	237 (71.3)	22 (6.6)

The composite score on attitude indicated that most respondents (57.1%) had positive attitudes towards food handling and safety. This could be a result of health education interventions in which participants had been exposed to food sanitation and hygiene-related issues. In addition, the attitude of respondents was good regarding the separation of raw and cooked foods and monitoring the refrigeration and frozen temperatures to prevent food spoilage. Generally, PPE shields food handlers from contaminating food, though the study showed that most respondents do not wear PPE prior to handling food and were observed talking freely during food packaging and distribution in wards with the assertion that PPE was not provided by the hospital for food handling services.

Respondents also thought that improper storage conditions for food creates a high-risk situation for patients. In addition, the respondents understood the importance of hand washing after using the toilet.

Overall, however, only 54.4% (185) respondents practice good food handling behavior, which would indicate that hands-on educational intervention is required and should be initiated and mainstreamed into the in-service training curriculum of nurses in Nigeria.

Most nurses (70.3%) knew that preparation of food well in advance is a risk to food contamination, in agreement with findings of Buccheri and co-authors (2007) and *always* washed their hands before handling food. Hand sanitization prior to handling food in hospitals is important because nurses have contact with patients, body fluids, and fomi-

TABLE 6

Test of Association of Sociodemographic Information With Food Safety and Hygiene Variables

Variables	Categories	Knowledge		Total	Test Statistic
		Poor, # (%)	Good, # (%)		
Religion	Islam	12 (20.3)	47 (79.7)	59	$\chi^2 = 6.927$, $df = 1$, $p = .008$
	Christianity	107 (38.4)	172 (61.6)	279	
	Total	119 (35.2)	219 (64.8)	338	
Raw and cooked food should be separated	Yes	107 (37.2)	181 (62.8)	288	$\chi^2 = 12.773$, $df = 2$, $p = .002$
	No	3 (50)	3 (50)	6	
	Uncertain	5 (11.9)	37 (88.1)	42	
	Total	115 (34.2)	221 (65.8)	336	
Defrosted food should not be refrozen	Yes	55 (36.4)	96 (63.6)	151	$\chi^2 = 22.317$, $df = 2$, $p = .0001$
	No	46 (46)	54 (54)	100	
	Uncertain	12 (14.6)	70 (85.4)	82	
	Total	113 (33.9)	220 (66.1)	333	
Personal protective equipment will reduces risk of food contamination	Yes	81 (30)	189 (70)	270	$\chi^2 = 12.277$, $df = 2$, $p = .002$
	No	27 (55.1)	22 (44.9)	49	
	Uncertain	8 (47.1)	9 (52.9)	17	
	Total	116 (34.5)	220 (65.5)	336	
Keeping mute when packaging and serving food to patients	Yes	101 (32)	215 (68)	316	$\chi^2 = 16.267$, $df = 2$, $p = .0001$
	No	11 (78.6)	3 (21.4)	14	
	Uncertain	5 (71.4)	2 (28.6)	7	
	Total	117 (34.7)	220 (65.3)	337	
Awareness about standard operating procedure for food hygiene and safety	Yes	45 (33.8)	88 (66.2)	133	$\chi^2 = 11.680$, $df = 2$, $p = .003$
	No	82 (52.3)	73 (47.1)	155	
	Don't know	23 (52.3)	21 (47.7)	44	
	Total	150 (45.2)	182 (54.8)	332	
Maintenance temperature for hot, ready-to-eat food, °C	21–30	18 (26.9)	49 (73.1)	67	$\chi^2 = 13.167$, $df = 4$, $p = .010$
	31–40	39 (52)	36 (48)	75	
	41–50	15 (37.5)	25 (62.5)	40	
	51–60	13 (59.1)	9 (40.9)	22	
	61–70	17 (48.6)	18 (51.4)	35	
	Total	102 (42.7)	137 (57.3)	239	
Attitude of respondents	Poor attitude	63 (43.2)	83 (56.8)	146	$\chi^2 = 6.857$, $df = 1$, $p = .009$
	Good attitude	56 (28.9)	138 (71.1)	194	
	Total	119 (35)	221 (65)	340	
Age, years	20–30	38 (31.4)	83 (68.6)	121	$\chi^2 = 11.996$, $df = 3$, $p = .007$
	31–40	56 (48.7)	59 (51.3)	115	
	41–50	39 (54.2)	33 (45.8)	72	
	>50	13 (41.9)	18 (58.1)	31	
	Total	146 (43.1)	193 (56.9)	339	
Length of service in the health care facility, months	0–4	38 (39.6)	58 (60.4)	96	$\chi^2 = 9.790$, $df = 3$, $p = .02$
	5–9	12 (25.5)	35 (74.5)	47	
	10–14	25 (46.3)	29 (53.7)	54	
	>15	59 (50.9)	57 (49.1)	116	
	Total	134 (42.8)	179 (57.2)	313	

tes in their immediate vicinity and could have handled invasive devices for patient care (Pittet, Allegranzi, & Boyce, 2009), which could easily contaminate the bulk food wheeled to their wards. In addition, hands are the most important vehicle for the transfer of pathogens from many sources to food and therefore, hand washing is important in the prevention of hospital-based foodborne diseases (WHO, 1989, 2009). As contained in the SOP, nurses should certify food wheeled to the wards from the kitchen and those privately procured from outside the hospital for patients. Most nurses (71.3%) did this occasionally instead of always, since the hospital is responsible for the food consumed during patients' admission.

Conclusion

Preventing foodborne illness through the consistent practice of food safety and hygiene is essential to public health. The gap between good and poor knowledge, attitudes, and practice is not as wide as revealed in previous studies. Interestingly, although respondents had high knowledge scores, their food safety hygiene practices did not always reflect this knowledge. Therefore, a need exists to establish and operationalize an HACCP process in the hospital's food safety management practices in order to identify principal hazards and control points. Nurses should be trained in the HACCP process specific to their assignments and periodic in-service refresher training should be mainstreamed into their training curriculum (Baird, Henry, Liddell, Mitchell, & Sneddon, 2001; Lund & O'Brien, 2009; Shih & Wang, 2011). This is necessary since the turnover of nurses in the wards of the hospital is rapid, with 30.7% respondents having spent less than five months in the current ward.

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Assessment of the Physicochemical Quality of Drinking Water Resources in the Central Part of Iran

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Abstract   **The aim of the study described in this article was to assess the physicochemical quality of water resources in Isfahan province, located in the central part of Iran, from June to November 2012. Comparison of the results with the acceptable limits recommended by the World Health Organization (WHO) for drinking water showed that nitrate, chloride, iron, and fluoride concentrations exceeded the maximum acceptable level in 12.3%, 9.2%, 6.8%, and 1.5% of samples, respectively. Total dissolved solids (TDS) and turbidity values also exceeded the maximum acceptable level in 9.2% and 3.1% of samples, respectively. In general, the quality of drinking water resources in the central part of Iran at present is mostly acceptable and satisfactory. It may be deteriorated in the future, however, because water quantity and quality in arid and semiarid areas are highly variable over time. Therefore, continued monitoring of the water resources quality is extremely important to environmental safety.**

Introduction

The basic and essential requirement in water works is to provide the public with an adequate supply of safe drinking water (World Health Organization [WHO], 2011). Preserving the safe quality of water is vital to sustain life, protect human health, and contribute to social development (Vrba & Lippon, 2007). As the 20th century progressed, the identification of chemical water pollution became more important due to the outbreaks associated with chemical spills or leaks into potable water. In the mid 1970s, an event occurred that led to concern about chemicals in water because of chloroform in finished water treated with chlorine (Calderon, 2000). The Centers for Disease Control and Prevention (CDC) reported 34 waterborne disease outbreaks from 1993 through 2006 in the U.S. related to chemical constituents including nitrate and nitrite, fluoride, and lead (Post, Atherholt, & Cohn, 2011).

Health risk concerns related to chemical contamination of drinking water differ from those related to microbial contamination and arise mainly from the ability of chemical constituents to cause adverse health effects after an extended time of exposure (WHO, 2011).

Changes in water quality occur progressively except for those substances that are discharged or leach intermittently to flowing surface waters or groundwater supplies from contaminated landfill sites (WHO, 2011). The problem of chemical contamination in drinking water bodies may cause several health problems. Tooth discoloration and skeletal fluorosis are caused by excessive fluoride intake from drinking water (Maheshwari, 2006; WHO, 2011). A high content of nitrate and nitrite leads to methemoglobinemia in infants less than six months of age and also possible formation of nitroso-compounds that are known to be carcinogens in the digestive system (Manassaram, Backer, & Moll, 2007).

Iron and chloride are also of widespread significance because of their effects on water taste and acceptability (American Public Health Association [APHA], 2012; WHO, 2011). Iron concentration in drinking water above the acceptable limit can be objectionable because it stains laundry and may affect taste (WHO, 2011). Turbidity is a principal physical characteristic of water quality that could provide absorption sites for toxic substances and microorganisms in the water and subsequently protect pathogenic and indicator microorganisms from disinfectants (Edzwald, 2011). Total dissolved solids (TDS) is the term used to describe the inorganic salts and small amounts of organic matter present in a given amount of water (APHA, 2012). Reliable data on possible health effects asso-

ciated with the ingestion of TDS in drinking water are not available (WHO, 2011). The WHO guideline value of 1,000 mg/L for TDS is based on the taste and acceptability rather than health effects. Acceptability may vary according to circumstances. Furthermore, water with extremely low concentrations of TDS may also be unacceptable to consumers because of its flat, insipid taste (WHO, 2011).

Many studies show groundwater pollution from chemicals is a growing problem worldwide that is caused by numerous types of human activities (Babiker, Mohamed, Terao, Kato, & Ohta, 2004; Celik, Unsal, Tufenkci, & Bolat, 2008; Fang & Ding, 2010; Hudak, 2012; Kumar, Kumari, Ramanathan, & Saxena, 2007; Lee, Min, Woo, Kim, & Ahn, 2003; Loni & Raut, 2012; Nas & Berkaty, 2006; Subramani, Elango, & Damodarasamy, 2005). The water quality is highly affected by residential, municipal, commercial, industrial, and agricultural activities (U.S. Environmental Protection Agency, 1993). Deterioration of groundwater quality especially in arid and semiarid areas is a major concern that has been intensified by population growth and increases in demand for food supplies. Decreasing rainfall combined with increased evaporation from increased temperature as a result of climate change will affect groundwater levels in these regions (Wilby et al., 2006). The lack of adequate water resources and access to safe drinking water in arid and semiarid regions cause serious health hazards and expose many people to health risks (Schmoll, 2006). Thus, providing safe drinking water through proper management and monitoring of water resources is vital for the protection of public health and environmental safety.

Iran is an arid/semiarid country with an average precipitation of 251 mm/year (Assadollahi, 2009). The entire renewable water resource in Iran totals 130 billion cubic meters, out of which 92% is used for agriculture, 6% is used for domestic use services, and 2% is used for industrial uses (Assadollahi, 2009). For this reason, our study was designed 1) to assess the quality of water resources in the central part of Iran, which uses water after chlorination and without any additional treatment for drinking; and 2) to evaluate the impact of decreasing rainfall on the quality of some water resources in two successive years.

Methods

A total of 65 raw water samples were collected in clean polyethylene bottles between June and November 2012 from different drinking water resources including wells, springs, and aqueducts in Isfahan province. Isfahan province is located in the center of Iran; it has a moderate and dry climate with an average annual temperature of 16.7°C and an average annual rainfall of 116.9 mm (Assadollahi, 2009). The sampling, preservation, and analysis of water was carried out as recommended by the American Public Health Association (2012).

The turbidity and electrical conductivity (EC) were determined and EC measurements were converted to TDS values by multiplying EC by a factor of 0.55 as recommended for water resources (APHA, 2012). The concentrations of nitrate, nitrite, and fluoride were assayed by DR5000 according to manufacturers' instructions and chloride concentration was determined by the Mohr method. Iron analysis of water samples was carried out using a flame atomic absorption spectrophotometer.

In order to evaluate the effect of decreasing rainfall and increasing temperature on resource water quality, 12 water resources were randomly selected and the concentration values of three important parameters including nitrate, chloride, and TDS in 2013 were compared with the data in 2012. Meteorological parameters were also obtained from the weather bureau.

Statistical analyses of data were performed using SPSS with a confidence limit of $p < .05$. A normality test was performed for distribution of chemical value to decide if parametric or nonparametric test procedures must be employed. In addition, to compare mean values of physicochemical parameters, Fisher's least significant difference procedure was used to determine the significant differences between group means in an analysis of variance setting.

Results

In our study the quality of 65 water resources in the central part of Iran that used water after chlorination and without any additional treatment for drinking was assessed. The results showed that the quality of examined water resources was mostly acceptable with respect to the standard guideline val-

ues recommended by WHO (Tables 1 and 2). In some samples, however, the measured parameters exceeded the acceptable level. According to the analysis of water samples, the TDS values showed a high degree of variability, ranging from 2.12 to 1,754.5, with an average 452 mg/L (Table 1). TDS content of about 91% of samples, however, was below the permissible limit set by WHO for drinking water (Table 2). In addition, water with a TDS level of less than 600 mg/L is more pleasant (WHO, 2011). We observed that TDS levels were as follows: about 69.4% of samples had excellent TDS (<600 mg/L), 21.5% were good (<1,000 mg/L), and 9.2% of samples had higher than 1,000 mg/L. Although the WHO guideline value for TDS is based on the taste and acceptability rather than health effects, the taste is a basic criterion for consumers to decide on the suitability of a water source for drinking.

Iron and chloride could also raise complaints from consumers due to their effect on taste and color. Chloride concentration varied from 8 to 400 mg/L and 9.2% of samples had a concentration beyond the acceptable limit set by WHO for drinking water (Tables 1 and 2). This study showed a significant difference in the levels of chloride in spring samples compared to well and aqueduct samples.

Iron concentration of samples ranged from 0.01 to 1.23 mg/L and 6.8% of samples had a concentration more than 0.3 mg/L.

Comparison of the analytical results with the acceptable limit of measured parameters showed that the highest percentage (12.3%) of water resources contamination was related to nitrate pollution (Table 2). While water resources were highly polluted by nitrate, nitrite concentration in all samples was within the permissible limit and with a mean value of 0.006 mg/L, ranging from 0.001 to 0.045 mg/L. In addition, the highest concentration of nitrate (15.4 mg/L as N) was found in the well water sample (Table 2), and a significant difference occurred between the nitrate concentration in well water and spring samples.

Observed fluoride concentrations revealed that 1.5% of samples exceeded the acceptable limit (Table 2). Only 52.3% of samples had fluoride levels in accordance with the WHO guideline (0.5 to 1.5 mg/L), which is recommended for children during the time of developing permanent teeth. Also, 46.2% of samples had

fluoride levels lower than the recommended level (<0.5 mg/L). The highest concentration of fluoride was detected in the well water samples, and spring waters generally had 0.5 mg/L of fluoride or lower in 90% of samples.

Turbidity does not have a health-based guideline, but to ensure effectiveness of disinfection it should be no more than 1 nephelometric turbidity unit (NTU) and preferably much lower (WHO, 2011). In addition, under the Long-Term 1 Enhanced Surface Water Treatment Rule, drinking water cannot exceed 1 NTU and must be under 0.3 NTU in 95% of each month's tests (Edzwald, 2011). Although only 3.1% of samples had turbidity levels beyond the acceptable limit set by WHO for drinking water (>5 NTU), turbidity levels in 23.1% of samples were also less than perfect (Table 3). Furthermore, turbidity below 0.1 and 0.3 NTU according to the WHO and Ireland's Environmental Protection Agency guidelines, respectively, could ensure water safety based on the removing of chlorine-resistant pathogens such as *Giardia* and *Cryptosporidium* (Environmental Protection Agency [Ireland], 2009; WHO, 2011).

In order to identify the possible association between the measured parameters, a correlation analysis was performed and the results are presented in Table 4. According to the correlation analysis, a high positive correlation was found between TDS, chlorine, fluoride, and nitrogen dioxide (Table 4). As EC and TDS are mainly contributed from salts of sodium, potassium, sulfate, chlorine, and other minerals (Babiker et al., 2004), this correlation was expected. This result is consistent with other studies that reported the increase or decrease of TDS and turbidity values were related to the increase or decrease in the values of inorganic salts and small amounts of organic matters in water (Gupta, Sarkar, & Bhardwaj, 2012; Kanade & Gaikwad, 2011). Also in association with iron levels, we noticed a positive correlation between iron and turbidity levels. Turbidity in some groundwater resources is a consequence of inert clay or chalk particles or the precipitation of nonsoluble reduced iron and other oxides when water is pumped from anaerobic waters (WHO, 2011). Other physicochemical parameters of water were not statistically significant.

Mean values of nitrate, chloride, and TDS concentration in two successive years are presented in Table 5. As shown in this table all

TABLE 1

Statistics of the Analytical Results of Measured Parameters From 65 Drinking Water Resources

Parameter	Mean±*SD*	Minimum	Maximum
Turbidity (nephelometric turbidity units)	1.07±1.61	0.08	9.26
Electrical conductivity (µs/cm)	821.96±717.11	3.85	3190
Total dissolved solids (mg/L)	452.08±394.41	2.12	1754.50
Nitrate nitrogen (mg/L)	5.35±3.77	0.6	15.40
Nitrite nitrogen (mg/L)	0.006±0.006	0.001	0.045
Chloride (mg/L)	93.70±96.32	8.0	400.0
Fluoride (mg/L)	0.57±0.36	0.01	1.60
Iron (mg/L)	0.10±0.21	0.01	1.23

TABLE 2

Comparison of Water Resources Quality With World Health Organization (WHO) Guideline Values for Drinking Water

Parameter	WHO Guideline (mg/L)	% Samples Exceeding the Guideline Value			
		Well	Spring	Aqueduct	Total
Total dissolved solids (mg/L)	1000	7.5	0.0	20.0	9.2
Nitrate nitrogen (mg/L)	10.0	17.5	0.0	6.7	12.3
Nitrite nitrogen (mg/L)	1.0	0.0	0.0	0.0	0.0
Chloride (mg/L)	250	10.0	0.0	13.3	9.2
Fluoride (mg/L)	1.5	2.5	0.0	0.0	1.5
Iron (mg/L)	0.3	8.6	11.1	0.0	6.8

values were increased in 2013 in comparison to 2012 and the increase was significant for nitrate and TDS. In comparison to the results of analyzed parameters in 2012, however, the concentration of nitrate for only one sample exceeded the standard guidelines. According to the meteorological information, the mean rate of annual rainfall from October 2011–September 2012 to October 2012–September 2013 reduced about 13.9%–14.5% in most regions. Temperature increased, however, about 1ºC–1.5ºC in all regions.

Discussion

Groundwater is an important source of water worldwide and is particularly vulnerable to the direct and indirect effects of industrial and agricultural activities as well as climate change. According to the results of our study, the quality of drinking water resources in the central part of Iran is mostly acceptable and

satisfactory (Table 2). Comparison of physicochemical parameters concentration among the different water resources indicated that the water obtained from springs is better than the other water resources except for iron levels (Table 2), which could be attributed to the stratigraphic structure (Nemerow, Agardy, & Salvato, 2009). Since iron is frequently found in water due to large deposits in earth's surface (WHO, 2011), spring samples contained more iron concentration that exceeded the acceptable limit. Additional study is required to provide the detailed mechanisms of such effects.

Higher levels of TDS and chloride in well and aqueduct samples compared to spring samples could be related to the natural occurrence of this mineral in deep aquifers (WHO, 2011). Furthermore, pollution of water resources by wastewater could also increase the chloride concentration (WHO, 2011). Results of Rossiter and co-authors (2010) and

Percent Frequency Distribution of Turbidity in Different Water Resources

Source	Turbidity (NTU[a])			
	<0.1	0.1–1	1–5	>5
Well	2.5	65.0	27.5	5.0
Spring	10.0	80.0	10.0	0.0
Aqueduct	0.0	80.0	20.0	0.0
Total	3.1	70.8	23.1	3.1

[a]NTU = nephelometric turbidity units.

TABLE 4

Correlation Matrix of the Measured Parameters in Water Resources

Parameter	Iron	Fluoride	Chloride	Nitrite	Nitrate	Total Dissolved Solids
Turbidity	0.344**	0.000	0.292**	0.031	-0.097	0.087
Total dissolved solids	-0.145	0.545**	0.886**	-0.238*	0.181	
Nitrate	-0.055	0.064	0.200	-0.099		
Nitrite	-0.022	-0.312**	-0.162			
Chloride	-0.022	0.411**				
Fluoride	0.036					

*Correlations are significant at $p < .05$.
**Correlations are significant at $p < .001$.

TABLE 5

Comparison of the Nitrate, Chloride, and Total Dissolved Solids (TDS) Concentrations in Two Successive Years for a Number of Water Resources

Year	Chemical Parameters (Mean±*SD*)		
	Nitrate (mg/L)	Chloride (mg/L)	TDS (mg/L)
2012	5.04±0.7	30.8±5.6	209.20±185.40
2013	6.7±0.5	32.4±6.7	335.36±234.63

Kumar and co-authors (2007) also showed that around 5.7% and 6.6% of well and borehole water samples, respectively, have higher chloride concentration than the permissible limit set by WHO for drinking water. Comparison of TDS and chloride concentrations in aqueduct and well samples showed that aqueduct waters were contaminated more than the well waters. This may be explained by the structure of aqueducts, which is an underground system with a series of well-like vertical shafts that facilitate the arrival of point or nonpoint pollution to this source (Assadollahi, 2009). In contrast to TDS and chloride, the highest concentration of fluoride was detected in the well water samples. In a study conducted by Rossiter and co-authors (2010), fluoride concentration varied from <0.1 to 4.238 and about 6.7% of the well and borehole water samples had concentrations above the permissible limit set by WHO for drinking water (1.5 mg/L). Kortatsi (2008) also reported that about 17% of the well and borehole water samples contained fluoride concentrations above the permissible limit.

The results of our study also showed that the highest percentage of water resource contamination was related to nitrate pollution. The result is consistent with other studies that reported that nitrate is the most frequently introduced pollutant into groundwater systems (Babiker et al., 2004; Fang & Ding, 2010; Nishikiori, Takamatsu, Kohzu, Nakajima, & Watanabe, 2012). Nitrate may be present in groundwater resources as a consequence of the excess application of inorganic or organic fertilizer as well as wastewater from industrial activities (WHO, 2011). According to the European Environment Agency report, the percentages of wells with an annual mean nitrate concentration of higher than the European Union standard for drinking water (11.3 mg/L as N) were observed in the UK (15%), Italy (10%), Spain (25%), Germany (15%), and France (9%). In the U.S., 8% of wells sampled from 1991 to 2003 had a nitrate concentration more than the permissible limit set by the U.S. Environmental Protection Agency for drinking water (Nishikiori et al., 2012). In Japan, 4% of wells contain water with nitrate levels that exceed the Japanese environmental standard for groundwater (Nishikiori, 2012). In Iran, several studies have reported groundwater contamination by nitrate due to agricultural activities and heavy leaching of pollutants from pesticides and fertilizers to the aquifers (Ghaisari, Atosa, Najafi, & Hodaji, 2007; Khosravi, Mosavi, & Afyoni, 2006; Malekabadi, Afyoni, Mosavi, & Khosravi, 2004). We frequently observed the nitrate contamination in well water samples without the presence of other contaminants such as chloride and TDS, which could reflect the high impact of human and especially agricultural activities on well waters (MacDonald & Calow, 2009).

Among the studied regions, water resources in Falavarjan city were more polluted than the others. This may be due to the intensity of agricultural and industrial activities in this region. The results also showed that when the distance increased from farmland and industrial regions, the chemical levels in

the water resources decreased. Previous studies also have reported high values of chemical concentrations in the water samples of these areas (Amin, Ebrahimi, Hajian, Iranpanah, & Bina, 2010; Malekabadi et al., 2004). Since this area is one of the most important industrial and agricultural regions in the central part of Iran, different issues of water resources management such as quality and quantity conservation, planning for water allocation for agricultural uses, industry, and drinking water issues have arisen in regard to the fluctuations of chemical parameters, particularly nitrate. This finding also indicates that inadequate attention to water resources in these regions may enhance the presence of other chemical pollutants, particularly heavy metals. It is therefore essential to determine the quality of these water resources on the basis of other chemical pollutants.

Quality monitoring of a number of resources in two successive years showed that the quality has been mostly impacted by increased concentration of nitrate, chloride, and TDS (Table 5). The quality of groundwater is highly dependent on the geochemistry of soil and rocks through which it moves and also anthropogenic pollutants (Bloomfield, 2013). Water quality may be impaired, however, if decreases in annual mean rainfall cause contaminants to become more concentrated. In addition, in arid and semiarid areas, the quality of shallow groundwater may be affected by an increase in salinization due to increased evaporation (Bates, Kundzewicz, Wu, & Palutikof, 2008). Based on the relatively stable conditions of studied areas in the present study, the higher concentration of analyzed parameters in 2013 than in 2012 is likely due to increased salinization as a result of rainfall reduction and increase of temperature. This effect could be confirmed by simultaneous increases in average concentration of nitrate and TDS (Table 5). In addition, sequences of dry summers in arid and semiarid areas lead to the buildup of inorganic nitrogen in the soil and an increased risk of leaching from soil into water resources (Stuart, Gooddy, Bloomfield, & Williams, 2011; Wilby et al., 2006). Nitrate concentration is predicted to rise in many places over the next decade as the most widespread groundwater quality problem (Stuart et al., 2011). Wilby and co-authors (2006) state that rising temperature as a result of climate change will lead to higher nitrate concentrations throughout the 21st century until a plateau is reached in 2050. Long-term monitoring of a high number of water resources is required to understand the impact of climate change on water quality in arid and semiarid areas. This is particularly essential for ensuring the sustainability of future water resources (Bloomfield et al., 2013).

Conclusion

In general, the quality of drinking water resources in the central part of Iran in the present status is mostly acceptable and satisfactory. Water quality may be impaired, however, if decreases in annual mean rainfall cause chemicals to become more concentrated. Therefore, continued monitoring of water resource quality in arid and semiarid areas is extremely important for the protection of human health and environmental safety. 🐾

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Seat Belt Usage Interventions for Motor Vehicle Crash Prevention on the Pine Ridge Indian Reservation, South Dakota

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Abstract **Motor vehicle crashes (MVC) are the leading cause of death from severe injuries on the Pine Ridge Indian Reservation (PRIR), averaging 16 MVC deaths per year from 2002 to 2011. The Sacred Cargo Coalition was established in PRIR in 2007 to implement intervention strategies to increase seat belt usage and reduce MVC fatalities, including seat belt law enforcement, creating a traffic court system, and educational campaigns on MVC prevention. The study described in this article examined the effectiveness of the interventions on increasing the seat belt usage rates and reducing MVC deaths. Secondary data were collected from the National Highway Traffic Safety Administration and other federal and local agencies. Seat belt usage rates increased an average of 6.8 percentage points from 2007 (10%) to 2012 (44%). MVC fatalities decreased by 46.7% from the preintervention to the intervention period. Maintenance and improvement of the intervention strategies may be achieved by seeking additional funding and including appropriate engineering activities in PRIR.**

Introduction

Death from motor vehicle crashes (MVC) is an alarming problem on Native American reservations across the U.S. MVCs were the leading cause of death due to unintentional injury in the U.S. for Native Americans for all ages from 1981 to 2000. MVC fatality rates are disproportionately higher among Native Americans compared to other race/ethnicity groups (National Center for Injury Prevention and Control [NCIPC], 2013; National Highway Traffic Safety Administration [NHTSA], 2010). MVCs were responsible for 6.8% of all deaths of Native American populations as compared to 1.6% of all deaths in the non-Hispanic white population (NHTSA, 2006a). Adult MVC death rates for Native Americans are more than twice that of whites and almost twice that of African-Americans (Centers

for Disease Control and Prevention [CDC], 2013). MVC death rates among American Indian and Alaska Native (AI/AN) vary across the U.S., but in five states (South Dakota, Wyoming, Montana, North Dakota, and Arizona) it is more the twice the national average for all AI/ANs and more than four times the rate of the general U.S. population (NCIPC, 2013). Fatally injured Native American children were the least likely to have used child safety seats (27%) and the least likely to have been wearing safety belts (<7%) (NHTSA, 2006a). Of the leading mechanisms of Native American deaths from unintentional injury, MVCs ranked highest in the 1–9 and 10–19 age groups and second highest for infants (Bernard, Paulozzi, & Wallace, 2007).

The Pine Ridge Indian Reservation (PRIR) is an Oglala Lakota Native American reserva-

tion located in southwest South Dakota. It encompasses 2.4 million acres with residents in 52 reservation communities. The reservation includes Shannon, Bennett, and Jackson counties. The Native American population percentage is 92% for Shannon County, 60% for Bennett County, and 51% for Jackson County (U.S. Census Bureau, 2013). More than 43,000 residents are enrolled members of the Oglala Sioux Tribe (OST) (Bureau of Indian Affairs, 2005). The total population in the PRIR was 18,834 in 2010, 16,906 (89.8%) of whom were AI/AN, alone or in combination (Norris, Vines, & Hoeffel, 2012). PRIR averaged 16 MVC deaths per year based on National Highway Traffic Safety Administration (NHTSA) data from 2002 to 2011. People who survive an MVC have higher rates of debilitating injuries that reduce their quality of life and increase their long-term healthcare costs.

The 2005–2007 data from the OST/Pine Ridge Service Unit Severe Injury Profiles demonstrated that MVCs were the leading cause of death from severe injuries in PRIR (Figure 1). Severe injury, as defined by the Indian Health Service (IHS) Severe Injury Surveillance System protocol, is an injury resulting in one of the following: amputation, head injury, major fracture (excludes fingers and toes), hospitalization for at least one day in an IHS hospital or contract facility, or fatality. Out of the 99 fatalities, MVC was the leading cause of death with 53 fatalities (53.5%) followed by "other" causes with 18 fatalities (18.2%) and suicide with 12 fatalities (12.1%). The "other" category included drowning, poisoning, and occupational and crushing injuries.

The major risk factors that influence MVC fatalities in tribal communities include low seat belt use, low child safety seat use, and

FIGURE 1

Leading Causes of Injury-Related Deaths on the Pine Ridge Indian Reservation
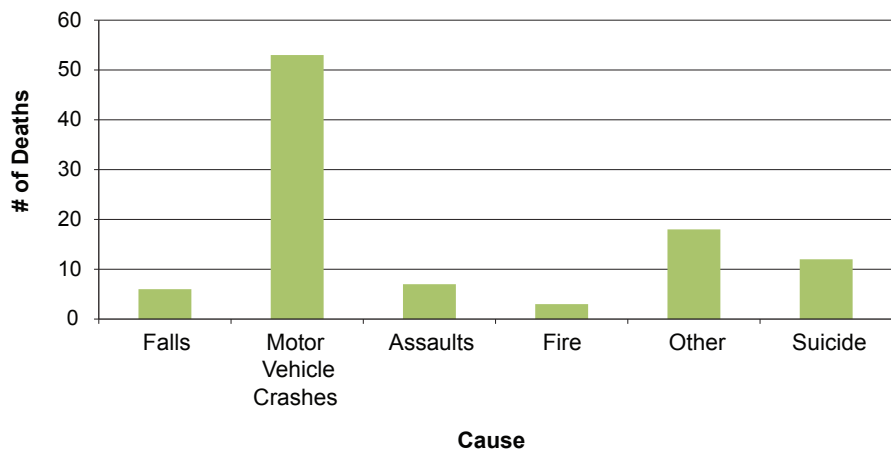
high prevalence of alcohol-impaired driving. Research shows that most of the people injured due to MVC were younger than 44 years old, had no health insurance, were not wearing a seat belt, and were alcohol impaired (NCPIC, 2013; NHTSA, 2010). Intervention addressing seat belt use is one of the well-established and effective MVC prevention strategies (CDC, 2001, 2013).

In an effort to reduce severe injury on the reservation from MVC, a local coalition was developed in 2007 to gather data on the most significant injury issues facing the reservation. Based on the data collected showing low seat belt usage and high MVC fatality rates, the coalition selected the appropriate intervention strategies and implemented them in the community to reduce MVC fatalities. The aims of our study were to describe these intervention strategies implemented in PRIR from 2007 to 2012 on increasing the seat belt usage rates and reducing deaths from MVCs, to investigate the effectiveness of the intervention strategies, and to determine if changes are necessary to improve these intervention strategies for MVC injury prevention among Native Americans.

Methods

Secondary Data Collection
Existing data on MVC fatalities and seat belt usage rates from federal, state, and tribal sources were collected for the years 2002–2012 for Native Americans on PRIR and all races in South Dakota and nationally. These data sources include 1) national seat belt usage rates from NHTSA; 2) national MVC mortality data from the Centers for Disease Control and Prevention (CDC); 3) fatality data from the NHTSA Fatality Analysis Reporting System (FARS); 4) local MVC fatality data for Native Americans from IHS for patients presented to the hospital emergency room or outpatient clinic or referred to another facility at the Pine Ridge Service Unit; 5) MVC reports and traffic citation data from the OST Department of Public Safety (DPS); 6) data on seat belt citations from the OST court; and 7) PRIR seat belt usage rates from the University of North Carolina (UNC) observational surveys conducted by the OST DPS and IHS Pine Ridge Office of Environmental Health (OEH).

MVC fatality data for Shannon, Jackson, and Bennett counties were collected from the NHTSA FARS database for MVC fatalities that occurred within PRIR boundaries between 2002 and 2011 regardless of race. Data on seat belt usage among the MVC fatalities were also collected from 2002 to 2009; seat belt usage data were not available for 2010–2011. The citation data were collected by the injury prevention specialists at OST DPS.

Data on seat belt usage rate in PRIR from 2007 to 2012 were obtained from a series of surveys conducted in the reservation by the OST DPS with the assistance of the IHS Pine Ridge OEH. The surveys were conducted according to the observational seat belt survey protocol developed by the UNC School of Public Health Department of Health Behavior and Health Education and adopted for the IHS Injury Prevention Program (University of North Carolina, 2005). These surveys were conducted biannually during the months of January and July from 2007 to 2012.

Implementation of Intervention Strategies
A local highway safety coalition named Sacred Cargo Coalition was created in PRIR in 2007 to take the responsibility of gathering information on the MVC injury issues facing the reservation and of selecting, prioritizing, and implementing intervention strategies in the community by improving seat belt use to reduce MVC fatalities. Membership in this coalition included the OST DPS, OST Head Start program, OST early child care program, OST substance abuse program, and IHS. The intervention strategies were based on CDC's *Guide to Community Preventive Services* (2013), and included 1) developing a distribution program for child safety seats, 2) enhancing the enforcement of the seat belt laws by the OST DPS through increasing citations in 2009, 3) developing a traffic court system in 2009 within the OST court to enforce seat belt citations, and 4) conducting an education campaign on the importance of seat belt use in reducing severe injuries from MVC by the OST DPS and the Sacred Cargo Coalition in local schools and media starting in 2007.

Data Analysis
Data were analyzed using the CDC Epi Info and Microsoft Excel 2010 for the calculation of descriptive statistics (i.e., means, percentages, and frequency distribution) and for data visualization (i.e., graphs). The overall seatbelt use rates and the changes in seat belt use rates during the intervention period of the populations living in PRIR, South Dakota, and U.S. were compared to determine if statistically significant differences were observed. Mann-Whitney tests were performed using Minitab 16 statistical software to determine if differences between the comparison groups were statistically significant ($p \leq .05$). The intervention strategies would

be considered effective if the goals set by the Sacred Cargo Coalition were achieved as follows: 1) seat belt usage rates in PRIR increase by 10 percentage points each year from 2007 to 2012 (50 points overall); 2) MVC fatalities decrease by 5% from 2007 to 2011 (six overall fewer deaths during the intervention).

Results

Seat Belt Usage Rate

The seat belt usage rates for the state of South Dakota showed a steady increase from 53.4% in 2000 to the low 70% by 2006, and remained in the low 70% until it dropped to 66.5% in 2012 (NHTSA, 2013; Struckman-Johnson, Baldwin, & Struckman-Johnson, 2011). The national seat belt usage rates for the U.S. were higher than those of South Dakota and showed a steady increase from 71% in 2000 to 86% in 2012 (Figure 2). The seat belt usage rates on PRIR were available from 2007 to 2012, showing an average increase of 6.8 percentage points per year and a 34 percentage point increase overall from 2007 (10% use) to 2012 (44% use), with a steeper increase after 2009. Despite the increase of PRIR seat belt usage rates during this period, PPIR rates were still significantly lower than the South Dakota population ($p = .0051$) and the national population ($p = .0050$) (Figure 2). The percentage increase in seat belt use from 2007 to 2012, however, was significantly greater on the PRIR than in South Dakota ($p = .0184$) and in the U.S. ($p = .0258$).

Table 1 summarizes the 2009–2012 data from the OST DPS on the number of MVCs, deaths, and injuries attributed to MVCs, seat belt citations issued, and percentage of drivers wearing seat belts in PRIR. These data showed a decrease in the number of MVCs and associated deaths and injuries during this period and an increase in the percentage of drivers using seat belts. Seat belt citations issued increased from 1,039 in 2009 to 1,430 in 2010, but then showed a decrease to 864 in 2011.

The NHTSA FARS data report that in the three counties (Shannon, Bennett, and Jackson) that cover PRIR, a total of 161 MVC fatalities occurred for all races from 2002 to 2011, or an average of 16.1 deaths per year, of which 142 (88.2%) were AI/AN (Table 2). Moreover, 0%–12.5% of the MVC fatalities during this period for all races were wearing seat belts (overall usage of 5.6%), with only

Seat Belt Usage Rates in the U.S., South Dakota (SD), and Pine Ridge Indian Reservation (PRIR), 2000–2012
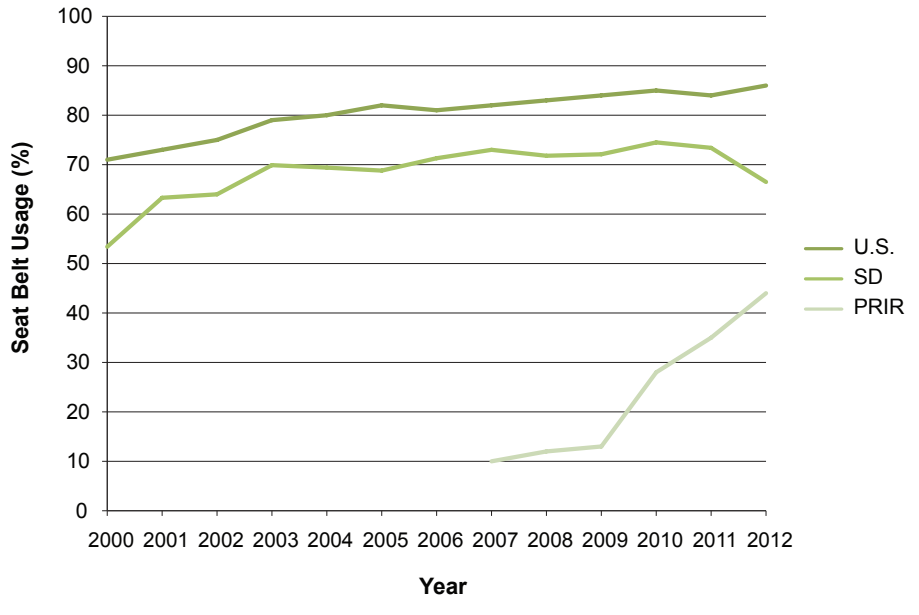
Motor Vehicle Crash (MVC) Injuries and Fatalities and Seat Belt Citations and Usage on the Pine Ridge Indian Reservation, South Dakota, 2009–2012

Fiscal Year (Oct–Sept)	Number of MVCs	Number of MVCs With Either Injury or Fatality	Number of Seat Belt Citations	Seat Belt Use (%)
2009–2010	318	106	1039	28
2010–2011	312	76	1430	35
2011–2012	248	70	864	44
Total	878	252	3333	–

Source: Oglala Sioux Tribe Department of Public Safety Injury Prevention Program.

0%–8.7% for AI/AN (overall usage of 2.1%), indicating that the MVC fatalities may be attributed to lack of seat belt use.

MVC Deaths and Injuries in PRIR

A total of 105 MVC fatalities for all races occurred during the preintervention period, 2002–2006, or an average of 21.0 MVC fatalities per year; while during the intervention period, 2007–2011, 56 MVC facilities occurred, with an average of 11.2 fatalities per year (Table 2). Therefore, a 46.7% reduc-

tion in MVC fatalities from the preintervention (2002–2006) to the intervention period (2007–2011) was observed, thus exceeding the 5% reduction goal. The annual number of MVC fatalities was significantly lower ($p = .0130$) during the intervention period in comparison to the preintervention period (2002–2006). Figure 3 shows that at the start of the intervention implementation in 2007, MVC fatalities dropped in numbers while seat belt usage rates started to rise with a notable increase after 2009.

Year	Number of MVC Fatalities		Number of Fatalities With Seat Belt Usage (%)	
	All Races	AI/AN[a]	All Races	AI/AN
2002	17	13	1 (5.9)	0 (0.0)
2003	26	23	2 (7.7)	2 (8.7)
2004	19	18	1 (5.3)	1 (5.6)
2005	23	19	2 (8.7)	0 (0.0)
2006	20	19	1 (5.0)	0 (0.0)
2007	8	7	1 (12.5)	0 (0.0)
2008	8	7	1 (12.5)	0 (0.0)
2009	13	12	0 (0.0)	0 (0.0)
2010	19	16	N/A[b]	N/A
2011	8	8	N/A	N/A
Subtotal 1 (2002–2006)	105	92	–	–
Subtotal 2 (2007–2011)	56	50	–	–
Total	161	142	9 (5.6)	3 (2.1)

[a]AI/AN: American Indian/Alaskan Native.
[b]N/A: not available.

FIGURE 3

Number of Pine Ridge Indian Reservation (PRIR) Motor Vehicle Crash (MVC) Fatalities and Seat Belt Usage Rates (%), 2002–2012
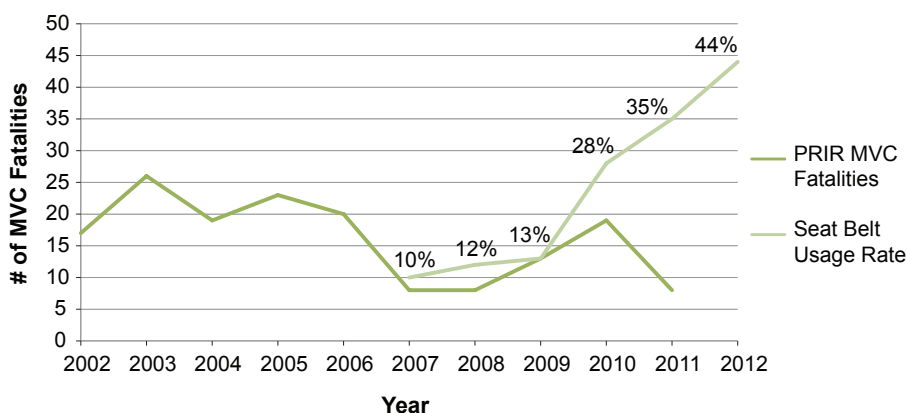
Intervention Implementation and Outcomes

Several intervention strategies were implemented in the PRIR since 2007 by several groups on the reservation to reduce MVC fatalities. MVC injury prevention activities and their time of implementation are summarized in Figure 4. Data collection and dissemination of educational information on seat belt usage started in 2005 by the IHS OEH. The OST traffic court began operation in 2009 and was a vital aspect of the enforcement of traffic laws on the PRIR. The Bureau of Indian Affairs (BIA) Indian Highway Safety Program (IHSP) funding was secured by the tribe in 2009 to support the OST DPS with enforcement of traffic laws by increasing the number of checkpoints, citations, and police officers dedicated to traffic safety. The IHS Tribal Injury Prevention Cooperative Agreement Program (TIP-CAP) and the CDC Tribal Motor Vehicle Injury Prevention Program (TMVIPP) grants were obtained through the Sacred Cargo Coalition in 2009 and awarded in 2010. The TMVIPP grant was focused on increasing seat belt usage and reducing impaired driving, while the TIP-CAP funding was focused on increasing child passenger safety seat usage. These grants provided funding for hiring two injury prevention specialists and for improving efforts in educating the community through local media on MVC injury prevention. The education efforts included seat belt and highway safety presentations by the OST DPS officers in all high schools and grade schools on the reservation. Public service announcements were placed on the local radio station and newspapers on the importance of wearing seat belts in reducing injury risk from MVC. These efforts brought awareness to the community on the number of MVC deaths and injuries on the reservation and on the intervention strategies that were implemented to decrease MVC fatalities.

Discussion

Increase in Seat Belt Use

The seat belt usage rates for PRIR, South Dakota, and the U.S. have shown a trend toward higher usage rates. The PRIR seat belt usage rates showed a 34 percentage point increase from 2007 to 2012, which may be attributed to the intervention strategies implemented in the PRIR starting 2007. The commencement of the OST traffic court operation in 2009 and enforcement of seat belt and other traffic laws on the PRIR may have influenced the further increase in seat belt usage in 2009 as well as the increase in issued seat belt citations in 2010. The steady increase in seat belt usage from that time forward may be attributed to the enhanced enforcement of traffic laws and extra financial support in 2009 and 2010. The 39.6% decrease in issued seat belt citations in 2011 may indicate that more PRIR residents were complying with the seat belt laws knowing that such laws are strictly enforced.

The percentage of drivers wearing seat belts increased from 10% in 2007 to 44% in 2012, with an average increase of 6.8 percentage points per year. Therefore, the targeted increase of seat belt use of 10 percentage points each year as set by the Sacred Cargo Coalition was not achieved. Although the goal was not attained, the usage rate increase was significantly higher than the state of South Dakota and the U.S., and may have positively contributed to the 46.7% reduction of MVC fatalities from the preintervention period (2002–2006) to the intervention period (2007–2011). Moreover, such seat belt use increase may have positive effects on other highway safety issues, such as decrease in severity of MVC injuries and decrease in hospitalizations due to MVCs, which were not included in the scope of our study.

Another goal of the interventions was to decrease MVC fatalities on the PRIR by five percentage points or six deaths during the intervention period from 2007 to 2011. NHTSA FARS data show a decline in MVC fatalities during the five-year intervention period (56 fatalities) relative to the five years immediately prior to the intervention (105 fatalities).

Seat Belt Law Enforcement
One of the most important intervention strategies implemented on the reservation is the increased enforcement activities by the OST DPS Highway Safety Department. The increase in issued traffic citations for seat belts and car seats as well as the greater visibility of checkpoints conducted and an increased and more stable number of police officers dedicated to traffic safety may have contributed to the increased seat belt usage. Moreover, the creation of a traffic court by the OST court in 2009 is vital in these enforcement efforts. Although OST did have a primary seat belt law that was passed by ordinance of the tribal council in 1998, the law was rarely enforced by the tribal court. Prior to 2009, when OST DPS would issue a traffic citation for nonusage of seat belts, no ramification occurred for not paying the fine because of lack of staff in the court system to enforce the citations. Due to the PRIR residents' noncompliance with seat belt law, police officers eventually stopped issuing citations out of frustration that such citations were not supported in tribal court. After the traffic court was instituted in 2009, an unpaid citation resulted

FIGURE **4**

Timeline of Motor Vehicle Crash Injury Prevention Activities on the Pine Ridge Indian Reservation

IHS: Indian Health Service.
BIA IHSP: Bureau of Indian Affairs Indian Highway Safety Program.
IHS TIPCAP: Indian Health Service Tribal Injury Prevention Cooperative Agreement Program.
CDC TMVIPP: Centers for Disease Control and Prevention Tribal Motor Vehicle Injury Prevention Program.

in the issuance of a warrant for arrest and imprisonment until the fines were paid, which sent a strong message to the community of the consequences of not obeying local traffic laws.

The "three Es" perspective to road safety by Groeger (2011) discussed several "E" components used to reduce the risk of injury from MVCs. Education, engineering, and enforcement components were the three major "Es". Education includes informing the public about MVC risk factors and skills to reduce such risk. Engineering focuses on making vehicles (i.e., through vehicle engineering designs, such as air bags, seat belts, electronic stability control, and speed limit warning systems) and roads (i.e., through sufficient lighting and installation of guard rails for roads with sharp curves) safer. The enforcement component makes risky driving a criminal offense. Checkpoints and arresting drivers for these criminal acts, especially when made public, has shown to be a powerful deterrent to these risky behaviors (DeJong & Hingson, 1998). Checkpoints were reported to decrease fatal MVCs by as much as 36% in some communities (Elder et al., 2002). Moreover, reservations with primary seat belt laws were found to have the highest use rates, followed by reservations with secondary seat belt laws; reservations with no seat belt laws have the lowest rates (NHTSA, 2006b, 2008). A study on the Navajo Nation demonstrated an increase in seat belt use from 14% to 60%

and decrease in MVC-related injury hospitalizations by 29% after the implementation of primary seat belt law, followed by a public information campaign to increase awareness of the law (CDC, 1992). Tribal policies are likely responsible for the increase in seat belt use and can be most effective in establishing and improving seat belt usage levels in reservations (CDC, 1992; NHTSA, 2008).

Study Limitations
A limitation of our study is the exclusion of fatalities and severe injuries not triaged through the Pine Ridge Hospital. Not all of the reservation residents use the Pine Ridge Hospital, considering that the hospital user population is 29,000 while the reservation population is approximately 43,000. With several hospitals in communities surrounding the reservation in South Dakota and Nebraska, it is possible that some MVC victims on the PRIR were sent to health care facilities in Nebraska or other states. These cases may be missed in the data collection if the NHTSA FARS system does not identify them as occurring on PRIR. Moreover, other factors that may affect MVCs and may serve as confounding factors, such as driver alcohol impairment and age, were not investigated in this study. Investigating the effects of these factors on seat belt use, MVCs, and MVC deaths in future studies may be worthwhile.

Conclusion and Recommendations

Government and community organizations on PRIR started addressing deaths and injuries from MVCs in 2005, which resulted in intervention programs to reduce MVC deaths and injuries. Data have begun to show an increase in seat belt usage in the PRIR during the intervention period (2007–2011), and a reduction in total MVC fatalities from the preintervention period (2002–2006) to the intervention period. Despite the steady increase of seat belt usage in the PRIR, the usage rate of 44% in 2012 is still much lower than the South Dakota (66.5%) and the national (86%) seat belt usage rates in 2012. For continued increase in seat belt usage and education among the PRIR members and maintenance of strict traffic law enforcement, the intervention strategies initiated at PRIR can still be strengthened through increased manpower in the OST DPS.

PRIR is a large area encompassing more than 2.4 million acres. The five officers are not adequate to provide constant coverage of the whole reservation. Also, an increase in culturally relevant education for the Lakota people who live on the reservation is important. Educational materials written and radio ads recorded in the Lakota language will help reach the Lakota-speaking segment of the tribal population on the reservation. Moreover, any intervention activities need to be conducted in all the communities on the reservation. The current intervention activities are held in the largest eight communities but over 40 smaller communities exist on PRIR. These intervention activities need to be brought to more of the smaller communities on the reservation. Efforts to reduce MVC fatalities on the PRIR must be a continuous program for the reservation communities. Funding for these efforts has been obtained but additional funding support must be sought from other agencies and programs to sustain these intervention strategies. Another element that must be focused on is the tribal program integration of activities that will sustain the intervention strategies, such as the collaboration of various tribal organizations (e.g., OST DPS, OST traffic court, Sacred Cargo Coalition, IHS OEH) and external stakeholders. The current interventions must annually undergo a comprehensive evaluation for effectiveness and further improvements each year.

The Sacred Cargo Coalition took a significant role of gathering information on MVC issues facing the reservation and of selecting and implementing intervention strategies to improve seat belt use and reduce MVC fatalities. In addition to coalition members from the OST government agencies and programs, however, more efforts must be made to include more community members from the reservation into the coalition to help gather more information and input for the success of these interventions from the communities' point of view.

Our study investigated the possible effects of the implemented intervention strategies on seat belt use and, consequently, on MVC fatalities in the PRIR. A reduction in MVC fatalities was observed from the preintervention to the intervention period. Despite the yearly increase of seat belt use during the intervention period, however, a yearly decrease in the number of MVC fatalities does not seem to be apparent. By contrast, the observed seat belt use increase may have positive effects on other MVC issues. To further evaluate the effectiveness of the interventions, investigating the effects on the severity of MVC injuries, the number of hospitalizations and long-term medical care costs due to MVCs, and other related MVC issues is recommended.

The implemented interventions in PRIR have addressed education and enforcement among the "three Es" discussed by Groeger (2011), except road engineering. No data were available on the engineering activities, such as installation of guard rails, street lighting, and straightening of roads that occurred at the PRIR during the study period. It is recommended that the coalition look into the need for road audits to be conducted by the reservation and state road departments to identify potential areas where MVCs may be occurring more frequently and to determine if physical barriers or increased lighting and signage are necessary in these areas to reduce MVCs.

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▶ **SPECIAL REPORT**

An Expanding and Shifting Focus in Recent Environmental Health Literature: A Quantitative Bibliometric Study

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Abstract **This special report characterizes the patterns of environmental health literature from 1993 to 2012 by using bibliometric techniques based on databases of the Science Citation Index and the Social Science Citation Index. "Research article" was the most widely used document type, accounting for 71.7% of the total records (5,053), and 94.9% of these articles were published in English. The number of environmental health publications is growing along with an increasing level of communication. The U.S. was the largest contributing country with the highest h-index (85) and the most publications (1,854), followed by the UK and Canada. *Environmental Health Perspectives* and the *Journal of Environmental Health* were the top two most productive journals. The most cited article in each main research area is also listed. The authors' study not only identifies global characteristics in environmental health research, but also influences researchers' selection of future studies and publications.**

Introduction

Novel environmental threats with potentially severe impacts on public health and ecosystems have emerged as a result of rapid growth of the world economy (Iverson & Perrings, 2012). More attention is being paid to environmental health than ever before. The environment used to be considered as "a minor player in the etiology of human illness; in part because only radiation, synthetic chemicals, and industrial by-products were included in the definition of environment (Olden, 2004)." Now, however, extensive studies have been undertaken on environmental health–related issues. These studies can be generally divided into two categories according to the defini-

tion of environmental health, i.e., the narrow definition (e.g., air, water, food, and soil pollutants), and the broad definition (e.g., lifestyle factors, occupational exposures, and pollutants) (McGuinn et al., 2012). Indeed, environmental health, according to the World Health Organization (WHO), "…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. Focus should be placed on preventing disease and creating health-supportive environments, which address the relationship between the environment and health (WHO, 2015)."

The biggest threat to human health appears to be adverse environmental changes. McMichael and co-authors (2008) noticed that global environmental changes are unprecedented in scale. Adverse environmental changes may even severely affect global life expectancy, which has increased largely since 1950 as a result of the scientific, social, and technological improvement (Kovats & Butler, 2012). The accurate and detailed relationship between environment and health has drawn an increasing level of attention in all fields, which has led to a surge in the number of related publications. Thus, a timely study is called for to critically evaluate the growing body of knowledge on environmental health. The bibliometric technique offers a useful quantitative and qualitative technique to assess the development and growth of research on the topic of environmental health.

Originally, bibliometric methods had been applied in library and information sciences for citation analysis and content analysis (Henderson, Shurville, & Fernstrom, 2009). In recent years, various characteristics of publications (e.g., author's affiliation, research fields, citation habits, and word distribution) were analyzed to obtain more refined information related to the research itself (Li, Ding, Feng, Wang, & Ho, 2009; Xie, Zhang, & Ho, 2008; Zhang, Wang, Hu, & Ho, 2010).

The aim of our study was to quantitatively and qualitatively evaluate environmental health research–related literature between 1993 and 2012, such as the countries' performance, the detailed analysis about the institute, the general trend, and the hotspots. Our findings provide a better understanding

Methods

Bibliometric analysis

Bibliometrics is a "statistical method of bibliography counting to evaluate and quantify the growth of literature for a particular subject" (Tsay, 2008)." Bibliometrics uses statistical and mathematical methods to research the distributed architecture, quantitative relation, varying pattern, and quantitative management of the document information and subsequently investigates the structure, characteristics, and patterns of the underlying science and technology. It is worth noting that bibliometrics can address qualitative features despite its quantitative nature (Wallin, 2005). Wallin suggested that bibliometric techniques offer a useful tool to transform intangible quality into a manageable entity and scale from micro (scientist and institute) to macro (national and global) levels. The main advantages associated with the implementation of bibliometric analysis are providing a time series evaluation of research in a specific topic with certain rules (Garfield, 1990) and recognizing the knowledge-intensive nature of scientific research (Van Raan, 2005). Indeed, this tool has been widely applied in various areas of science in order to measure scientific progress (Van Raan, 2005).

of global characteristics of environmental health research, which serves as a useful reference for future endeavors.

Statistical Analysis of Documents

The statistical analysis of documents forms an essential part of document research. Publication statistics generally describe countries, publishing houses, subjects, languages, journals, research institutions, and the number of published articles by different authors.

In our study, the h-index was adopted to measure the influence of countries. The h-index is an objective indicator of the impact of a researcher or journal (Du, Wei, Brown, Wang, & Zheng, 2012). It is defined as "A scientist has index H if H of his/her Np papers have at least H citations each, and the other (Np-H) papers have no more than H citations each," where Np is the number of papers published over *n* years (Hirsch, 2005). Therefore, the h-index measures both quantity (number of publications) and impact (number of citations) (Costas & Bordons, 2007).

Social Network Analysis

Social network analysis (SNA), which stems from graph theory, is a regulation or a method of the analysis on social relations (Serrat, 2009). The focus of SNA is placed on the structure of relationships, either casual acquaintance or close bonds (Nan & Zhe, 2011). Thus, a social network consists of multiple points (i.e., social actors) and the connections between them (i.e., the relationships between each social actor). In our study, SNA was adopted to analyze the collaborative relationships among the top 20 productive countries and institutions. The term "productive" is used in this study to express that one country or an institute had many publications and abundant research in the environmental health field.

Results

In this study, "environmental health" was searched in titles, abstracts, or keywords of those papers published between 1993 and 2012 in the database of the Science Citation Index-Expanded (SCI-E) and Social Science Citation Index (SSCI). As a result, 5,053 records were obtained. These records were analyzed according to their type, language(s), subject(s), journal(s), citation analysis of articles, authors' address information, and keyword distribution.

Type of Documents

Of 5,053 records, research articles (3,624) took the biggest share, accounting for 71.7%,

followed by editorial material (9.54%), reviews (8.43%), proceeding papers (7.74%), meeting abstracts (4.79%), book reviews (2.00%), news items (1.92%), and others, such as letter, correction, note, book chapter, biographical-item, and software review. Therefore, only research articles were selected for further analysis in our study.

Language of Documents

Results showed that English was clearly the dominant language used to communicate the results of environmental health research with 3,438 records (94.90%), followed by French (1.60%), Portuguese (1.49%), Spanish (1.05%), and German (0.55%). Japanese, Italian, Turkish, Chinese, Slovak, Czech, Hungarian, Korean, Polish, and Estonian were used less than 0.1%.

Characteristics of Publications

Characteristics of the environmental health publications during 1993–2012 are discussed below. The number of publications increased from 83 to 344, the number of publications with authors increased from 81 to 344, the number of total authors increased from 197 to 1,700, and the number of authors participating in each article on average increased from 2.4 to 4.9. The number of total references increased from 1,716 to 13,899, and the number of references in each article on average increased from 20.7 to 40.4. The general increase of publications and references indicated a growth trend and an increasing level of communication in the field of environmental health research during the last two decades.

Contribution of the Countries/ Regions and Institutes

The contribution of different countries/regions and institutes can be evaluated by analyzing the author' addresses. Only 3,537 articles were analyzed as 87 articles had no author addresses. Of them, 2,961 (83.7%) articles were independent publications without any collaboration.

The top 20 productive countries are listed in Table 1, which showed that the U.S. was the most productive country with the largest number of single-country publications and international collaborative publications, followed by UK (324) and Canada (244). The h-index of the U.S. was also the highest (85), followed by Canada (56), UK (55), Australia (43), and Germany (42), which was almost

The Cooperative Relationships Among the Top 20 Productive Countries/Regions
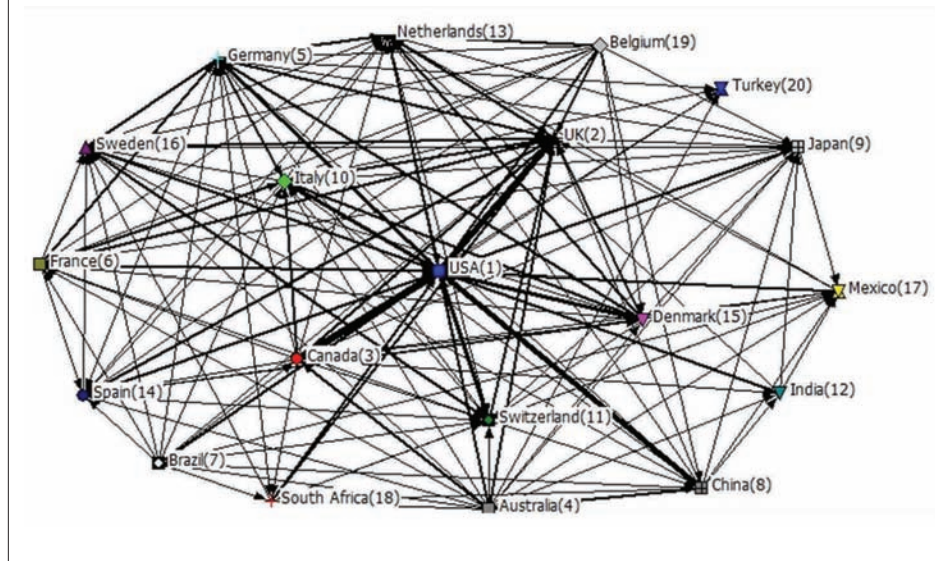
identical to the rank of these countries' total publications. The time-series analysis of the six most productive countries showed that the U.S. took a significant lead during 1993–2012, especially during its rapid growth since 1998. The analysis of keywords of articles published by U.S. scholars showed that "risk assessment," "environmental justice," "asthma," and "children" were main focuses of their environmental health studies.

We further analyzed the cooperative relationships among the 20 most productive countries during 1993–2012 using SNA (Figure 1). The number in parentheses represents the ranking of the country's total publications. The lines between the two countries represent their cooperative relationships, and the thicker the line is, the closer the cooperative relationship was. As shown in Figure 1, the top 20 productive countries/regions worked closely with each other as shown by the crisscross lines presented in the collaboration network diagram. It indicated that the U.S. took the lead in the environmental health research, and it had cooperative relationships with all the other 19 productive countries/regions. The cooperation between the U.S. and Canada was outstanding in the network; meanwhile the cooperation between the U.S. and the UK, China, Mexico, and Germany

was also noticeable. Similarly, the UK and Italy were also active in the collaboration network having close connections with the other 19 countries.

Among the 3,537 articles with authors' addresses, 53.3% of them involved interinstitutional collaboration. The contribution of the top 20 most productive institutes in environmental health research from 1993 to 2012 is shown in Table 2. Ninety percent of these top producing institutes are from North America. It was worth noting that the U.S. not only published the most articles but also had the most productive institutes. This indicated that the U.S. was the biggest contributor to environmental health research.

The U.S. Environmental Protection Agency (U.S. EPA), the most productive institute, mainly focused on "risk assessment," "epidemiology," "exposure assessment," and "children." The Centers for Disease Control and Prevention (CDC) was the second most productive institute and paid more attention to "children," "pesticides," "lead poisoning," and "epidemiology." The National Institute of Environmental Health Sciences (NIEHS) ranked as the third most productive institute and mainly focused on "toxic genomics," "public health," "risk assessment," "environmental justice," and "epidemiology."

Contribution of the Top 20 Institutes During 1993–2012

Institutes	TP[a]	TP R (%)[a]	SP[a] R (%)	CP[a] R (%)	FP[a] R (%)	RP[a] R (%)
U.S. Environmental Protection Agency	99	1 (2.8)	2 (1.27)	2 (4.14)	2 (1.53)	1 (1.6)
Centers for Disease Control and Prevention	94	2 (2.66)	4 (0.73)	1 (4.35)	4 (1.22)	5 (0.99)
National Institute of Environmental Health Sciences	91	3 (2.57)	1 (1.82)	5 (3.24)	1 (1.55)	1 (1.6)
University of North Carolina	81	4 (2.29)	4 (0.73)	3 (3.66)	3 (1.24)	3 (1.1)
Harvard University	72	5 (2.04)	14 (0.54)	4 (3.34)	5 (1.13)	4 (1.05)
University of California, Berkeley	62	6 (1.75)	11 (0.61)	6 (2.76)	7 (0.93)	7 (0.93)
Columbia University	59	7 (1.67)	4 (0.73)	7 (2.49)	5 (1.13)	6 (0.96)
University of Michigan	49	8 (1.39)	11 (0.61)	8 (2.07)	10 (0.65)	10 (0.61)
University of Washington	44	9 (1.24)	9 (0.67)	9 (1.75)	8 (0.85)	8 (0.81)
São Paulo University, Brazil	33	10 (0.93)	22 (0.42)	11 (1.38)	11 (0.54)	24 (0.38)
Duke University	33	10 (0.93)	4 (0.73)	15 (1.11)	15 (0.48)	16 (0.44)
University of Occupational and Environmental Health, Japan	32	12 (0.9)	3 (1.15)	34 (0.69)	9 (0.71)	9 (0.76)
Johns Hopkins University	31	13 (0.88)	43 (0.3)	11 (1.38)	22 (0.4)	35 (0.29)
Mount Sinai School of Medicine	31	13 (0.88)	58 (0.24)	10 (1.43)	11 (0.54)	12 (0.52)
University of Minnesota	30	15 (0.85)	4 (0.73)	20 (0.95)	13 (0.51)	11 (0.55)
Emory University	30	15 (0.85)	43 (0.3)	13 (1.33)	22 (0.4)	16 (0.44)
University of British Columbia	29	17 (0.82)	43 (0.3)	14 (1.27)	13 (0.51)	12 (0.52)
University of Wisconsin	27	18 (0.76)	16 (0.48)	19 (1.01)	18 (0.45)	16 (0.44)
University of Colorado	26	19 (0.74)	14 (0.54)	24 (0.9)	20 (0.42)	21 (0.41)
University of Toronto	26	19 (0.74)	43 (0.3)	15 (1.11)	41 (0.28)	40 (0.26)

[a]TP = number of total publications; R (%) = rank and the percentage of total publications; SP = single institute publications; CP = inter-institutionally collaborative publications; FP = the first author's institute publications; RP = the corresponding author's institute publications.

The Cooperative Relationships Among the Top 20 Productive Institutes
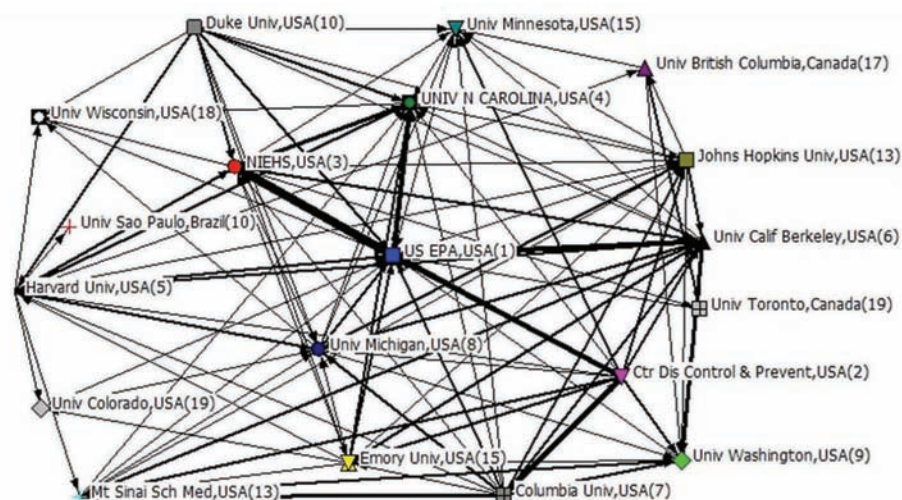
The cooperative relationships among the 20 most productive institutes during 1993–2012 are shown in Figure 2. U.S. EPA took the lead in the network diagram, and its cooperation with NIEHS was outstanding in the network. Additionally, the cooperation between U.S. EPA and University of California, Berkeley; CDC; and University of North Carolina was also noticeable.

Major research partners of the top three institutes were analyzed to optimize the analysis of institutions in the field of environmental health. Considering the number of publications greater than five, for U.S. EPA, the Office of Research and Development was the most productive research partner with 15 publications, followed by the National Exposure Research Laboratory (14), the National Health and Environmental Effects (12), and National Center for Environmental Assessment (9). For CDC, the National Center for Environmental Health (46) was the most productive research partner, followed by Division of Laboratory Sciences (9) and Epidemic

TABLE **3**

Number of Publications Within Main Topic and Subtopic Areas

Main Topics and Subtopics	# (%) 1993–2012	# (%) 1993–1997	# (%) 1998–2002	# (%) 2003–2007	# (%) 2008–2012
Environmental media pollution					
Water	215 (8.5)	11 (6.43)	32 (7.94)	58 (7.93)	114 (9.31)
Air	187 (7.39)	10 (5.85)	27 (6.7)	53 (7.25)	97 (7.92)
Food	92 (3.64)	7 (4.09)	10 (2.48)	31 (4.24)	44 (3.59)
Soil	47 (1.86)	4 (2.34)	11 (2.73)	16 (2.19)	17 (1.39)
Wastes	10 (0.4)	7 (4.09)	0	1 (0.14)	2 (0.16)
Environmental health hazards					
Chemical	89 (3.52)	8 (4.68)	19 (4.71)	24 (3.28)	38 (3.1)
Climate	43 (1.7)	0	3 (0.74)	7 (0.96)	33 (2.7)
Biological	34 (1.34)	6 (3.51)	8 (1.99)	8 (1.09)	12 (0.98)
Disaster	19 (0.75)	2 (1.17)	2 (0.5)	5 (0.68)	10 (0.82)
Physical	16 (0.63)	1 (0.58)	0	4 (0.55)	11 (0.9)
Dust	11 (0.43)	1 (0.58)	7 (1.74)	3 (0.41)	2 (0.16)
Environmental exposure					
Monitoring	169 (6.68)	4 (2.34)	11 (2.73)	39 (5.34)	38 (3.1)
Exposure assessment	34 (1.34)	4 (2.34)	5 (1.24)	14 (1.92)	11 (0.9)
Environmental illness					
Cancer	64 (2.53)	4 (2.34)	11 (2.73)	26 (3.56)	23 (1.88)
Respiratory	25 (0.99)	3 (1.75)	1 (0.25)	11 (1.5)	10 (0.82)
Birth defects and developmental diseases	21 (0.83)	1 (0.58)	0	7 (0.96)	12 (0.98)
Reproduction	6 (0.24)	0	1 (0.25)	1 (0.14)	4 (0.33)
Neurological disorders	4 (0.16)	1 (0.58)	2 (0.5)	1 (0.14)	0
Work environment and health					
Occupational exposure	11 (0.43)	0	1 (0.25)	6 (0.82)	4 (0.33)
Occupational disease	6 (0.24)	2 (1.17)	1 (0.25)	0	3 (0.25)
Vulnerable groups					
Children	151 (5.97)	7 (4.09)	27 (6.7)	68 (9.3)	49 (4)
Elderly	5 (0.2)	0	1 (0.25)	2 (0.27)	2 (0.16)
Environmental health risk assessment					
Risk communication	28 (1.11)	6 (3.51)	3 (0.74)	10 (1.37)	9 (0.74)
Risk prevention	2 (0.1)	0	0	0	2 (0.2)

Intelligence Service (6). For NIEHS, the Division of Extramural Research and Training (8) was the most productive research partner, followed by the Epidemiology Branch, and the Women's Health Group (5). This statistical analysis provides some more detailed information about the top producing institutes.

Analysis of Subjects and Journals

In terms of the total number of annual publications, the five most frequent subject categories are presented below. The 3,624 articles on environmental health were divided into 203 subject categories in SCI-E and SSCI. Among them, public, environmental, and occupational health ranked first with 1,523 publications, and environmental science ranked second (1,202). They showed a steady growth of the annual number of publications in the last two decades. The third subject category, toxicology, was far less than the top two subject categories with 298 publications, followed by environmental engineering (181) and environmental studies (141).

In terms of annual number of publications, the top six journals presented a general increasing trend. The top journal, *Environmental Health Perspectives*, published 265 articles in total, and the *Journal of Environmental Health* ranked second with 165 pub-

lications. *International Journal of Hygiene and Environmental Health* didn't have relevant articles until 2001, and it ranked third with 60 publications. Its growth rate was relatively higher compared with the following journals, *Science of the Total Environment*, *Environmental Research*, and *Environmental Science & Technology* with 51, 42, and 42 publications, respectively. These journals also had very few articles before 2001, and presented a slow rising volatility since then.

Main Research Fields

Table 3 lists the main topics and subtopics of environmental health according to the rank-

TABLE **4**

Most Frequently Cited Articles During 1993–2012

Year	TC[a]-2012	TC/Y[a]	Article	Journal	Country
1993	255	13	Lead Toxicity—Current Concerns	*Environmental Health Perspectives*	Canada
1994	390	21	Gender, Race, and Perception of Environmental Health Risks	*Risk Analysis*	U.S.
1995	133	7	Longitudinal Neurodevelopmental Study of Seychellois Children Following in utero Exposure to Methylmercury From Maternal Fish Ingestion: Outcomes at 19 and 29 Months	*Neurotoxicology*	U.S., Seychelles, Sweden
1996	129	8	The Use of Toxic Equivalency Factors in Assessing Occupational and Environmental Health Risk Associated With Exposure to Airborne Mixtures of Polycyclic Aromatic Hydrocarbons (PAHs)	*Chemosphere*	Switzerland
1997	107	7	Geographic Information Systems: Their Use in Environmental Epidemiologic Research	*Environmental Health Perspectives*	U.S.
1998	963	64	Widespread Sexual Disruption in Wild Fish	*Environmental Science & Technology*	UK
1999	165	12	Pesticides and Inner-City Children: Exposures, Risks, and Prevention	*Environmental Health Perspectives*	U.S.
2000	544	42	Public-Health Impact of Outdoor and Traffic-Related Air Pollution: A European Assessment	*Lancet*	Switzerland, France, Austria, Australia
2001	109	9	Ecologic Versus Individual-Level Sources of Bias in Ecologic Estimates of Contextual Health Effects	*International Journal of Epidemiology*	U.S.
2002	128	12	Carcinogenicity of Dimethylarsinic Acid in Male F344 Rats and Genetic Alterations in Induced Urinary Bladder Tumors	*Carcinogenesis*	Japan
2003	297	30	Global Amphibian Declines: Sorting the Hypotheses	*Diversity and Distributions*	U.S.
2004	148	16	Unhealthy Landscapes: Policy Recommendations on Land Use Change and Infectious Disease Emergence	*Environmental Health Perspectives*	U.S., UK
2005	172	22	Maternal Fish Consumption, Hair Mercury, and Infant Cognition in a U.S. Cohort	*Environmental Health Perspectives*	U.S.
2006	359	51	Inequality in the Built Environment Underlies Key Health Disparities in Physical Activity and Obesity	*Pediatrics*	U.S.
2007	169	28	Development of a Base Set of Toxicity Tests Using Ultrafine TiO_2 Particles as a Component of Nanoparticle Risk Management	*Toxicology Letters*	U.S.
2008	128	26	Oxidative Stress and Apoptosis Induced by Titanium Dioxide Nanoparticles in Cultured BEAS-2B Cells	*Toxicology Letters*	South Korea
2009	69	17	The Genomic Basis of Trophic Strategy in Marine Bacteria	*Proceedings of the National Academy of Sciences of the United States of America*	Australia, U.S., Turkey
2010	52	17	Prenatal Phthalate Exposure Is Associated With Childhood Behavior and Executive Functioning	*Environmental Health Perspectives*	U.S.
2011	52	26	The Comparative Toxicogenomics Database: Update 2011	*Nucleic Acids Research*	U.S.
2012	14	14	Titanium Dioxide Nanoparticles in Food and Personal Care Products	*Environmental Science & Technology*	U.S., Switzerland, Norway

[a]TC = total citations; TC/Y = average annual citations since publication.

ing of keywords and the hotspot analysis of pertinent literature. The largest amount of retrieved journal articles was on the public health aspects of environmental media pollution, followed by environmental health hazards, environmental exposure, vulnerable groups, environmental illness, environmental health risk management, and work environment and health.

(1) Environmental media pollution: water pollution was the dominant area of environmental media pollution research. Most studies focused on the supply and quality of drinking water and groundwater. The second largest area of research on this topic was concentrated on air pollution. The focus was mainly on ambient indoor and outdoor pollution. For food pollution, the focus was

mainly on food safety and food contaminants. In the water pollution research area, the article entitled, "Drinking Water Disinfection Byproducts: Review and Approach to Toxicity Evaluation," published in *Environmental Health Perspectives* in 1999 by Boorman and co-authors, had been cited the most (141) by the time of our study. In the air pollution research area, the article "Atopic Eczema and

Other Manifestations of Atopy: Results of a Study in East and West Germany," published in *Allergy* in 1996 by Schäfer and co-authors, was cited most (87) by the time of our study. In the food pollution research area, the article "Maternal Fish Consumption, Hair Mercury, and Infant Cognition in a U.S. Cohort," published in *Environmental Health Perspectives* in 2005 by Oken and co-authors was cited most (172) by the time of our study.

(2) Environmental health hazards: the publications on environmental health hazards mainly concentrated on chemical hazards, followed by climate, biological, disaster, physical, and dust. The article "Climate Change Risk: An Adaptation and Mitigation Agenda for Indian Cities," published in *Environment and Urbanization* in 2008 by Revi, had the highest annual number of citations.

(3) Vulnerable groups: children and elderly people face a higher degree of risks to health when exposed to environmental hazards (Tarkowski, 2007). Only a very small percentage of articles related to vulnerable groups focused on elderly people, however, in terms of their health risks derived from environmental exposures. The research on children mainly focused on children's health and development. Some studies were on children's illness, welfare, and so on. In the subject area of children, the article "Pesticides and Inner-City Children: Exposures, Risks, and Prevention," had been cited most (165) by the time of our study. It was a review article published in *Environmental Health Perspectives* in 1999 by Landrigan and co-authors.

(4) Environmental illness: Cancer was the main focus of environmental health research with 64 articles from 1993 to 2012, followed by respiratory, birth defects and developmental diseases, reproduction, and neurological disorders. In the subject area of cancer, the article "A Global Health Problem Caused by Arsenic From Natural Sources," had been cited most (158) by the time of our study. It was a review article published in *Chemosphere* in 2003 by Ng and co-authors.

The Most Frequently Cited Articles

Table 4 lists the most frequently cited articles, the total citations of articles, average annual citations of articles, article's title, journal's title, and the country of origin during 1993–2012. The most frequently cited article, entitled "Widespread Sexual Disruption in Wild Fish" and authored by Jobling and co-authors, was published in *Environmental Science & Technology* in 1998, with 963 citations and 64 annual citations. Furthermore, among the 20 most cited articles, six of them were published in *Environmental Health Perspectives*.

Discussion and Conclusion

Based on the databases of SCI-E and SSCI, our study investigated the characteristics of environmental health literature from 1993 to 2012 by using bibliometric techniques. In total 5,053 articles were published, 71.7% of which were research articles and 94.9% of which were published in English. The increasing number of total articles and references reflected that environmental health research had become extensive and global during the past two decades. The results indicated that the U.S. was the biggest contributor to environmental health research in terms of the total publications, the h-index, and also the collaboration analysis, focusing on "risk assessment," "environmental justice," "asthma," and "children." U.S. EPA was the most productive institution (99) and also took an important role in the collaboration network among the top 20 institutes. With public, environmental, and occupational health and environmental science being the top two subject categories, *Environmental Health Perspectives* (265 publications) and the *Journal of Environmental Health* (165 publications) were the top two most productive journals. Our study also found that the hotspots of the research area were mainly on environmental pollution, environmental health hazards, vulnerable groups, environmental illness, and so on. The list of the most frequently cited articles revealed the significant contribution of *Environmental Health Perspectives*. These findings offer a useful reference to researchers with interest in environmental health, which also influences the researchers' selection of future studies and publications. ♣♣♣

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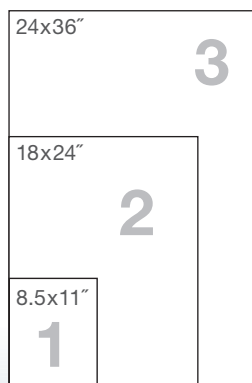
▶ **INTERNATIONAL PERSPECTIVES/SPECIAL REPORT**

Pesticide Exposure in the Caribbean: A Case From Nutmeg Processing

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Abstract **Many developed countries around the world have implemented regulations to phase out or greatly restrict the use of pesticides. Pesticides are still utilized with minimal restrictions, however, in fumigating agricultural commodities in developing countries such as Grenada. This special report presents the case of a nutmeg factory worker in Grenada who worked with various pesticides including methyl bromide, magnesium phosphide (magtoxin), and aluminum phosphide (phostoxin) without the proper awareness and utilization of health and safety measures. The nutmeg factory worker later developed metastatic bladder cancer, which may have been triggered by a combination of individual risk factors along with long-term occupational exposure to these pesticides. In this special report, the occupational health importance of prevention in a work environment with significant exposure to pesticides is highlighted as well as some of the fundamental deficiencies in awareness among workers in developing nations concerning the deleterious effects of frequent exposure to pesticides.**

Introduction

Many developed countries around the world have banned or placed strict restrictions on a variety of pesticides that pose significant threats to health and the environment. Some developing countries around the world still apply pesticides such as methyl bromide, magnesium phosphide (magtoxin), and aluminum phosphide (phostoxin) with minimal restrictions on use. In Grenada, methyl bromide was used in the fumigation of nutmeg until around 1995 and then was discontinued due to a national ban. Magnesium phosphide and aluminum phosphide pellets have been used in Grenada recently. These pesticides can lead to severe health issues for exposed workers (Wesseling, McConnell, Partanen, & Hogstedt, 1997).

Methyl bromide is an extremely toxic vapor and the predominant route of entry is through the lungs, although methyl bromide can also enter through the mouth by ingestion and skin by absorption. Since methyl bromide is a fumigant, it can disrupt the exchange of oxygen at a cellular level. Chronic exposure may lead to detrimental health effects including depression, euphoria, personality changes (U.S. Environmental Protection Agency [U.S. EPA], 2013), and various types of cancer. Methyl bromide has been linked to fatal cases of testicular cancer in industrial workers exposed to brominated compounds (Pira et al., 2010) and to cases of prostate cancer in individuals with occupational and community exposure (Alavanja

et al., 2003; Budnik, Kloth, Velasco-Garrido, & Baur, 2012; Cockburn et al., 2011). After methyl bromide was discontinued in the nutmeg plant, magtoxin and phostoxin were utilized as the main pesticides in the treatment of nutmeg starting around 1995. Magtoxin and phostoxin pellets react with moisture from the air to release phosphine gas, which is a highly toxic aromatic amine with health effects such as malaise, tinnitus, pulmonary edema, cyanosis, syncope, and even death with extensive exposure (U.S. EPA, 2015).

This special report examines occupational exposure to these pesticides, highlights the importance of prevention measurements when working with harmful pesticides, and provides valuable insight into the fundamental deficiencies in awareness among workers in developing nations concerning the deleterious effects of frequent exposure to pesticides in the absence of basic workplace precautions.

Case Report

A 46-year-old male presented to his physician in August 2009 with hematuria, which had been persistent since May 2009. Prior to this medical visitation, the male did not obtain any preventative health services. His family medical history was only significant for uterine cancer on his mother's side. Additionally, the male was a nonsmoker with no noteworthy history of heavy drinking or hazardous environmental exposure outside of his current occupation or work history apart from the nutmeg industry. Biopsy revealed that he had metastatic adenocarcinoma of the bladder. The male had been a worker in the nutmeg plant in Grenada for the previous 30 years and eventually stopped working in the plant three months prior to his death

in 2012. The worker signed a consent form to release his medical records for review and agreed to his inclusion in this report.

In 1979, he worked in the stencil room where he was in daily contact with certain dyes and in the pesticides and fumigation room where he was exposed to methyl bromide, magtoxin, and phostoxin. Magtoxin was used as a pesticide in 1999 and then replaced with phostoxin in 2005. In 1999, he was permanently transferred to the pesticides and fumigation room. His primary tasks in this room included spraying the nutmeg with pesticide and fumigating the nutmeg by opening and placing the packets of pesticides in various locations in a 15 ft. x 15 ft. room that was tightly sealed afterwards. After two days, the nutmeg worker manually reopened the room to ventilate the pesticide on the nutmeg.

All tasks were performed by the worker without the utilization of any personal protective equipment (PPE—mask, glove, or proper outfit) and without awareness of the health dangers associated with the pesticide exposure. He never received any pesticide handling training. A visit to the processing plant in 2011 found that the workers in the fumigation room who experienced detrimental health effects also did not wear any PPE and did not receive any safety training or follow a formal procedure regarding the handling of the fumigant and timing of reentry into the fumigation room. The site visit revealed that the solid pesticide tablets used in the fumigation room immediately reacted with atmospheric moisture to produce the toxic gas phosphine. No material safety data sheet (MSDS) for the pesticides used nor product label for the fumigant existed.

Discussion

Occupational exposure to the pesticides mentioned without the utilization of proper prevention measurement might have caused detrimental health effects among workers in the fumigation room. To examine if the lack of proper prevention and the development of adverse health outcomes in the nutmeg worker were related, confounding variables such as smoking status, non-work-related hazardous environmental exposure, alcohol consumption, chronic bladder irritation and infections, bladder birth defects, cancer-causing genes, prior utilization of chemotherapy and radiation therapy, and fluid consumption were controlled for. The information from the site visit and previous literature (Kesavachandran et al., 2009) show that over 13 years of unprotected exposure to the pesticides methyl bromide, magtoxin, and phostoxin could have been carcinogenic to the nutmeg worker and also this exposure poses a health risk to the other nutmeg workers. Another major finding from the workplace assessment was that a widespread deficiency in awareness existed among the nutmeg workers about their personal safety, which could mean that basic workplace safety precautions have seldom been implemented in developing countries. Low levels of education, low perceived benefits of PPE use (Taha, 2000), and competing social, economic, and political challenges (Ahasan & Partanen, 2001) could be possible explanations for this inadequate awareness. Further research is needed to look into this matter and on the chronic effects of exposure to the mentioned pesticides in order to make a conclusive association between pesticide exposure and bladder cancer development in the nutmeg worker. The occupational work included fumigant replacement, increased ventilation, and worker training and successfully led to workplace alterations, the formulation of a health and safety committee, and an increase in awareness among workers. A genuine need still exists, however, to promote regular health screenings for workers and the continuous updating of MSDS about hazardous chemicals (Ward, 2010). By implementing collaborative health education and awareness programs and promoting various disease prevention strategies, it is hoped that a substantial and long-lasting improvement in the health of the workers in the nutmeg facility in Grenada as well as other developing countries will be achieved.

Conclusion

An important key point of this research is that occupational health and safety must be utilized by workers when working with pesticides or in a substantial pesticide exposure environment. In addition, awareness about the inherent dangers of a work environment is essential in preventing the development of detrimental health effects in workers. Both developed and developing countries must work together and with their individual governments to provide and maintain a safe work environment for all workers. Most importantly, a significant amount of literature is available on pesticide exposure and utilization patterns in workers but most of the literature is from developed countries. Developed countries have different working conditions, exposure patterns, and chemicals compared to developing countries so it is beneficial to gain a perspective on occupational health from a developing country's perspective. This new perspective will help decision makers from both developed and developing countries to make occupational health and safety decisions that are best suited for the needs of that particular country.

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Did You Know?

We have a fresh, new face at NEHA who is blogging about her experience with us as a Public Health Associate. Solly Poprish's goal for the new blog is to provide a look into NEHA and the work we do, talk about her experience as a young professional entering the workforce, and provide information on environmental health topics that are important and relatable. We invite you to join the conversation at www.neha.org/membership-communities/get-involved/day-in-life/young-professional-entering-public-health-workforce.

Association Between Low Temperature During Winter Season and Hospitalizations for Ischemic Heart Diseases in New York State

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Abstract Most prior research investigating the health effects of extreme cold has been limited to temperature alone. Only a few studies have assessed population vulnerability and compared various weather indicators. The study described in this article intended to evaluate the effects of cold weather on hospital admissions due to ischemic heart disease, especially acute myocardial infarction (AMI), and to examine the potential interactive effects between weather factors and demographics on AMI. The authors found that extremely low universal apparent temperature in winter was associated with increased risk of AMI, especially during lag4–lag6. Certain demographic groups such as the elderly, males, people with Medicaid insurance, people living in warmer areas, and areas with high $PM_{2.5}$ concentration showed higher vulnerabilities to cold-AMI effects than other groups.

Introduction

With climate change, extreme weather events such as heat waves and cold spells will become more frequent and longer in duration (Intergovernmental Panel on Climate Change [IPCC], 2007). The relationship among low ambient temperature and extreme cold events and ischemic heart disease (IHD) is not well understood. Most prior studies of the cold weather-IHD relationship have focused on mortality, finding statistically significant increased risks of 1.16–1.44 (Bhaskaran et al., 2009). In the cold weather sea-son, December and January had the highest frequency of death (Kloner, Poole, & Perritt, 1999; Sheth, Nair, Muller, & Yusuf, 1999).

Even fewer studies have evaluated the association between cold temperature and IHD hospital admissions as an indicator of morbidity. A comprehensive review by Bhaskaran and co-authors (2009) reported a statistically significant short-term increased risk of myocardial infarction (MI) at lower temperatures in winter in 8 of 12 studies; relative risks (RR) ranged from 1.01 to 1.40 and the strongest association was observed at lags of 2–7 and 8–14 days (Bhaskaran et al., 2009, 2010). Other research observed a seasonal variation for acute myocardial infarction (AMI) hospitalization that peaked in winter (Lee et al., 2010; Marchant, Ranjadayalan, Stevenson, Wilkinson, & Timmis, 1993; Spielberg, Falkenhahn, Willich, Wegscheider, & Voller, 1996). Old age and previous heart conditions increased vulnerability to cold effects (Analitis et al., 2008; Barnett et al., 2005; Bhaskaran et al., 2010; Danet et al., 1999; Morabito et al., 2005; Wichmann, Ketzel, Ellermann, & Loft, 2012). Other studies, however, observed no clear cold temperature-IHD morbidity association (Hajat & Haines, 2002; Schwartz, Samet, & Patz, 2004).

Gaps identified in scientific literature include lack of sensitive weather indicators of low temperature on health, lack of consideration of other weather factors in addition to temperature, relative paucity of data on cardiovascular morbidities, no assessment of population vulnerability, and no assessment of interaction between low temperature and air pollution. Our study fills these knowledge gaps by evaluating the effects of various cold indicators and temperature ranges in the winter on IHD hospitalizations, cold temperature's individual and cumulative lag effect, and identifying potential vulnerable population groups to help inform climate adaptation planning.

Materials and Methods

Study Population and Study Design

The study population consisted of subjects hospitalized for IHD, which included AMI (International Classification of Disease 9th Revision [ICD9] codes, ICD9 410), angina pectoris (AP) (ICD9 413), chronic IHD (CIHD) (ICD9 414), and other IHD (OIHD) (ICD9 411, 412) from 1991 to 2004 in New York State (NYS) during the cold weather season. A time-stratified case-crossover design was employed to assess the weather-health relationships (Maclure & Mittleman, 2000). Time was divided into two disjointed strata and exposure indicators in the hazard period and exposure indicators in multiple reference periods were compared within strata of time (Janes, Sheppard, & Lumley, 2005). Cases serve as their own controls and exposure indicators were assigned on 1–6 days before hospital admission (during hazard period). Cases were compared to exposure indicators at the same lags between the hazard and control period. Time-stratified selection of referents provided three referents per case per month on average.

Sources of Data

Hospital admission data were obtained from the NYS Department of Health (NYSDOH) Statewide Planning and Research Cooperative System (SPARCS), which collects inpatient information for all NYS hospitals except psychiatric and federal hospitals. The SPARCS database includes ≥95% of acute care hospitalizations (Lin et al., 2008). Meteorological data, including hourly observations for temperature (T), dew point (DP), barometric pressure (P), and wind speed (W) were provided by the Data Support Section of the Computational and Information System Laboratory and the National Center for Atmospheric Research of the National Weather Service. These data were used to derive daily maximum, mean, and minimum for each variable.

Exposure Definition

The cold weather season was defined as December 24 to February 18 of each year as the mean daily average universal apparent temperature (UAT) during this period was relatively stationary. Steadman's UAT was calculated using the formula:

$$UAT = -2.7 + 1.04*T + 2.0*VP - 0.65*W,$$

where T is measured in °C, VP in kPa, and W in m*s^{-1}. VP was derived from DP:

$$VP = 0.6105 * EXP(17.27 * DP[°C] / (237.7 + DP[°C]).$$

Maximum, average, and minimum UAT values were calculated (Steadman, 1984). UAT is used in our study as it combines temperature, humidity, and wind, which more accurately represents the overall winter atmosphere and environment than temperature alone (Madrigano et al., 2013).

Fourteen weather regions were assigned in NYS. These regions were created by overlaying and merging the National Climate Data Center's 10 NYS climate divisions with 11 ozone regions developed for NYS (Chinery & Walker, 2009; Guttman & Quayle, 1996). Small regions that did not coincide completely were merged with the adjacent regions they were most similar to. This resulted in 14 regions of relatively homogeneous weather exposure. Although ozone exposure is not of interest in the winter season, we used temperature-ozone regions to be able to compare this study with our other studies of other diagnoses and in different seasons. Each hospitalization was geocoded by address and assigned to one region using MapMarker Plus.

We created three temperature indicators: mean of the daily average UAT (UATavg), three-day moving average of UATavg, and extreme temperature (10th percentile of UATavg distribution). We also assessed the effects of daily minimum UAT (UATmin) and daily maximum UAT (UATmax) on IHD hospitalizations. Since temperature did not have a linear relationship with IHD hospitalizations, 5°F interval groups were created for the mean of UATavg and the three-day moving UATavg, UATmin, and UATmax. For the stratified analysis we grouped temperature in 10°F intervals to avoid small sample size problems. In both analyses the temperature group closest to and above water's freezing point (32°F) was selected as the reference.

Confounders and Effect Modifiers

Potential sociodemographic confounders were controlled for by the study design. Case-crossover design is one kind of time-series analysis and a special type of matched case-control design where cases serve as their own controls. This design controls for confounding due to time-invariant variables, by having constant subject characteristics such as sex, race-ethnicity, age, and source of treatment in both exposure and control periods, which also controls for seasonality as both periods occur within the same month (Maclure, 1991). Barometric pressure was also included as a confounding factor in the analysis. Stratified analysis was conducted for the following variables: sex, race-ethnicity, age, source of treatment payment, weather region, and particulate matter ≤2.5 µm (PM$_{2.5}$). Five categories were created for race-ethnicity: white-Hispanics, white non-Hispanics, black-Hispanics, black non-Hispanics, and other. Age was categorized as follows: 18–24, 25–44, 45–64, 65–74, and ≥75. Three sources of payment were considered: Medicare, Medicaid, and other programs. PM$_{2.5}$ was categorized in two groups based on the U.S. Environmental Protection Agency (U.S. EPA) annual National Ambient Air Quality Standard: <15 µg/m^3 and ≥15µg/m^3. In December 2012, after our study period, U.S. EPA strengthened the annual fine particle standard from 15.0 µg/m^3 to 12.0 µg/m^3.

Statistical Analysis

Conditional logistic regression models using the SAS PHREG procedure were employed to analyze the data. Initially, crude analyses were stratified by sex, race-ethnicity, age, source of payment, weather region, and PM$_{2.5}$. Separate multivariate analyses were conducted for each exposure variable (mean of daily average and UATmax, mean of three-day moving average of UATavg, and extreme temperature). These models included potential effect modifiers along with product terms between main exposure variables and potential effect modifiers. Reduced models were built through a backward elimination process and limited to variables with complete information (Agresti, 2007). Effect modification on the multiplicative scale was assessed as deviation from perfect multiplicatively as determined by the likelihood ratio test with an alpha of .05 and results supported in stratified analysis. Odds ratio (*OR*) estimates were adjusted for atmospheric pressure by including it in the conditional logistic regression model.

Statewide analyses of AMI hospitalizations were conducted for UATavg, UATmax, and UATmin separately on the day of hospitaliza-

TABLE **1**

Associations Between Various UATavg[a] Groups and AMI[a] Hospitalizations by Lag, New York State, 1991–2004

UATavg (ºF)	Cases/ Controls	Lag0 OR[a] (95% CI[a])	Lag1 OR (95% CI)	Lag2 OR (95% CI)	Lag3 OR (95% CI)	Lag4 OR (95% CI)	Lag5 OR (95% CI)	Lag6 OR (95% CI)
-20 to -15	104/279	1.06 (0.85, 1.34)	1.17 (0.95, 1.45)	0.98 (0.78, 1.24)	1.03 (0.82, 1.29)	1.25 (1.00, 1.57)	1.29 (1.03, 1.61)	1.05 (0.83, 1.32)
-15 to -10	294/941	0.93 (0.82, 1.07)	0.87 (0.75, 1.00)	0.97 (0.84, 1.12)	0.90 (0.79, 1.04)	1.13 (0.99, 1.30)	1.01 (0.88, 1.16)	0.98 (0.85, 1.13)
-10 to -5	711/2,356	0.91 (0.83, 1.00)	0.96 (0.88, 1.05)	0.99 (0.91, 1.09)	1.05 (0.95, 1.15)	1.01 (0.92, 1.10)	1.05 (0.95, 1.15)	0.98 (0.89, 1.08)
-5 to 0	1,830/5,240	1.07 (1.00, 1.14)	0.99 (0.92, 1.05)	1.01 (0.95, 1.08)	1.04 (0.97, 1.11)	1.14 (1.06, 1.21)	1.04 (0.97, 1.12)	1.07 (1.00, 1.15)
0–5	8,617/26,518	0.99 (0.95, 1.03)	1.01 (0.96, 1.05)	1.03 (0.98, 1.07)	1.02 (0.97, 1.06)	1.05 (1.00, 1.10)	1.05 (1.01, 1.10)	1.04 (1.00, 1.09)
5–10	8,238/25,339	1.00 (0.96, 1.04)	1.00 (0.96, 1.04)	1.00 (0.96, 1.05)	1.00 (0.96, 1.05)	1.05 (1.01, 1.10)	1.05 (1.01, 1.10)	1.04 (0.99, 1.09)
10–15	11,300/34,641	0.99 (0.96, 1.03)	1.00 (0.96, 1.04)	1.02 (0.98, 1.06)	1.01 (0.97, 1.05)	1.05 (1.01, 1.09)	1.02 (0.98, 1.07)	1.04 (0.99, 1.08)
15–20	13,662/41,664	1.00 (0.96, 1.04)	0.98 (0.95, 1.02)	1.00 (0.97, 1.04)	1.00 (0.97, 1.04)	1.04 (1.00, 1.08)	1.03 (0.99, 1.08)	1.03 (0.99, 1.08)
20–25	15,976/47,339	1.03 (0.99, 1.07)	1.01 (0.97, 1.05)	1.00 (0.97, 1.04)	1.00 (0.96, 1.04)	1.02 (0.98, 1.05)	1.04 (1.00, 1.08)	1.04 (1.00, 1.08)
25–30	14,367/41,540	1.03 (0.99, 1.06)	0.99 (0.95, 1.02)	1.01 (0.87, 1.04)	1.02 (0.98, 1.06)	1.06 (1.02, 1.10)	1.00 (0.96, 1.04)	1.02 (0.98, 1.06)
30–35	10,001/29,795	1.01 (0.97, 1.05)	0.98 (0.94, 1.02)	0.99 (0.95, 1.03)	1.01 (0.95, 1.08)	1.03 (0.99, 1.08)	1.02 (0.97, 1.06)	1.01 (0.97, 1.05)
35–40	5,146/15,610	1 (Referent)	1 (Referent)	1 (Referent)	1 (Referent)	1 (Referent)	1 (Referent)	1 (Referent)

[a]UATavg = daily average universal apparent temperature; AMI = acute myocardial infarction; *OR* = odds ratio; *CI* = confidence intervals.

*Note: OR*s were adjusted for atmospheric pressure, weather region, sex, age, race/ethnicity, particulate matter less than 2.5 µm, and source of treatment payment.

tion (lag0) and each of the previous six days (lag1–lag6). Similarly, statewide analyses for AP, CIHD, and OIHD were also related to UATavg on the day of hospitalization (lag0) and each of the previous six days (lag1–lag6). The effect of extreme temperatures on hospitalizations of all categories of IHD was also analyzed. Data management and analysis were conducted using SAS version 9.2.

Results

Our analysis included 232,905 IHD hospitalizations (AMI: 83,650 [35.92%], AP: 10,794 [4.63%], CIHD: 100,496 [43.15%], and OIHD: 37,965 [16.3%]). The statewide mean of the UATavg in the NYS cold weather season, 1991–2004, was 18.0ºF with a range of -30ºF to 60ºF, and varied among weather regions with the highest mean in New York City (24.4ºF) and the lowest in the Adirondack region (7.5ºF) (data not shown). The

Adirondack, Mohawk Valley, Rochester, Binghamton, and Buffalo regions had the lowest UATavg in NYS. Consistent with low temperature trends, the rates of IHD admissions were highest in the Mohawk Valley (18.0/1,000 population), followed by the Buffalo region (15.7/1,000) (data not shown). A large heterogeneity in race-ethnicity distribution occurred with the highest percentage of whites in the northern, central, and western weather regions of the state and a higher percentage of Hispanics in New York City. The mean age in the study population was 66.4 years (data not shown).

Table 1 shows the results of the conditional regression analysis that examines the association between low UATavg and hospital admissions due to AMI by lag (lag0–lag6) in NYS. Compared to the reference temperature group (35ºF–40ºF), temperatures below 35ºF were associated with increased admissions

due to AMI in lag4–lag6. The most elevated association was observed for the -20ºF to -15ºF temperature group, with statistically significant *OR*s ranging from 1.25 (95% confidence interval [*CI*] 1.00, 1.57) to 1.29 (95% *CI* 1.03, 1.61) at lag4 and lag5, respectively. For temperatures ranging between -5ºF and 35ºF, the statistically significant *OR*s for hospital admissions due to AMI varied between *OR* = 1.05 (95% *CI* 1.01, 1.10) for 5ºF–10ºF and 10ºF–15ºF temperature groups at lag4, 0ºF–5ºF and 5ºF–10ºF temperature groups at lag5, and *OR* = 1.14 (95% *CI* 1.06, 1.21) for -5ºF to 0ºF temperature group at lag4. The most consistent detrimental effect occurred at lag4. The association was not statistically significant for lag0–lag3.

Table 2 shows results of analysis using the three-day moving average of UATavg. For temperatures below the reference (35ºF–40ºF), no significant effects were observed for the major-

Associations Between Various Three-Day Moving Averages of the UATavg[a] Groups and AMI[a] Hospitalizations by Lag, New York State, 1991–2004

UATavg Three-Day Moving Average (ºF)	Lag0+Lag1+Lag2 OR[a] (95% CI[a])	Lag1+Lag2+Lag3 OR (95% CI)	Lag2+Lag3+Lag4 OR (95% CI)	Lag3+Lag4+Lag5 OR (95% CI)	Lag4+Lag5+Lag6 OR (95% CI)
-20 to -15	1.06 (0.65, 1.72)	0.73 (0.45, 1.17)	0.90 (0.54, 1.48)	0.68 (0.34, 1.21)	1.00 (0.59, 1.69)
-15 to -10	0.89 (0.70, 1.13)	0.88 (0.68, 1.15)	1.17 (0.91, 1.50)	1.09 (0.86, 1.39)	1.36 (1.08, 1.71)
-10 to -5	0.89 (0.78, 1.02)	0.99 (0.87, 1.13)	1.05 (0.92, 1.20)	1.05 (0.92, 1.20)	1.01 (0.88, 1.15)
-5 to 0	0.99 (0.91, 1.09)	0.98 (0.90, 1.07)	1.01 (0.92, 1.10)	1.07 (0.98, 1.17)	1.07 (0.98, 1.17)
0–5	0.99 (0.94, 1.05)	1.00 (0.95, 1.05)	1.06 (1.00, 1.12)	1.04 (0.98, 1.10)	1.04 (0.98, 1.09)
5–10	0.97 (0.92, 1.02)	0.98 (0.93, 1.03)	1.04 (0.99, 1.10)	1.03 (0.98, 1.08)	1.03 (0.98, 1.09)
10–15	0.97 (0.93, 1.03)	0.99 (0.94, 1.04)	1.01 (0.96, 1.06)	1.03 (0.98, 1.08)	1.03 (0.98, 1.08)
15–20	0.97 (0.93, 1.02)	0.96 (0.92, 1.01)	1.02 (0.97, 1.07)	1.01 (0.96, 1.06)	1.02 (0.97, 1.07)
20–25	0.98 (0.94, 1.03)	0.98 (0.93, 1.03)	1.02 (0.97, 1.07)	1.01 (0.96, 1.06)	1.01 (0.97, 1.06)
25–30	0.97 (0.93, 1.02)	0.97 (0.93, 1.02)	1.01 (0.97, 1.06)	1.02 (0.97, 1.07)	1.02 (0.97, 1.07)
30–35	0.96 (0.91, 1.00)	0.96 (0.91, 1.01)	1.04 (0.99, 1.10)	1.02 (0.97, 1.07)	1.02 (0.97, 1.07)
35–40	1 (Referent)	1 (Referent)	1 (Referent)	1 (Referent)	1 (Referent)

[a]UATavg = daily average universal apparent temperature; AMI = acute myocardial infarction; OR = odds ratio; CI = confidence intervals.

*Note: OR*s were adjusted for atmospheric pressure, weather region, sex, age, race/ethnicity, particulate matter less than 2.5 µm, and source of treatment payment.

ity of the temperature groups of the moving averages except for the -15ºF to -10ºF temperature group with OR = 1.36 (95% CI 1.08, 1.71) at lag4–lag6 and for the 0ºF–5ºF temperature group with OR = 1.06 (95% CI 1.00, 1.12) at lag2–lag4. Although not statistically significant, ORs at lag2–lag4 showed detrimental effect with values ranging from 1.01 (95% CI 0.96, 1.06) to 1.17 (95% CI 0.91, 1.50).

Table 3 displays the results of the stratified analyses of the association between UATavg and AMI by demographics, weather region, and PM$_{2.5}$ concentration. Since the UATavg-AMI hospitalization association was statistically significant and most consistent at lag4, we conducted the stratified analysis at lag4 only. In general, statistically significant results were consistently observed for temperature group 0ºF–10ºF. Temperatures below 30ºF increased the odds of hospitalizations among males: OR = 1.07 (95% CI 1.02, 1.11) for 0ºF–10ºF and OR = 1.03 (95% CI 1.00, 1.07) for 10ºF–20ºF temperature group; people of races other than whites or blacks: OR = 1.17 (95% CI 1.05, 1.29) for 0ºF–10ºF and OR = 1.09 (95% CI 1.00, 1.20) for 10ºF–20ºF; among subjects aged 25–64: OR range 1.05–1.14 for 0ºF–10ºF; and among subjects aged 65–74: OR = 1.06 (95% CI 1.01, 1.12) for 20ºF–30ºF temperature group. Stratification by source of

payment categories showed increased ORs for hospitalizations among Medicaid patients (OR range 1.13–1.61). With respect to weather region, the most elevated association was observed in Binghamton in the -20ºF to -10ºF interval, OR = 2.99, (95% CI 1.27, 7.03). Elevated ORs were also consistently observed for temperature group 0ºF–10ºF in NYC-LGA, Staten Island, Long Island, and Hudson Valley South. In the Buffalo region the odds of hospital admissions were consistently and significantly less than one for 0ºF–30ºF temperatures. PM$_{2.5}$ concentration above the U.S. EPA annual standard concentration increased the risk of hospitalization of AMI for temperature group 0ºF–10ºF.

We further examined the association between extremely low UAT (≤10th percentile) and various IHD categories in lag0–lag6; Figure 1 describes the statistically significant estimates for different types of IHD at lag4–lag6. We observed a statistically significant harmful effect on hospital admissions of AMI at lag4–lag6 and for CIHD at lag6. Conversely, extreme low temperature displayed a protective effect on hospitalization due to AP and OIHD at lag0 and lag1, and for CIHD at lag1, lag2, and lag4. We also further examined the associations between UATavg and various IHD subtypes including AP, CIHD,

and OIHD. We did not find any significant relationships between low temperature and IHD other than AMI such as AP, CIHD, and OIHD (data not shown).

We analyzed the effect of UATmax on AMI hospital admissions by different lag periods as described in Table 4. Consistently increased ORs were observed in lag5–lag6. The strongest association was observed at lag6 in the -15ºF to -10ºF interval (OR = 1.42 [95% CI 1.03, 1.97]). For temperature groups between 0ºF and 35ºF at lag5 and lag6, the ORs of AMI hospitalization varied between OR = 1.04 (95% CI 1.00, 1.07) and OR = 1.07 (95% CI 1.03, 1.11). With respect to UATmin, no increased risk of hospitalization was observed for UATmin <35ºF (data not shown).

Discussion

The present study found that low ambient temperature in winter was associated with increased odds of hospital admissions due to AMI. We found that the association was statistically significant at UAT <35ºF. The effect is consistent when using multiple exposure indicators (UATavg, extreme UATavg, UATmax). The increases in risk of AMI hospital admission for all indicators range from 4% to 29%, which is within the range of findings

TABLE **3**

Associations Between Various UATavg[a] Groups and AMI[a] hospitalizations at Lag4, by Sociodemographic Characteristics and Weather Regions in New York State, 1991–2004

Variable	-20°F to -10°F OR[a] (95% CI[a])	-10°F to 0°F OR (95% CI)	0°F–10°F OR (95% CI)	10°F–20°F OR (95% CI)	20°F–30°F OR (95% CI)	30°F–40°F OR (95% CI)
Sex						
Males	1.25 (0.96, 1.64)	1.04 (0.94, 1.15)	1.07 (1.02, 1.11)	1.03 (1.00, 1.07)	1.02 (0.99, 1.06)	1 (Referent)
Females	1.06 (0.75, 1.48)	0.98 (0.87, 1.11)	0.99 (0.95, 1.04)	1.00 (0.96, 1.04)	1.01 (0.97, 1.05)	1 (Referent)
Race						
White-Hispanics	—	0.91 (0.19, 4.45)	1.08 (0.87, 1.34)	1.14 (0.95, 1.36)	1.00 (0.85, 1.17)	1 (Referent)
White non-Hispanics	1.18 (0.93, 1.49)	1.00 (0.91, 1.09)	1.03 (0.99, 1.06)	1.01 (0.98, 1.05)	1.02 (0.99, 1.05)	1 (Referent)
Black-Hispanics	—	—	0.82 (0.47, 1.42)	0.85 (0.53, 1.35)	0.86 (0.58, 1.29)	1 (Referent)
Black non-Hispanics	0.56 (0.12, 2.58)	1.19 (0.81, 1.74)	0.93 (0.84, 1.04)	0.91 (0.83, 1.00)	0.92 (0.85, 1.00)	1 (Referent)
Others	2.39 (0.40, 14.36)	1.02 (0.58, 1.80)	1.17 (1.05, 1.29)	1.09 (1.00, 1.20)	1.09 (1.00, 1.17)	1 (Referent)
Age						
18–24	—	—	0.97 (0.30, 3.51)	0.75 (0.27, 2.05)	0.88 (0.36, 2.15)	1 (Referent)
25–44	1.13 (0.52, 2.48)	1.26 (0.93, 1.70)	1.14 (1.00, 1.29)	1.02 (0.91, 1.15)	1.01 (0.90, 1.12)	1 (Referent)
45–64	1.10 (0.76, 1.59)	1.03 (0.90, 1.18)	1.05 (1.00, 1.11)	1.04 (0.99, 1.09)	1.03 (0.98, 1.07)	1 (Referent)
65–74	1.49 (1.00, 2.21)	1.00 (0.85, 1.16)	1.04 (0.98, 1.10)	1.06 (1.00, 1.11)	1.06 (1.01, 1.12)	1 (Referent)
75+	1.05 (0.72,1.52)	0.97 (0.84, 1.11)	1.00 (0.95, 1.05)	0.98 (0.94, 1.02)	0.98 (0.94, 1.02)	1 (Referent)
Pay source						
Medicare	1.19 (0.91, 1.56)	1.01 (0.91, 1.12)	1.02 (0.98, 1.06)	1.01 (0.97, 1.05)	1.02 (0.98, 1.05)	1 (Referent)
Medicaid	0.80 (0.26, 2.46)	1.61 (1.17, 2.22)	1.13 (1.02, 1.26)	1.08 (0.98, 1.19)	1.04 (0.96, 1.13)	1 (Referent)
Other programs	1.17 (0.82, 1.66)	0.95 (0.83, 1.08)	1.03 (0.98, 1.08)	1.02 (0.98, 1.07)	1.01 (0.97, 1.05)	1 (Referent)
Weather region						
NYC-LGA	—	1.19 (0.74, 1.09)	1.07 (1.01, 1.14)	1.04 (0.98, 1.09)	1.02 (0.92, 1.09)	1 (Referent)
NYC-JFK	—	—	1.01 (0.91, 1.11)	1.03 (0.95, 1.11)	0.95 (0.89, 1.02)	1 (Referent)
Staten Island	—	1.14 (0.23, 5.68)	1.21 (1.01, 1.44)	1.06 (0.91, 1.23)	1.10 (0.97, 1.25)	1 (Referent)
Long Island	—	—	1.09 (1.01, 1.10)	1.03 (0.97, 1.10)	1.07 (1.02, 1.13)	1 (Referent)
White Plains	—	0.76 (0.34, 1.67)	0.94 (0.84, 1.07)	1.05 (0.95, 1.16)	1.05 (0.96, 1.15)	1 (Referent)
Hudson Valley S	—	—	1.24 (1.06, 1.45)	1.10 (0.96, 1.27)	1.07 (0.94, 1.23)	1 (Referent)
Hudson Valley N	0.72 (0.29, 1.78)	1.16 (0.93, 1.45)	1.03 (0.89, 1.18)	0.98 (0.86, 1.12)	1.01 (0.89, 1.15)	1 (Referent)
Adirondack and North	1.23 (0.77, 1.96)	1.15 (0.78, 1.69)	1.14 (0.80, 1.61)	1.15 (0.81, 1.64)	1.20 (0.83, 1.71)	1 (Referent)
Mohawk Valley	0.82 (0.32, 2.09)	0.96 (0.71, 1.30)	0.90 (0.73, 1.10)	0.92 (0.76, 1.13)	0.94 (0.77, 1.14)	1 (Referent)
Binghamton	2.99 (1.27, 7.03)	1.01 (0.77, 1.33)	0.99 (0.84, 1.18)	1.01 (0.85, 1.20)	1.02 (0.86, 1.21)	1 (Referent)
Rochester	1.20 (0.76, 1.91)	0.85 (0.69, 1.03)	0.94 (0.81, 1.09)	0.94 (0.81, 1.09)	0.97 (0.83, 1.13)	1 (Referent)
Central Lakes	—	0.92 (0.69, 1.23)	1.02 (0.89, 1.18)	1.02 (0.89, 1.17)	1.00 (0.87, 1.14)	1 (Referent)
Western Plateau	0.21 (0.03, 1.59)	1.20 (0.65, 2.23)	1.09 (0.88, 1.34)	1.03 (0.85, 1.25)	1.02 (0.84, 1.22)	1 (Referent)
Buffalo	1.28 (0.68, 2.41)	0.79 (0.60, 1.04)	0.84 (0.75, 0.94)	0.84 (0.75, 0.93)	0.83 (0.74, 0.92)	1 (Referent)
PM$_{2.5}$[a] concentration						
<15 µg/m^3	1.15 (0.93, 1.43)	1.01 (0.94, 1.10)	1.03 (0.99, 1.07)	1.02 (0.98, 1.05)	1.03 (1.00, 1.06)	1 (Referent)
≥15 µg/m^3	—	—	1.17 (1.01, 1.36)	1.04 (0.96, 1.12)	1.01 (0.96, 1.07)	1 (Referent)

[a]UATavg = daily average universal apparent temperature; AMI = acute myocardial infarction; *OR* = odds ratio; *CI* = confidence intervals; PM$_{2.5}$ = particulate matter less than 2.5 µm in diameter.

from previous studies (Bhaskaran et al., 2010; Danet et al., 1999; Hopstock et al., 2012). Bhaskaran and co-authors (2010) examined the short-term relationship between ambient temperature and MI risk in 15 conurbations in England and Wales and found that each 1°C reduction in daily mean temperature was associated with a 2% (95% *CI* 1.1%, 2.9%) cumulative increase in risk of MI. Another study assessing the effects of atmospheric temperature and pressure on occurrence of MI and coronary deaths conducted by Danet

Association Between Various Categories of Ischemic Heart Disease Hospitalizations and Extreme UATavg by Lag, New York State, 1991–2004
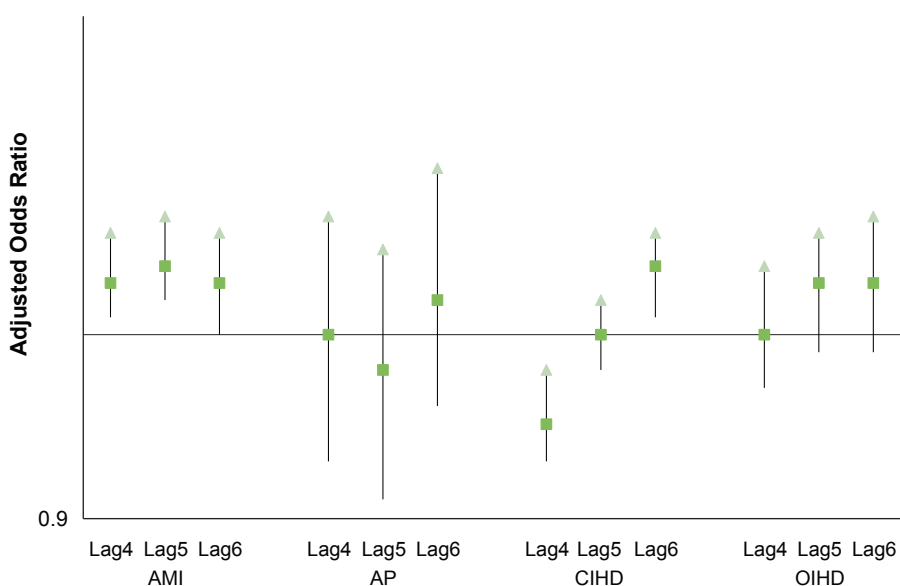
UATavg = daily average universal apparent temperature; AMI = acute myocardial infarction; AP = angina pectoris; CIHD = chronic ischemic heart disease; OIHD = other ischemic heart disease.

and co-authors (1999) found that for a 10°C temperature decrease, the increase in disease rates was 13% for all age groups ($p < .0001$). Similar findings on the effect of daily weather conditions on MI incidence in cold weather areas were reported by Hopstock and co-authors (2012), who found that the MI risk increased by 47% when comparing the lower and upper limits of the temperature distribution (-10°C versus 20°C). The actual impact of cold temperature on AMI could be larger as difficulties in getting to the hospital during temperature extremes might lead to more out-of-hospital MI deaths, which would not have been included in our study.

Several explanatory mechanisms have been suggested for the higher occurrence of IHD in winter. Cold causes constriction of skin vessels, which increases blood pressure and consequently increases oxygen demand (Kloner, 2006). Cold may induce an increase in coronary artery resistance that can, in turn, result in coronary artery vasospasm (Kloner, 2006). Additionally, cold causes an increase in red and white blood cell and platelet concentrations, an increase in plasmatic fibrinogen and blood viscosity, and a shift of protein C to the extracellular space (Kloner, 2006; Nayha, 2005). Protein C along with changes in blood pressure and thrombosis may be responsible for acute heart conditions after exposure to cold temperature (Nayha, 2002).

We found that the effect of UATavg on AMI hospitalizations showed a delayed pattern, with an effect occurring four days after cold temperature. Our results are consistent with the findings of Wolf and co-authors (2009), who observed the strongest association between daily average temperature and nonfatal MI for a lag of three days, as well as Donaldson and Keatinge (1997), who found that the increase in IHD-related deaths was maximal at three days after the peak of cold. Compared to morbidity, other studies found an even longer delay between exposure and cardiovascular mortality, ranging from a lag of 2 weeks to 20 days (Analitis et al., 2008;

Carder et al., 2005). The lagged effect may be due to inclement weather accompanying extreme cold, effectively reducing access to a hospital or inclination to be admitted (Schwartz et al., 2004). The peak observed in odds of hospitalization several days after extreme low temperatures might be related to persons postponing admissions. Compared to respiratory diseases, cold-related IHD hospitalizations showed a longer latency, i.e., 4–6 days after low ambient temperature. Longer latency may be a secondary consequence of respiratory infections, which may be triggers for IHD by affecting blood coagulation and potentially damaging the vessel walls and promoting atherosclerosis (Nayha, 2002).

When comparing four cold temperature indicators, we found that UATmax has the highest and most significant effect on AMI (*OR*: 1.42) at lag6, and followed by three-day moving UATavg (highest *OR*: 1.36). The effects of UATavg (highest *OR*: 1.29) and extreme cold (≤10th percentile, *OR*: 1.04) on AMI and different IHD are slightly lower. In a review of 12 studies investigating low ambient temperature on MI, most prior studies used mean temperature as the indicator, a few used maximum temperature, and only one or two considered winter wind chill and dew point (Bhaskaran et al., 2010). The effects of cold temperature on MI seemed to be larger in the studies using maximum temperature than those using mean temperature, which is consistent with our findings. Few or no studies using moving average or extreme indicators are available to compare our results. The different findings among various studies could be due to differences in adaptation to extreme low temperature of people living in different climates, humidity, and wind patterns. Since almost all previous studies examining cold and IHD focused on AMI, no previous literature is available to compare with our findings for other IHD admissions. While low UATmax with 4–5 single day lag had shown strongest AMI effect, we cannot neglect the cumulative effect of low UAT from lag4 to lag6 days on AMI although little to no previous literature is available to compare with our findings. Our study also diverges from other studies in its use of UAT, which includes dew point and wind chill in addition to temperature to represent the real atmosphere in winter.

TABLE **4**

Associations Between Various UATmax[a] groups and AMI[a] hospitalizations by Lag, New York State, 1991–2004

UATmax (ºF)	Lag 0 OR[a] (95% CI[a])	Lag 1 OR (95% CI)	Lag 2 OR (95% CI)	Lag 3 OR (95% CI)	Lag 4 OR (95% CI)	Lag 5 OR (95% CI)	Lag 6 OR (95% CI)
-20 to -15	1.08 (0.35, 3.40)	0.88 (0.18, 4.25)	0.35 (0.05, 2.68)	0.67 (0.14, 3.08)	1.11 (0.29, 4.17)	1.85 (0.57, 6.01)	0.31 (0.04, 2.39)
-15 to -10	0.90 (0.62, 1.30)	0.95 (0.68, 1.34)	0.76 (0.53, 1.10)	1.01 (0.72, 1.42)	1.34 (0.98, 1.88)	1.14 (0.82, 1.58)	1.42 (1.03, 1.97)
-10 to -5	1.03 (0.86, 1.23)	0.86 (0.71, 1.04)	1.05 (0.87, 1.27)	0.85 (0.70, 1.04)	0.98 (0.81, 1.19)	1.06 (0.87, 1.28)	1.04 (0.85, 1.27)
-5 to 0	0.88 (0.78, 1.00)	0.99 (0.88, 1.11)	0.99 (0.88, 1.12)	1.00 (0.88, 1.13)	0.91 (0.81, 1.03)	1.09 (0.97, 1.23)	1.01 (0.90, 1.15)
0–5	0.99 (0.95, 1.04)	1.04 (0.99, 1.09)	1.06 (1.01, 1.11)	1.01 (0.97, 1.07)	1.05 (1.00, 1.10)	1.05 (1.00, 1.10)	1.01 (0.96, 1.07)
5–10	0.98 (0.94, 1.03)	1.02 (0.98, 1.06)	1.02 (0.98, 1.06)	1.02 (0.98, 1.07)	1.02 (0.98, 1.07)	1.06 (1.01, 1.11)	1.05 (1.00, 1.10)
10–15	0.97 (0.94, 1.01)	1.04 (1.00, 1.08)	1.04 (1.00, 1.08)	1.01 (0.97, 1.05)	1.01 (0.97, 1.05)	1.07 (1.03, 1.11)	1.06 (1.02, 1.10)
15–20	1.01 (0.98, 1.04)	1.02 (0.99, 1.06)	1.02 (0.99, 1.05)	1.01 (0.97, 1.04)	0.99 (0.96, 1.03)	1.04 (1.01, 1.08)	1.03 (1.00, 1.07)
20–25	0.98 (0.95, 1.01)	1.02 (0.99, 1.05)	1.00 (0.97, 1.04)	0.99 (0.96, 1.02)	1.00 (0.96, 1.03)	1.04 (1.00, 1.07)	1.03 (0.99, 1.06)
25–30	1.01 (0.98, 1.04)	1.02 (0.99, 1.05)	1.03 (1.00, 1.06)	1.00 (0.97, 1.03)	0.98 (0.95, 1.01)	1.05 (1.02, 1.09)	1.03 (1.00, 1.07)
30–35	1.02 (0.99, 1.05)	1.03 (1.00, 1.06)	1.02 (0.99, 1.05)	1.00 (0.97, 1.03)	1.00 (0.97, 1.03)	1.01 (0.98, 1.04)	1.04 (1.01, 1.08)
35–40	1 (Referent)	1 (Referent)	1 (Referent)	1 (Referent)	1 (Referent)	1 (Referent)	1 (Referent)

[a]UATmax = daily maximum universal apparent temperature; AMI = acute myocardial infarction; *OR* = odds ratio; *CI* = confidence intervals.

*Note. OR*s were adjusted for atmospheric pressure, weather region, sex, age, race/ethnicity, particulate matter less than 2.5 µm, and source of treatment payment.

Our analyses showed subjects age 65 and older had higher odds of AMI hospitalization, which is consistent with previous findings by Bhaskaran and co-authors (2010), Hopstock and co-authors (2012), and Morabito and co-authors (2005), showing the highest risks and a same day effect in the elderly population compared to delayed lag in other age groups. The increased risk in older age can be explained by the deterioration of effective body thermoregulation. Our findings of slight but persistent increased AMI risks of cold temperature among males compared to females is supported by the studies of Wichmann and co-authors in Denmark (2012), Kysely and co-authors in Czech Republic (2009), and Loughnan and co-authors in Australia (2008). This gender difference may be explained by occupational exposure in winter by men as men are more likely than women to work outdoors. Other studies reported contradictory findings, however, with increased risks among women (Barnett et al., 2005; Panagiotakos et al., 2004). Our study also found that people using Medicaid were more susceptible to the cold effect on IHD, which is supported by prior studies identifying low socioeconomic status as a risk factor of vulnerability to cold (Wichmann et al., 2012; Wolf et al., 2009). We also found that warmer/southern areas of NYS

(i.e., Binghamton, Western Plateau) showed higher AMI risks to cold weather than other areas, which is consistent with prior studies showing increased vulnerability to cold days in locations with higher mean temperatures (Bhaskaran et al., 2009). No prior research has assessed the modifying effect of air pollution on cold-AMI to compare with our findings of an interaction between PM$_{2.5}$ and cold weather on AMI.

Study Strengths
This is one of the few studies examining the association between cold weather conditions and IHD morbidity, especially AMI, over a long period in NYS, a state with multiple subclimate regions. The unique contributions of this project include comparing the IHD effects using different cold weather indicators, in different temperature ranges during winter, by different lag periods, short-term vs. cumulative effects, and assessing different subgroups of IHD. Using UAT allowed us to consider multiple weather factors including temperature, dew point, and wind simultaneously. Since both health outcome and exposure data (weather and air pollution data) are objective, routinely collected datasets, recall bias is unlikely. By examining potential interactions between low temperature and

pollution/sociodemographics, we were able to identify vulnerable populations, which is useful for future adaptation planning.

Study Limitations
This study used hospital admission data as health endpoints and thus may have captured only the most severe IHD cases. To minimize case under-ascertainment, we focused on AMI, a condition that requires immediate medical attention and treatment through hospital admission. Another limitation is that meteorological data were obtained from fixed monitoring sites, which assumes uniformity across regions. Although some factors such as daily activity patterns, family history of IHD, seasonal weight gain, and sociodemographic factors are important confounders, the case-crossover design automatically controls for these factors by using cases as their own controls. In addition, some factors such as quality of housing, heating use, insulation, and influenza are potential confounders that are unavailable in our current study and will be examined through surveys in the future.

Conclusion
The present study found that extreme low UAT in winter was associated with increased risk of AMI, especially during lag4–lag6,

but not associated with other IHD subgroup diseases. We also found that low UATmax in winter was a more sensitive indicator to AMI than mean and UATmin. This study also found that certain demographic groups such as the elderly, males, people with Medicaid insurance, and people living in warmer areas and areas with high $PM_{2.5}$ concentration showed higher vulnerabilities to cold-AMI effects than other groups. Further studies should validate our findings by adjusting heating and ventilation confounders. Interventions based on these findings, such as targeting vulnerable areas/populations and monitoring sensitive cold indicators and AMI should be considered in climate change adaptation efforts. ●●●

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▶ **INTERNATIONAL PERSPECTIVES**

Measurements of Arsenic in the Urine and Nails of Individuals Exposed to Low Concentrations of Arsenic in Drinking Water From Private Wells in a Rural Region of Québec, Canada

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Abstract **Chronic exposure to inorganic arsenic leads to an increased risk of cancer. A biological measurement was conducted in 153 private well owners and their families consuming water contaminated by inorganic arsenic at concentrations that straddle 10 µg/L. The relationship between the external dose indicators (concentration of inorganic arsenic in wells and daily well water inorganic arsenic intake) and the internal doses (urinary arsenic—sum of As^{III}, DMA, and MMA, adjusted for creatinine—and total arsenic in toenails) was evaluated using multiple linear regressions, controlling for age, gender, dietary sources of arsenic, and number of cigarettes smoked. It showed that urinary arsenic was associated with concentration of inorganic arsenic in wells ($p < .001$) and daily well water inorganic arsenic intake ($p < .001$) in adults, and with daily well water inorganic arsenic intake ($p = .017$) and rice consumption ($p = .022$) in children ($n = 43$). The authors' study reinforces the drinking-water quality guidelines for inorganic arsenic.**

Introduction

Exposure to arsenic primarily occurs via food, drinking water, soil, and air (Kendall, Bens, & Cobb, 2003). Cigarette smoking is also a source of inorganic arsenic (Cui, Kobayashi, Akashi, & Okayasu, 2008). In the case of populations dwelling in the vicinity of an important geological source of inorganic arsenic, drinking water could represent the most significant source of inorganic arsenic exposure (Health Canada, 2006a).

Chronic exposure to inorganic arsenic in drinking water can lead to an increased risk of cutaneous, pulmonary, bladder, and hepatic cancer (Ferreccio et al., 2000; Morales, Ryan, Kuo, Wu, & Chen, 2000; Rossman, Uddin, & Burns, 2004; Steinmaus, Yuan, Bates, & Smith, 2003). To limit such cancer risks, a guideline or a standard of 10 µg/L for public drinking water supplies has been adopted by different organizations (Health Canada, 2006b; U.S. Environmental Protection Agency, 2001; World Health Organization, 2003). This level is not enforceable, however, for private wells in the province of Québec, Canada (Gouvernement du Québec, 2008).

Levels of arsenic and its metabolites in urine and nails have been used as biomarkers of short-term (Agency for Toxic Substances and Disease Registry, 2007) and long-term arsenic exposure (Orloff, Mistry, & Metcalf, 2009), respectively. Various studies have demonstrated a correlation between these biomarkers and the inorganic arsenic exposure via contaminated water (Agusa et al., 2009; Caceres et al., 2005; Gault et al., 2008; Hinwood et al., 2003; Kendall et al., 2003; Mandal, Ogra, & Suzuki, 2003; Meza, Kopplin, Burgess, & Gandolfi, 2004; Sun et al., 2007; Uchino, Roychowdhury, Ando, & Tokunaga, 2006). Almost all of these correlations were established, however, using median well water inorganic arsenic levels exceeding 50 µg/L. Few studies have established a clear relationship between lower levels and the consumer's internal dose after controlling dietary sources; solid food is a major contributor to urine arsenic levels (Clayton, Pellizzari, Whitmore, Perritt, & Quackenboss, 1999).

Flow Chart of Household Selection

Initial list
338 households

Additions
18

Nobody reached
94

Nobody interested
49

Nobody eligible
37

Withdrawals
23

Final list
153 households
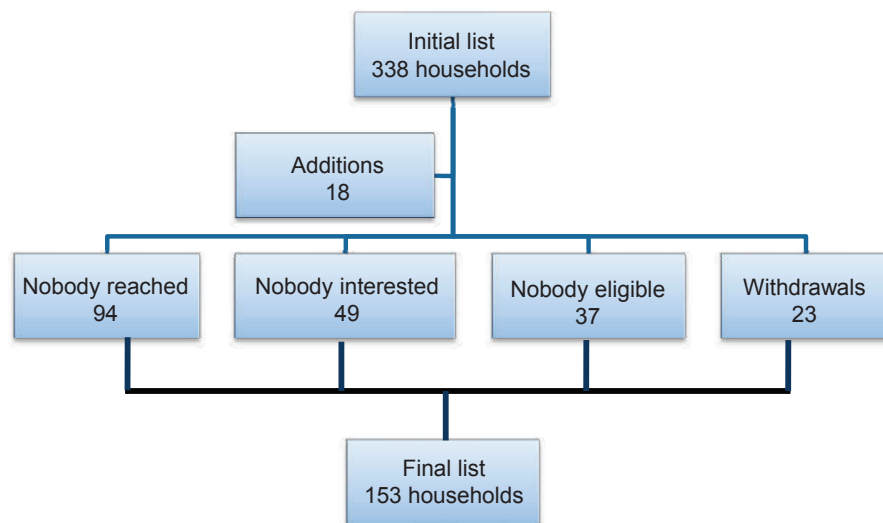
The objectives of our project were as follows:

1. Conduct a biological measurement study of inorganic arsenic exposure in a population living in Abitibi-Témiscamingue, Québec, a rural area where groundwater is affected by a natural geological source of arsenic.

2. Evaluate variations in the internal doses of inorganic arsenic in terms of the various well contamination levels, the external dose, and other potential sources of arsenic (primarily diet).

Materials and Methods

Study Population
Our study concerns a population of private well owners and their families living in the Abitibi-Témiscamingue region of Québec, Canada.

Recruitment of Subjects
On the basis of a previous screening campaign three groups of private wells were established: group 1 with inorganic arsenic levels <10 µg/L, group 2 with inorganic arsenic levels 10–20 µg/L, and group 3 with inorganic arsenic levels ≥20 µg/L (Poissant, 1997). Of the 400 households initially available for the first group, 150 were randomly selected. For the second group, all of the 67 potential households were contacted. The 121 potential households from the third group and 18 new households were all included.

To be eligible, interested individuals had to live in a home supplied by a private well, had to drink or use this water for preparing beverages and food for at least one month, and had to be seven years of age or older. Those who had an arsenic treatment system, who were occupationally exposed, or who consumed homeopathic medications or herbal dietary supplements were excluded. Pregnancy, kidney or liver diseases, and active cancer were also considered as exclusion criteria. Participants were recruited via telephone.

Variables and Data Collection
During a first home visit, a water sample of 125 mL was collected from the most frequently used tap in an opaque amber bottle containing 1.25 mL of ethylenediaminetetraacetic acid (EDTA) 0.25M. The samples were then kept at 4°C until analysis.

Two questionnaires regarding participant lifestyle and dietary habits (Bouchard, Normandin, Levallois, & Ayotte, 2007a; Bouchard et al., 2007b) were distributed to each participant.

In the lifestyle questionnaire, participants were asked to estimate their usual daily well water consumption in the past year, including all types of beverages prepared with well water (i.e., number of servings equivalent to 250 mL). Age, gender, and smoking habits were then recorded.

The diet questionnaire was self administered during the two days prior to biological sampling. This questionnaire was designed to quantify the portions of inorganic arsenic–contaminated (rice, breakfast cereals, and pasta; based on the equivalent portion presented for each), and organic arsenic–contaminated foods (chicken, fish, seaweed, shellfish, and mushrooms) (Hughes, 2006). The participants were also asked to record their well water consumption (i.e., number of servings), including water alone or beverages prepared with well water.

These two questionnaires, the first morning void urine, and nail clippings from the big toes were collected from the participant during a second visit. Urine samples were then frozen (-20°C) and toenails refrigerated (4°C) until analysis.

Data Analysis
Water samples were analyzed with a high performance liquid chromatography with inductively coupled argon plasma mass spectroscopy (Centre d'Expertise en Analyse Environnementale du Québec, 2008; Garbarino, Bednar, & Burkhardt, 2002). All chemicals were American Chemical Society–certified quality. The determination of trivalent arsenic (As^{III}) and pentavalent arsenic (As^V) was done to look for varying toxicological properties of these forms in further analysis. This speciation raised the limit of detection (LD) to 5 µg/L for each chemical forms, an effect that was controlled by a sensitivity analysis (see Discussion).

As for the biological samples, the two forms of urinary inorganic arsenic (As^{III} and As^V) and their metabolites (MMA and DMA), as well as arsenocholine and arsenobetaine were all measured (Calderon, Hudgens, Schreinemachers, & Thomas, 1999). Total arsenic concentrations were measured in the toenail samples. Gas chromatography extraction and inductively coupled plasma-mass spectrometry (ICP-MS) identification procedures

(Belanger & Dumas, 2010) were used for the analysis of the biological samples. The LDs for urinary arsenic and toenail arsenic were 0.7 µg/L and 0.1 µg/g, respectively. Urinary creatinine was measured using colorimetry (Jaffé, 1886).

An imputed value of LD/$\sqrt{2}$ was used for water or biological samples with levels below the LD. The concentration of inorganic arsenic in wells was determined by adding the As^{III} and As^{V} concentrations. The internal doses were estimated by urinary and ungual arsenic concentrations. Urinary arsenic concentration was calculated by adding As^{III}, DMA, and MMA, adjusted for creatinine. External doses were estimated by the concentration of inorganic arsenic in wells and the short- and long-term inorganic arsenic daily intakes from well water that were calculated by multiplying inorganic arsenic in wells (µg/L) with the mean daily well water consumption (L) in the two days prior to sampling, in the first case, and the usual daily well water consumption (L) on an annual basis, in the second case.

Descriptive statistics, including Chi squared distribution analysis and Fisher's test, were used to compare sociodemographic characteristics in the three groups. Analysis of variance was performed to compare the geometric mean internal dose among the three exposure groups. T-tests were used to compare variation of these levels depending on water uses (i.e., drinking or using this water for preparing beverages vs. using this water only for preparing food) in the two days prior to sampling or the average daily well water consumption in the past year.

The relationship between the external dose indicators and the internal doses was evaluated using multiple linear regressions, controlling for potential confounding variables (age, gender, dietary sources of arsenic, number of cigarettes smoked). The short-term daily well water inorganic arsenic intake was used as an independent variable in models with urinary arsenic and the long-term daily well water inorganic arsenic intake in models with toenail arsenic. The multiple linear regression analyses performed with urinary arsenic were also repeated excluding those participants with significant organic arsenic exposure, as estimated by the presence of detectable arsenocholine and arsenobetaine in their urine.

This strategy has been proposed as the best way to control the influence of organic arsenicals of marine origin (arsenosugars and arsenolipids) on urine DMA (Navas-Acien, Silbergeld, Pastor-Barriuso, & Guallar, 2009). The logarithmic conversion of variables was carried out as required in the regression analysis. Results were considered statistically significant when $p < .05$. Data were analyzed using SPSS version 17.0.

Ethical Considerations
Our project was approved by Health Canada's research ethics board and by the human research ethics board at the Centre Hospitalier Universitaire de Sherbrooke.

Results
Of the 356 households initially available, 153 were included in our study (see flow chart in Figure 1). In terms of participants, 489 individuals were available for the study in the households contacted, but 71 were uninterested, 69 were ineligible, and 54 withdrew because they changed their mind during the interval between the phone call and the home visit. In the end, 304 participants were recruited, including 43 children.

TABLE **1**

Sociodemographic Characteristics of Participants (Adults and Children) by Exposure Group

Groups[a]	Adults (n = 261)			Children (n = 43)		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
n	126	55	80	20	12	11
Age groups (%)						
7–12 years	–	–	–	65	33	36
13–17 years	–	–	–	35	67	64
18–44 years	31	33	31	–	–	–
45–64 years	55	6	53	–	–	–
65 and over	14	7	16	–	–	–
p-Value[b]	.649			.140		
Gender (%)						
Male	42	53	41	50	42	27
Female	58	47	59	50	58	73
p-Value	.344[b]			.486[c]		
Last year of education completed (%)						
Primary	14	11	20	75	33	45
Secondary	47	49	52	25	67	55
Junior college or vocational	18	25	23	–	–	–
University	21	15	5	–	–	–
Data missing	1	–	1	–	–	–
p-Value[b]	.072			.049		
Active smoker (%)						
Yes (n)	21 (26)	16 (9)	23 (18)	0 (0)	0 (0)	18 (2)
No (n)	79 (100)	84 (46)	78 (62)	100 (20)	100 (12)	82 (9)
p-Value[b]	.679			.061		

[a]Group 1: <10 µg arsenic/L water; group 2: 10–20 µg arsenic/L water; group 3: ≥20 µg arsenic/L water.
[b]Determined using Pearson Chi-square test.
[c]Determined using Fisher's test.

Distribution of Urinary and Toenail Arsenic (As) Among Participants

Distribution	Urinary As[a] (µg/L)		Urinary Arsenocholine + arsenobetaine (µg/L)		Toenail As (µg/g)	
	Adults n = 261	Children n = 43	Adults n = 261	Children n = 43	Adults n = 261	Children n = 43
5th percentile	2.49	3.23	0.50	0.50	0.07	0.14
95th percentile	34.23	22.70	81.6	18.60	0.89	1.37
Arithmetic mean	12.66	8.93	26.55	3.33	0.28	0.48
Standard deviation	26.23	5.64	281.39	7.92	0.30	0.37
Geometric mean	8.06	7.53	1.89	0.97	0.20	0.37
Median	7.70	7.39	1.00	0.50	0.18	0.30
Missing data (n)	1	0	1	0	5	1
Data below limit of detection (n [%][b])	–	–	113 (43.5%)	30 (69.8%)	55 (21.2%)	1 (2.4%)

[a]Urinary As = Σ (MMA + DMA + As^{III}).
[b]Percentage indicated: number of values below the limit of detection/total number of samples analyzed.

The three exposure groups were similar in terms of age group, male-to-female ratio, and smoking status (Table 1). The average length of residence of participants at their current address was 17.2 years (range: 1–24).

External Doses

A difference existed between the usual daily well water consumption (L/day) on an annual basis among the three adult groups (group 1: 1.24; group 2: 1.41; group 3: 0.67; $p < .001$). A difference also occurred between the mean daily well water consumption in the two days prior to sampling among the three adult groups and the three children groups.

The concentration of inorganic arsenic in wells had a log-normal distribution with an arithmetic mean of 22.77 µg/L ($n = 153$), a geometric mean of 14.18 µg/L, and a median of 10.54 µg/L. Data were below the LD in 70 wells (46% of samples) for both As^{III} and As^V, and the highest concentration was 193.54 µg/L.

Internal Doses

Urinary arsenic and toenail arsenic distributions are described in Table 2. Practically all the values in the form of DMA were above the LD in adults (98.5%) and children (97.7%). By contrast, practically all the values for As^V were below the LD in adults (98.1%) and children (100%).

In total, 21.1% of adults and 2.4% of children had toenail arsenic concentrations below the LD.

Relationships Between Internal and External Doses

Bivariate Analysis
A statistically significant difference between the geometric mean urinary arsenic (µg/g creatinine) among the three exposure groups was observed in adults (group 1: 5.83; group 2: 8.93; group 3: 11.67; $p < .001$) but not in children (group 1: 6.12; group 2: 6.52; Group 3: 7.59; $p = .585$). A statistically significant difference was observed in urinary arsenic between adults who drank well water in the two days prior to sampling and those who only use this water for preparing food in groups 2 and 3 ($p = .042$ and $p < .001$, respectively).

With regard to toenail arsenic (µg/g), a statistically significant difference occurred among the three groups for both adults (group 1: 0.130; group 2: 0.210; group 3: 0.358; $p < .001$) and children (group 1: 0.305; group 2: 0.308; group 3: 0.656; $p = .034$, respectively). For adults, only group 3 showed toenail arsenic concentrations that were significantly higher for those who normally drink well water compared with those who did not ($p = .013$).

The correlation between urinary arsenic and toenail concentration in adults was 0.34 ($p < .001$).

Multivariate Analyses

An analysis of residuals of regression demonstrated diverging observations that were apparently due to lobster consumption in the two days prior to sampling. Each serving of lobster increased urinary arsenic by 133.7 µg/L on average (see coefficient; model A; Table 3). Consumption of one serving of crab in the two days prior to sampling also increased urinary arsenic concentration by 25.7 µg/L ($p = .022$) (data not shown).

A second regression model was generated by excluding the seven participants (2.7% of the total sample) who consumed lobster or crab in the two days prior to sampling (model B). As in the case of the first model, the short-term daily well water inorganic arsenic intake was the only independent variable having a significant impact on the urinary arsenic concentration. At this level, however, it was the effect of fish that was more obvious, with one serving of fish increasing urinary arsenic by 7.6 µg/L ($p = .001$).

A final model was developed by withdrawing all 146 participants (56% of total sample) who had detectable arsenocholine or arsenobetaine in their urine. The short-term daily intake remained related to urinary arsenic ($p < .001$; model C). The tight control over dietary sources of arsenic in this model allowed us to isolate the direct influence of inorganic arsenic in wells on urinary arsenic ($p < .001$; model C). Women had about 4 µg/L more urinary arsenic than men on average ($p < .001$).

In children, the basic regression model accounted for 35.9% of the total variation of urinary arsenic ($p = .002$) in part owing to the contribution of the short-term daily well water inorganic arsenic intake ($p = .017$; model D, Table 3) and food containing arsenic; one serving of rice increased urinary arsenic by 8.5 µg/L on average. Each additional year of age decreased urinary arsenic by a little less than 1 µg/L.

With regard to toenail arsenic, the basic regression model accounted for 45.0% of the total toenail arsenic variation in adults after logarithmic transformation of toenail arsenic concentrations ($p < .0001$; model E, Table 4).

After excluding 12 extreme values, a restricted model accounted for 61.9% of the

total toenail arsenic variation ($p < .001$; model F). As in the former model, the concentration of inorganic arsenic in wells and long-term daily intake were still statistically significant for explaining variability in the total toenail arsenic concentration ($p < .001$ and $p = .002$, respectively). Total toenail arsenic decreased significantly with age ($p < .001$).

In children, the regression model using logarithmically transformed variables accounted for 29.1% of the total toenail arsenic variation ($p = .004$; model G; Table 4). Inorganic arsenic in wells was the only independent variable statistically significant for explaining this variability ($p = .001$). The older the child, the lower the toenail arsenic concentration ($p = .042$).

Discussion

Compared with median exposures that were measured in the 2003–2004 National Health and Nutrition Examination Survey (NHANES) study in the U.S. (Navas-Acien, Silbergeld, Pastor-Barriuso, & Guallar, 2008), the participants in our study were more exposed to inorganic arsenic than the general U.S. population based on the results obtained in adults for comparable forms (for DMA, 5.70 µg/L vs. 3.0 µg/L, respectively). By contrast, our participants were less exposed to arsenic than Native American adults living in communities of Arizona served by public water systems with inorganic arsenic levels from less than 10 to 61 µg/L (median of urinary total arsenic concentrations: 7.70 µg/L vs. 18.6 µg/L, respectively; Gribble et al., 2012). For adults in our study, a statistically significant difference existed in the mean urinary arsenic concentration across the three groups of wells. This difference was also seen in long-term exposure, as measured in toenail concentrations in both adult and child participants.

For the multiple linear regressions, it is noteworthy that lobster, crab, and fish influenced urinary arsenic in adults. Excluding participants with detectable urinary arsenocholine or arsenobetaine increased the strength of the association between urinary arsenic and short-term daily well water inorganic arsenic intake while highlighting the direct effect of the concentration of inorganic arsenic in wells. These two independent variables mutually accounted for 85.5% of the total variation in the model ($p < .001$) once

combined with age and gender (model C). While it could be suggested that the independent influence of gender in the regression models could be caused by gender differences in arsenic metabolism, in fact, it cannot be an explanation here considering that urinary arsenic is the sum of inorganic arsenic and methylated arsenic species in urine. Smoking did not contribute to measured internal doses as seen in other studies (Karagas et al., 2000, Marano et al., 2012).

In adults, the model for toenail arsenic shows the concentration of inorganic arsenic in wells and the long-term daily well water inorganic arsenic intake as independent variables ($R^2 = .619$; model F). This high R^2 is consistent with studies suggesting that toenail arsenic is a useful marker for low

concentrations of inorganic arsenic (Karagas et al., 2000; Slotnick & Nriagu, 2006, Slotnick, Meliker, AvRuskin, Ghosh, & Nriagu, 2007). The good relationship between toenail arsenic and inorganic arsenic in wells is also consistent with a study reporting that toenail arsenic levels are primarily inorganic arsenic (Mandal, Ogra, & Suzuki, 2001). Although no speciation occurred in toenail arsenic, it is reasonable to expect that the excluded participants' exposure was in fact dietary: the inorganic arsenic in their well water was below the LD; and even if fish, seafood, or seaweed are especially known for their high arsenic content in organic forms, they can nevertheless contain an appreciable amount of inorganic arsenic (up to 10% in the case of mollusks; Food and Drug Admin-

Multiple Linear Regression Models Between Urinary Arsenic[a] and External Dose Indicators[b] by Age Group

Variables	Nonstandardized Coefficient	p-Value
Model A in adults: $R^2 = .729$, $p < .0001$, $n = 260$		
Short-term daily intake (µg/d)	0.300	<.001
Gender (men = 0; women = 1)	4.097	.001
Age	0.067	.135
Mean lobster consumption in the two days prior to sampling (servings/day)	133.687	<.001
Model B in adults: $R^2 = .567$, $p < .0001$, $n = 253$		
Short-term daily intake (µg/d)	0.301	<.001
Gender (men = 0; women = 1)	4.153	<.001
Age	0.007	.837
Mean fish consumption in the two days prior to sampling (servings/day)	7.642	.001
Model C[c] in adults: $R^2 = .855$, $p < .0001$, $n = 114$		
Short-term daily intake (µg/d)	0.379	<.001
Arsenic concentration in well (µg/L)	0.087	<.001
Gender (men = 0; women = 1)	3.550	.001
Age	-0.029	.423
Model D in children: $R^2 = .359$, $p = .002$, $n = 43$		
Short-term daily intake (µg/d)	0.294	.017
Gender (boys = 0; girls = 1)	2.749	.056
Age	-0.853	.002
Mean rice consumption in the two days prior to sampling (servings/day)	8.504	.022

[a]Σ (MMA + DMA + AsIII) corrected for urinary creatinine (µg/g Cr*L).

[b]Inorganic arsenic concentration in well water or short-term daily well water inorganic arsenic intake.

[c]After withdrawing all 146 participants (56% of total sample) having detectable arsenocholine or arsenobetaine in their urine.

Multiple Linear Regression Models Between Toenail Arsenic[a] and External Dose Indicators[b] by Age Group

Variables	Nonstandardized Coefficient	p-Value
Model E in adults: $R^2 = .450$, $p < .0001$, $n = 256$		
Arsenic concentration in well (log [µg/L])	0.577	<.001
Long-term daily intake (log [µg/d])	0.071	.014
Gender (men = 0; women = 1)	0.030	.372
Age	-0.006	<.001
Model F[c] in adults: $R^2 = .619$, $p < .0001$, $n = 244$		
Arsenic concentration in well (log [µg/L])	0.636	<.001
Long-term daily intake (log [µg/d])	0.069	.002
Gender (men = 0; women = 1)	0.014	.602
Age	-0.006	<.001
Model G in children: $R^2 = .291$, $p = .004$, $n = 42$		
Arsenic concentration in well (log [µg/L])	0.435	.001
Gender (boys = 0; girls = 1)	-0.058	.511
Age	-0.033	.042

[a](log [µg/g]).
[b]Inorganic arsenic concentration in well water or long-term daily well water inorganic arsenic intake.
[c]After withdrawing 12 participants (4.7% of total sample) with extreme values.

istration, 1993; Gagnon, Tremblay, Rouette, & Cartier, 2004).

The children in our study seem to be less exposed than children aged 6–12 years old from agricultural areas in Mexico (sum of urinary As[III], As[V], MMA, and DMA: arithmetic mean of 8.93 µg/L vs. 30.9 µg/L, respectively; Meza-Montenegro et al., 2013). In the Mexican children, food consumption or dust inhalation may be more important routes of arsenic exposure than drinking water (Roberge et al., 2012). For children in the present study, the total variation in urinary arsenic and toenail arsenic determined through modeling was lower than in adults ($R^2 = .359$ and $p = .002$ for model D in Table 3; $R^2 = .291$ for model G in Table 4). A better methylation capacity in children may explain this for toenails (Sun et al., 2007). It is also difficult for them to estimate their water consumption. A larger proportion of water intake by children may also come from outside their home (school, neighborhood).

With regard to the child participants, it was interesting to observe that age was inversely related to internal dose as measured in urine or toenails. This could be explained by greater inhalation of inorganic arsenic contaminated dust by younger children; the soil of the region is naturally rich in inorganic arsenic. With regard to urine, the inverse relationship could also be caused by correction measurements, since urinary creatinine is higher in adolescents than in children owing to their greater muscle mass. In adults, the inverse relationship observed between age and toenail internal dose may well be due to lower consumption of fish and seafood by older people.

Generally, internal arsenic doses were associated with indicators of external doses whose inorganic arsenic concentrations were measured in the participants' wells even at concentrations that straddle 10 µg/L. In group 1, no significant difference in urinary arsenic concentration was observed in people who drank well water in the two days prior to sampling and those who only used this water for preparing food. Overall, we could consider as nonclinically significant the difference between the mean concentration of urinary arsenic in participants of the first group of wells and a comparable group of citizens ($n = 328$) in another sector of the same area served by a noncontaminated water supply system (6.9 µg/L vs. 4.6 µg/L; Gagné, 2007). This suggests that for users of wells with arsenic concentrations less than 10 µg/L, consuming well water represented a negligible contribution in comparison with all other sources of exposure to inorganic arsenic, and it is not an argument for an even more restrictive guideline. Moreover, a recent study has shown that mean aggregate inorganic arsenic intake among subjects living in homes with tap water arsenic ≤ 10 µg/L, 5 µg/L, and 3 µg/L was similar, with >54% of this exposure from food (Kurzius-Spencer et al., 2014).

The strengths of our study are the random selection of households in group 1 and the exhaustive recruitment of households in groups 2 and 3, the high participation rate (74.9%, or 373 of the 489 potential participants before exclusion of ineligible individuals), and the fact that our study considered not only drinking water but also water used to prepare food and beverages. The 71 uninterested individuals did not differ from participants in terms of gender, age group, education, and historical inorganic arsenic level in their well ($p > .05$).

The percentage of values below the LD (particularly for water samples) had a very small effect on the results. First, the comparisons between the geometric mean of internal doses among the three exposure groups were not influenced by the LD. Second, for the regression models, a sensitivity analysis was done after excluding participants with well water results below the LD; for all these additional analyses, the coefficients were similar and the results remained statistically significant (data not shown). Third, the relative weight of wells with arsenic below the LD for the exposure charge in the models is relatively modest (i.e., 13% after applying the contamination level of LD/√(2) to the 70 wells concerned, the arithmetic mean of 23 µg/L to the other wells, and assuming a uniform distribution of participants among the 153 households).

Conclusion
The results of our study confirm that concentrations of inorganic arsenic in wells contribute significantly to human exposure to inorganic arsenic and hence reinforce the recommendation for drinking water issued by the U.S. Environmental Protection Agency, the World Health Organization, and Health Canada regarding this contaminant.

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Health Risk Assessment Research on Heavy Metals Ingestion Through Groundwater Drinking Pathway for the Residents in Baotou, China

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Abstract **Drinking groundwater is a significant pathway for human exposure to heavy metals. To evaluate the health effect of some heavy metals ingestion through the groundwater drinking pathway, the authors collected 35 groundwater samples from the drinking water wells of local residents and the exploitation wells of waterworks in Baotou, China. The monitoring results indicate that the groundwater had been polluted by heavy metals in some regions of the study area. A health risk assessment model derived from the U.S. Environmental Protection Agency was used to determine the noncarcinogenic and carcinogenic effects to residents who drink groundwater. All the respondents in the study area were at potential risk of carcinogenic health effects from arsenic when using the lowest safe standard for carcinogenic risk (1E-06). The hazard quotient values for noncarcinogenic health risk of arsenic exceeded 1 in 14.3% of the sampling wells in the study area. The research results could provide baseline data for groundwater utilization and supervision in the Baotou plain area.**

Introduction

Groundwater is an important water resource in China. The current groundwater exploitation quantity accounts for 18% of the total water supply, and 65% of the domestic water is from groundwater in north China. At present, groundwater pollution in some regions of China has become increasingly prominent with accelerated urbanization and industrialization processes. According to the *Bulletin of Chinese Environment in 2012*, the monitoring wells with water quality at the poor and very poor grades accounted for 40.5% and 16.8%, respectively, among the 4,929 groundwater monitoring wells in 198 prefecture-level administrative regions of China (China Ministry of Environmental Protection [MEP], 2013). The concentrations of heavy metals in groundwater in some monitoring wells exceed the groundwater quality standard of China, and the main pollutants are chromium, cadmium, lead, and mercury in the north plain of China (China MEP, 2013).

Heavy metals are discharged from various industries such as storage batteries, textiles, pigment, fertilizer, plastic, ceramic and glass manufacturing, mining, electroplating, and metallurgical processes (Montazer-Rahmati, Rabbani, Abdolali, & Keshtkar, 2011). Heavy metals can be accumulated along the food chain, which can pose a risk to animals and humans (Barakat, 2011; Nguyen et al., 2013; Yang, Zhao, Xing, & Lin, 2013; Zhu, Han, Bi, & Yang, 2012). Heavy metal contamination is a known causative of various disorders, and the exposure to heavy metals can cause damage to many parts of human bodies if the safe thresholds are exceeded (Hashim, Mukhopadhyay, Sahu, & Sengupta, 2011; Khan, Malik, & Muhammad, 2013; Nguyen et al., 2013; Zhao et al., 2014).

FIGURE **1**

Location of the Study Area and Groundwater Sampling Sites
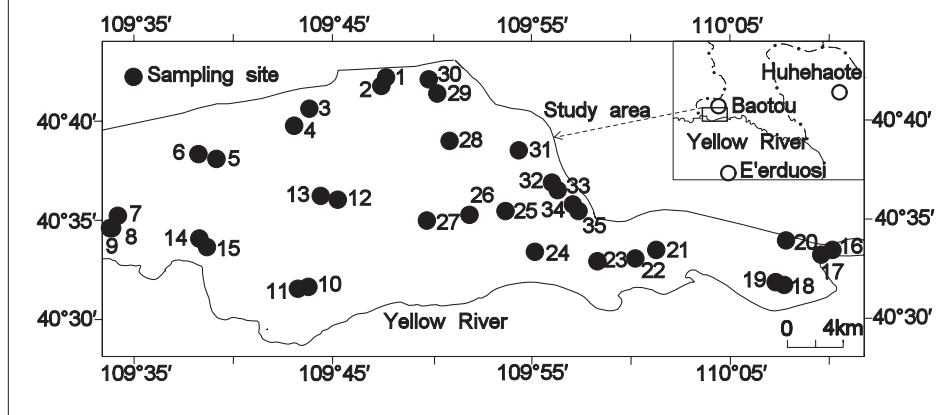
Drinking groundwater is a significant pathway of human exposure to heavy metals, and long-term exposure to heavy metals can cause damage to human health. Exposure to heavy metals in drinking water can result in serious health effects, including reduced growth and development, cancer, organ damage, circulatory and nervous system damage, and in extreme cases, death (Barakat, 2011).

Baotou is not only an important base of heavy industry of north China, but also the biggest industrial city of the Inner Mongolia autonomous region. Groundwater is the main water supply in some regions of Baotou, especially in the rural areas. At present, the overall situation of groundwater pollution in Baotou is not optimistic, and the groundwater pollution is serious in some regions.

Evaluation of groundwater pollution conditions and potential health risk of heavy metals has great significance for the groundwater utilization and supervision in Baotou. The objectives of our study were (1) to investigate the groundwater contamination of arsenic, mercury, cadmium, chromium (VI), lead, and other parameters in Baotou; and (2) to assess the noncarcinogenic and carcinogenic risks of local residents exposed to heavy metals through the groundwater drinking pathway. To the best of our knowledge, the health risk assessments of heavy metals exposure through the groundwater drinking pathway in Baotou has not been reported.

Materials and Methods

The Study Area

The Baotou plain terrain was selected as the study area, which contains a total area of 768 km². Baotou is an arid and semiarid region. The yearly average precipitation is 306.5 mm, and the yearly average evaporation is 2273.8 mm (Bai, Wang, & Meng, 2012). Baotou city has a population of two million people, and the main water supply sources are surface water and groundwater. Baotou is an important iron and steel industry base of China, and the current dominant industries include steel and aluminum, equipment manufacturing, electric power, coal chemical, and rare earth metals. Figure 1 shows the location of the study area.

The stratum of the study area mainly includes the Archaeozoic metamorphic rocks, the Mesozoic Jurassic sandstone and conglomerate, and the Cenozoic Quaternary unconsolidated sediments. The Quaternary strata is widely distributed and closely associated with the groundwater system of the study area. The main aquifers in the study area can be classified as confined and unconfined aquifer, and the groundwater flows from northeast to southwest. The broadly distributed muddy clay exists between the confined and unconfined aquifer, and the confined aquifer has not been contaminated at present. The unconfined aquifer consists of Pleistocene to Holocene sand and gravel. The thickness of unconfined aquifer is 20–30 m in the northern and central area, and 5–10 m in the southern area. The unconfined aquifer recharges from lateral flow, precipitation infiltration, irrigation and surface water, and discharges by exploitation and evaporation.

Sample Collection and Analysis

The groundwater quality of Baotou had been regularly monitored by the Environmental Protection Bureau and Environmental Monitoring Station of Baotou since the 1990s. In this research, the groundwater sampling sites were located at the drinking water wells of local residents and the exploitation wells of waterworks. Thirty-five groundwater samples were collected from the wells of the study area in July 2012 (Figure 1), and the collected samples were analyzed by the Environmental Monitoring Station of Baotou. Water was directly taken out of the wells for drinking in the study area, and the sampling wells served over 600 people (approximately 17 people per well).

The groundwater samples were collected from a tube well after 5–10 minutes of flushing to remove any standing water from the tube (Phan et al., 2010), then the collected samples were preserved in an ice chamber and immediately sent to the test department. In this research, all the collected groundwater samples were analyzed in the laboratory of Baotou Environmental Monitoring Station. Arsenic and mercury in the groundwater samples were analyzed by atomic fluorescence spectrometry (China MEP, 2014). Iron and manganese concentrations were determined by phenanthroline spectrophotometry (China MEP, 2007a) and formaldehyde oxime spectrophotometry, respectively (China MEP, 2007b). Lead concentrations were determined by oscillopolarography (China MEP, 1992). Cadmium in the groundwater samples was analyzed by spectrophotometric method with dithizone (China MEP, 1987a), and chromium (VI) concentrations were determined by 1,5 dtphenylcarbohydrazide spectrophotometric method (China MEP, 1987b).

Based on the analyzed results of the groundwater samples, the data analysis was performed by SPSS. Correlation analysis of the 15 parameters was carried out using Kendall's tau coefficient.

Health Risk Assessment Model

A health risk assessment model derived from the U.S. Environmental Protection Agency (U.S. EPA) was used to determine the noncar-

TABLE **1**

The Values of Exposure Parameters of Health Risk Assessment in the Study Area

	Ingestion Rate (Liters/Day)	Exposure Frequency (Days/Year)	Exposure Duration (ED) (Year)	Body Weight (kg)	Average Time Expectancy (Day)
Values	1.8	350	30	60	70×365 (carcinogenic) ED×365 (noncarcinogenic)

TABLE **2**

Mean, Median, Standard Deviation, Minimum, and Maximum Values of Groundwater Samples Analyzed in the Study Area

Parameters	Standard of China (mg/L)	Mean	Median	SD	Minimum	Maximum
pH	6.5–8.5	7.699	7.620	0.186	7.42	8.20
Hardness	450	732.583	481.000	696.226	95.4	3240
Sulfate	250	390.829	163.000	1150.967	23	7060
Chlorine	250	354.491	182.000	697.145	23.600	3390
Nitrate	10	20.225	5.850	26.852	0.080	111
Nitrite	–	0.011	0.009	0.009	0.003	0.039
Ammonium	–	0.890	0.093	1.528	0.025	5.484
Iron	0.3	0.375	0.040	0.819	0.030	3.600
Arsenic	0.01	0.00408	0.00068	0.00680	0.00008	0.0238
Cadmium	0.005	0.000109	0.0001	0.000041	0.0001	0.00033
Chromium (VI)	0.05	0.008	0.004	0.016	0.004	0.096
Lead	0.01	0.00232	0.00208	0.00106	0.001	0.00497
Manganese	0.1	0.065	0.010	0.102	0.010	0.340
Mercury	0.001	0.00006	0.00006	0.000	0.000006	0.000006
Total dissolved solids	1000	1941.743	1130.000	2927.936	336.000	15700

cinogenic and carcinogenic effects to people drinking groundwater. The formula to compute the dose of pollutant ingestion is

$$EDI = \frac{CW \times IR \times EF \times ED}{BW \times AT} \quad (1)$$

Where EDI represents the dose of pollutant ingestion (mg/[kg·day]); CW represents the pollutant concentration in groundwater (mg/L); IR represents the groundwater ingestion rate (L/day); EF represents the exposure frequency (day/year); ED represents the exposure duration (year); BW represents body weight (kg); and AT represents the average time expectancy (day).

The carcinogenic risk is computed by the formula:

$$HI = EDI \times SF \quad (2)$$

Where HI represents the carcinogenic risk and SF represents the slope factor (mg/kg·d)$^{-1}$.

The slope factor is the cancer risk per unit of dose. The slope factor can be used to compare the relative potency of different chemical substances on the basis either of chemical weight or moles of chemical (U.S. Environmental Protection Agency [U.S. EPA], 1992). U.S. EPA (2000) established a theoretical value of an excess acceptable lifetime cancer risk that ranges from 1E-04 to 1E-06. U.S. EPA (2000) usually requires remedial action at locations where the calculated cancer risks are greater than 1E-04.

The noncarcinogenic risk is computed by the formula:

$$HQ = \frac{EDI}{RfD} \quad (3)$$

Where HQ represents the hazard quotient, and RfD represents oral reference dose (mg/kg·day).

The reference dose (RfD) is an estimate of a daily exposure to the human population that is likely to be without an appreciable risk of deleterious effects during a lifetime (U.S. EPA, 1993). Doses less than the RfD are not likely to be associated with adverse health risks, and the probability of adverse effects in a human population increases when the frequency or magnitude of the exposures exceeding the RfD increases (U.S. EPA, 1993). If HQ equals or exceeds one, concern may exist for potential exposure to site contaminants (U.S. EPA, 2000). U.S. EPA (2000) typically considers the need for remedial action at locations where the HQ values equal or are slightly greater than one, and the remedial action is usually

FIGURE 2

Distribution Maps of Iron (Fe), Manganese (Mn), Arsenic (As), and Chromium (Cr) (VI) Concentrations of the Sampling Wells in the Study Area
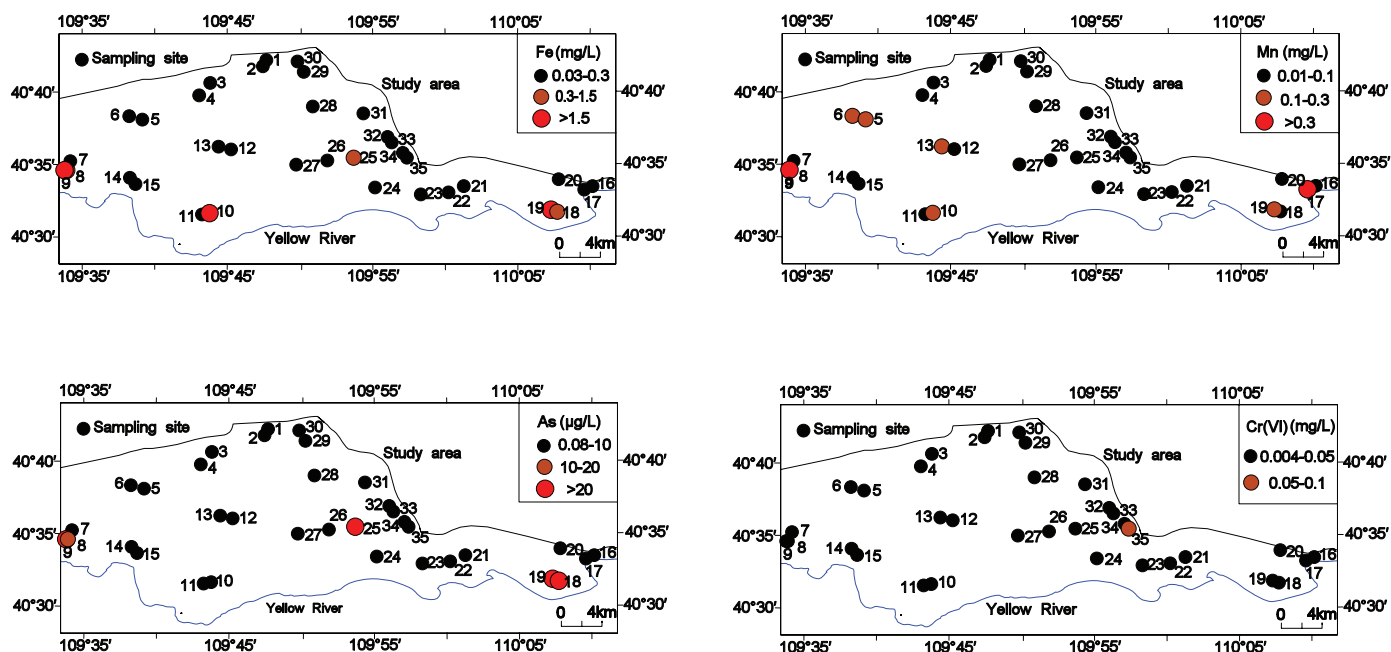
The orange and red points represent the wells with concentrations of pollutants that exceed the guideline values.

required at locations where HQ values significantly exceed one.

In our study, a door-to-door investigation was carried out to get the groundwater consumption data in every household, and the groundwater ingestion rate (IR) was computed by the groundwater consumption and the population. The exposure frequency (EF), the exposure duration (ED), the body weight (BW), and the average time expectancy (AT) were determined by the recommended values of Beijing environmental site assessment guideline (Beijing Municipal Administration of Quality and Technology Supervision, 2009). The evaluation parameters of the heavy metals were acquired by the recommended value of U.S. EPA (2005). RfD values of arsenic, cadmium, chromium (VI), lead, and mercury are 0.0003, 0.0005, 0.003, 0.0014, and 0.0003, respectively, and the SF value of arsenic is 1.5. Exposure to arsenic (inorganic) can result in noncarcinogenic and carcinogenic effects, and

the RfD and SF values of arsenic are recommended by U.S. EPA. Table 1 shows the values of exposure parameters of health risk assessment in the study area.

Results and Discussion

Monitoring Results of Groundwater Quality

The monitoring results and guideline values of the main parameters in the study area are shown in Table 2. The aesthetically based guideline values for iron and manganese are 0.3 and 0.1 mg/L, respectively (China Ministry of Health, 2006). Based on the monitoring results, the concentrations of lead, mercury, and cadmium of the samples are less than the drinking water quality standard of China. Concentrations of sulfate, chlorine, nitrate, iron, manganese, arsenic, and chromium (VI) exceed the guideline values of the drinking water quality standard of China. Over 17% of

the 35 sampling wells detected iron > 0.3 mg/L, 20% had manganese > 0.1 mg/L, 14.3% found arsenic > 0.01 mg/L, and 2.9% had chromium (VI) > 0.05 mg/L. Concentrations of iron, manganese, arsenic, and chromium (VI) in the groundwater samples ranged from 0.03 to 3.6 mg/L, 0.01 to 0.34 mg/L, 0.08 to 23.8 µg/L, and 0.004 to 0.096 mg/L, respectively, and the mean concentrations were 0.375 mg/L, 0.065 mg/L, 4.081 µg/L, and 0.008 mg/L, respectively. The groundwater-polluted regions include Xiheyan, Languiyaozi, Wanshuiquan, Hanqingba, Dongba, and Dengkou. Figure 2 shows the distribution maps of iron, manganese, arsenic, and chromium (VI) concentrations in the sampling wells of the study area.

The analytical results indicate that the groundwater had been polluted by heavy metals in some regions of the study area. Based on the correlation analysis of the 15 parameters of the 35 samples, the positive significant correlation between arsenic and

TABLE **3**

Mean, Median, Minimum, and Maximum Values of Hazard Quotient and Computed Carcinogenic Risk of Heavy Metals in the Study Area

Value	Hazard Quotient					Carcinogenic Risk
	Arsenic	Cadmium	Chromium (VI)	Lead	Mercury (Inorganic)	Arsenic
Mean	0.39137	0.00628	0.07973	0.04768	0.00575	7.5E-05
Median	0.09397	0.00575	0.03836	0.05096	0.00575	1.8E-05
Minimum	0.00767	0.00575	0.03836	0.02055	0.00575	1.5E-06
Maximum	2.28219	0.01899	0.92055	0.10212	0.00575	4E-04

FIGURE **3**

Distribution of the Computed Hazard Quotient (HQ) and Carcinogenic Risk (R) of Arsenic (As) in the Study Area
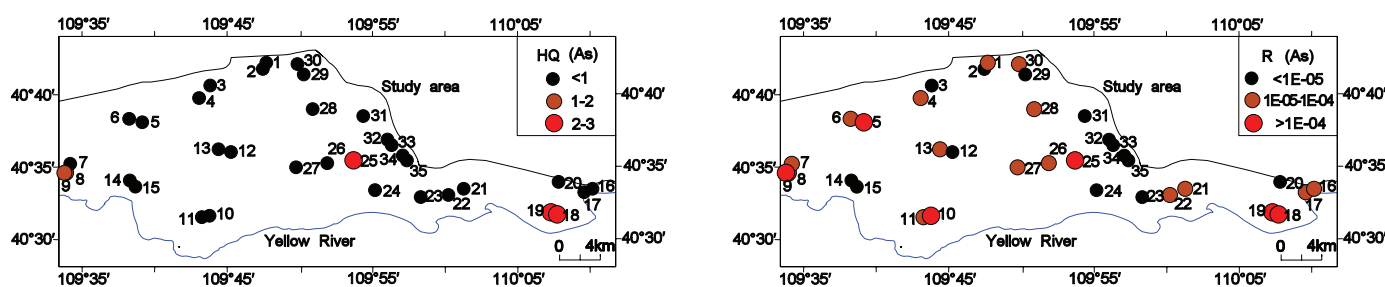
iron ($r = .426$, $p < .01$) and arsenic and manganese ($r = .389$, $p < .01$) could be determined. Guo and co-authors (Guo, Guo, Jia, Liu, & Jiang, 2013; Guo, Liu, et al., 2013) suggested that high concentrations of iron and manganese could be frequently found in the arsenic-polluted groundwater in China. The positive significant correlation between arsenic and iron suggests that reductive dissolution of arsenic-rich iron (oxy) hydroxides is a possible mechanism, driving arsenic release to groundwater (Phan et al., 2010).

Risk Assessment of Arsenic, Mercury, Cadmium, Chromium (VI), and Lead
The carcinogenic risk of arsenic was computed by formula (2), and the hazard quotient of arsenic, cadmium, chromium (VI), lead, and mercury was computed by formula (3). Based on the computational results, none of the respondents in the study area appeared to have carcinogenic

and noncarcinogenic effects of cadmium, chromium (VI), lead, and mercury, while the local residents were at potential risk of carcinogenic and noncarcinogenic effects of arsenic (Table 3 and Figure 3). The HQ values for noncarcinogenic health risk of arsenic exceeded 1 in 14.3% of the sampling wells in the Baotou plain area. In addition, the HI values for carcinogenic risk of arsenic were greater than 1E-04 in 20% of the wells, which exceeded the highest safe standard for carcinogenic risk. All the respondents in the study area were at potential risk to carcinogenic health effects of arsenic when using the lowest safe standard for carcinogenic risk (1E-06). The HI values for carcinogenic risk of arsenic were greater than 1E-05 in 60% of the wells. The arsenic-contaminated groundwater was frequently used to irrigate crops in some rural regions of the study area, and the actual ingestion of arsenic might be higher than that of the drinking pathway.

Arsenic is a known human carcinogen and assigned to the Group I carcinogen by the International Agency for Research on Cancer (IARC, 2013). The arsenic contamination of groundwater has increasingly been recognized as a major global issue of concern (Cho, Sthiannopkao, Pachepsky, Kim, & Kim, 2011). Individuals can be exposed to arsenic through several pathways, but the most critical one is daily diet and drinking water ingestion (Phan et al., 2010). The increased exposure of arsenic is generally associated with the incidences of cancer and other public health hazards, and the occurrence of arsenic (mostly inorganic forms) in groundwater has been documented in several parts of the world including the U.S., Europe, Australia, Southeast Asia, and several Latin American countries (Chatterjee et al., 2010; Luu, Sthiannopkao, & Kim, 2009; Nguyen, Bang, Viet, & Kim, 2009; Phan et al., 2010).

At present, regional environmental pollution has become one of the vital factors restricting the economic development of Baotou. The health risk of heavy metals exposure through the groundwater drinking pathway in Baotou has been recognized in recent years. To the best of our knowledge, no other study exists relating the groundwater pollution sources of arsenic. Based on our research results, all the respondents in the study area were at potential risk to carcinogenic health effects of arsenic. The causes of arsenic pollution in Baotou may include geologic and human factors. At present, the groundwater pollution sources cannot be clearly determined, and the further studies are needed in the future.

Conclusion

(1) Based on the analytical results, 17.1% of the 35 sampling wells detected iron > 0.3 mg/L, 20% had manganese > 0.1 mg/L, 14.3% found arsenic > 0.01 mg/L, and 2.9% had chromium (VI) > 0.05 mg/L. The groundwater in some regions of the Baotou plain area had been polluted by heavy metals, and the strongly positive significant correlation could be determined among iron, arsenic, and manganese.

(2) The computational results indicate that the respondents in the study area appeared to have carcinogenic and noncarcinogenic effects of arsenic. The HQ values for noncarcinogenic health risk of arsenic exceeded 1 in 14.3% of the sampling wells in the study area. The HI values for carcinogenic risk of arsenic were greater than 1E-04 in 20% of the wells.

(3) All the respondents were at potential risk of carcinogenic health effects of arsenic when using the lowest safe standard for carcinogenic risk (1E-06). If effective measures are not taken, cases of arsenic poisoning might be found in the future. The research results could provide basic data for the groundwater utilization and supervision in Baotou. ❦

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AEHAP gratefully acknowledges the support of the National Center for Environmental Health, Centers for Disease Control and Prevention, for this competition.

▶ **INTERNATIONAL PERSPECTIVES**

The Impact of Extremes in Outdoor Temperature and Sunshine Exposure on Birth Weight

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Abstract **Following the "fetal origins of adult disease" hypothesis, environmental determinants of birth weight regained interest. The authors applied a detailed spatial-time exposure model for climatological factors thought to affect fetal growth: seasonality, temperature, and sunshine. Daily climatological data (29 stations) were linked to 1,460,401 term births with an individual exposure matrix for each pregnancy. Linear regression was utilized to determine effects of climatological factors on individual birth weight and existing spatial variations in birth weight. In the Netherlands substantial regional climatological differences exist. Summer was associated with significantly reduced birth weight (16–19 g). Minimum and maximum temperatures were significantly associated with increased and reduced birth weight, respectively. Spatial birth weight differences ranged from -11 to +25 g, with lowest birth weights in inland areas. The authors demonstrate birth weight to be associated with climatological factors; negative birth weight effects of maximum temperature exposure confirm results from animal studies. Consequently, a climate footprint is visible in the spatial birth weight differences.**

Introduction

Over 2,000 years ago, Hippocrates had already postulated effects of "warm and cold winds, seasons, and changes in weather" on health (Hippocrates, 1978). Currently, a large body of evidence exists on the effects of seasonality, ambient temperature, and sunshine exposure on adult health (Bhaskaran et al., 2012; Lambert, Reid, Kaye, Jennings, & Esler, 2002; Seretakis et al., 1997). Next to adult health, many studies have also focused on exposure to climatological factors in the intrauterine period coinciding with the advent of the "fetal origins of adult disease" hypothesis (Barker, 2006; Strand, Barnett, & Tong, 2011). In this context, specifically cli-matological determinants of birth weight are of renewed interest as new modifiable factors might be identified. In line with the "Barker hypothesis" (Barker, 2006) these factors might be useful for the development of strategies that prevent possible disease in later life (Lawlor, Leon, & Davey Smith, 2005; Murray et al., 2000; Pereira, Cook, Haggar, Bower, & Nassar, 2012; Strand et al., 2011; Torche & Corvalan, 2010).

Seasonality, ambient temperature, and sunshine appear the most likely climatological factors to influence birth weight (Lawlor et al., 2005; Murray et al., 2000; Pereira et al., 2012; Strand et al., 2011; Torche & Corvalan, 2010). Studies show inconsistent results, however, due to differences in methodology and study size, little or no adjustment for known confounders, and considerable differences in exposure definitions (Lawlor et al., 2005; Murray et al., 2000; Pereira et al., 2012; Strand et al., 2011; Torche & Corvalan, 2010). As a result, no universal exposure concept has emerged. Most studies use mean temperature during pregnancy as the exposure measure (Lawlor et al., 2005; Murray et al., 2000; Pereira et al., 2012; Strand et al., 2011; Torche & Corvalan, 2010), while extremes during heat and cold waves are of particular interest as they increase cardiovascular mortality in adult deaths through blood flow changes (Huynen, Martens, Schram, Weijenberg, & Kunst, 2001). In contrast for sunshine, cumulative rather than peak exposure is of interest as it is thought that its effect runs mainly through vitamin D (Urrutia & Thorp, 2012).

Here, we study the impact of temperature extremes and cumulative sunshine on birth weight, distinguishing among five exposure windows: periconceptional; in the first, second, and third trimesters of pregnancy; and the day of delivery. We obtained geographically detailed climatological data that permitted us to compute day-to-day individual exposure patterns. The impact of climatological factors on birth weight was then studied using an individual exposure model, taking into account the association between temperature and sunshine exposure, and the competing impact of other factors influencing birth weight (Wilcox, 2010). The resulting temporal-spatial relations were mapped to demonstrate the contribution of the selected climatological factors to existing regional differences in birth weight.

Map of the Netherlands With the 29 Temperature Stations and Their Catchment Areas in Shades of Grey

Methods

Patient Data

In this retrospective cohort study we derived data on maternal factors and child factors from the Netherlands Perinatal Registry. This registry contains complete population-based information of >97% of all pregnancies in the Netherlands (Netherlands Perinatal Registry, 2011). Source data are collected during routine care by 94% of midwives, 99% of gynecologists, and 68% of pediatricians including 100% of neonatal intensive care unit pediatricians (www.perinatreg.nl) (Netherlands Peri-

natal Registry, 2011). The basis of the Netherlands Perinatal Registry has been extensively described (Tromp, Meray, Ravelli, Reitsma, & Bonsel, 2005). Furthermore, the registry has been used in several recent studies (de Jonge et al., 2013; von Schmidt auf Altenstadt, Hukkelhoven, van Roosmalen, & Bloemenkamp, 2013). Data used for our study were collected between January 2000 and December 2008 (N = 1,620,126 births). We excluded multiple pregnancies (n = 35,326), births with gestational age < 37 weeks or unknown (n = 116,139), births with unknown parity or neonate's sex (n = 353 and n = 433, respec-

tively), and unknown or erroneous zip code (n = 7,474). The final database consisted of 1,460,401 births.

Climatological Data

Daily maximum and minimum temperatures (in ºC) and sunshine (in hours) were derived from 29 temperature stations throughout the Netherlands (Figure 1). The catchment area of each temperature station was based on two-digit zip codes with an average population of 182,228 per zip code area. Data were obtained from the Royal Netherlands Meteorological Institute (www.knmi.nl/index_en.html).

Exposure Concept

From past evidence and biological considerations (reproductive windows) (Lawlor et al., 2005; Murray et al., 2000; Pereira et al., 2012; Strand et al., 2011; Torche & Corvalan, 2010), we derived five exposure windows with a minimal overlap between E1 and E2 (Figure 2):

- from three days before to three days after conception, periconceptional (E1);
- from conception to 91 days (0–13 weeks) after conception, first trimester (E2);
- from 92 days to 182 days (13–26 weeks) after conception, second trimester (E3);
- from 183 days to 273 days (26–39 weeks) after conception, third trimester (E4); and
- day of birth (E5).

Usually, the periconceptional period is defined as four weeks before and eight weeks after conception. As we assumed an acute effect (if any) of temperature extremes specifically, we used a window of three days before and three days after conception.

Climatological exposure was defined as follows: seasonality (captured by month of birth), the daily measurement of minimum and maximum temperature (with no consideration of humidity), individually calculated for each exposure window (E1–E5), and total sunshine exposure (in hours) individually calculated for windows E2–E4.

The computation of exposure started with determining date of conception, which was estimated from recorded information on gestational age at birth and date of delivery. The climatological exposure information was subsequently projected on each pregnancy individually for E1 to E5, providing an individual exposure profile for each woman. Climate data were linked to individual records

using the zip code. Date of delivery (a consecutive number from 1 to 3,288 for every day in the study period) was used as a variable to capture the secular trend of increasing birth weight (Murray et al., 2000).

Although seasonality was captured by month of birth, for convenience we mention seasons in some parts of this article: winter (January, February, March), spring (April, May, June), summer (July, August, September), and autumn (October, November, December).
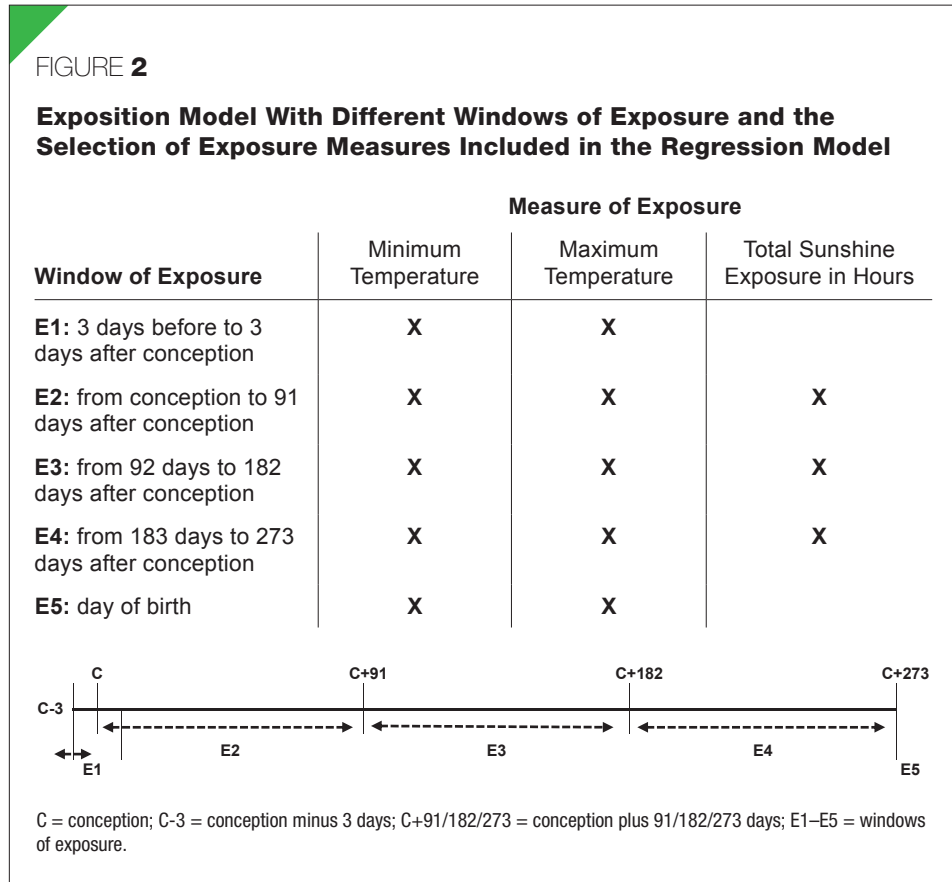
Definition of Outcome and Maternal and Child Factors

The main outcome was birth weight in grams. Known maternal and child factors affecting birth weight were also included. Maternal factors were parity (primiparous/multiparous), ethnicity (western/non-western), maternal age (continuous), and socioeconomic status (SES) score based on zip code of residence. Since the effect of maternal age on birth weight appears to be inverse U-shaped (reduced birth weight for the youngest and oldest mothers), we used the quadratic value of maternal age as determinant. As a proxy for neighborhood SES we used zip-code-specific (publicly available) SES scores, which are made available by the National Statistics Office (Web site in Dutch: www.scp.nl/Organisatie/Onderzoeksgroepen/Wonen_Leefbaarheid_Veiligheid/Lopend_onderzoek_van_WLV/Statusscores). These SES scores are zip code based and use individual data on, e.g., income, taxes, hours of work, and educational level. The scores are approximately normally distributed at the neighborhood level, where a negative score represents a high SES.

Child factors were gestational age (six categories), presence of congenital anomalies (yes/no), and neonate's sex (male/female).

Analysis

Linear regression models were specified in a predefined order. First, all maternal and child factors and consecutive number of day of birth were included as determinants (model 0). Next, season (month of birth) was added (model 1). In models 2 and 3, the temperature and sunshine exposure measures were then added. Subsequently, we aimed to study regional differences in mean birth weight attributable to our climatological exposure measures using a methodology from a previous study (Poeran et al., 2014). We did so by studying the birth weight difference between a dataset in which

Exposition Model With Different Windows of Exposure and the Selection of Exposure Measures Included in the Regression Model

Window of Exposure	Measure of Exposure		
	Minimum Temperature	Maximum Temperature	Total Sunshine Exposure in Hours
E1: 3 days before to 3 days after conception	X	X	
E2: from conception to 91 days after conception	X	X	X
E3: from 92 days to 182 days after conception	X	X	X
E4: from 183 days to 273 days after conception	X	X	X
E5: day of birth	X	X	

C = conception; C-3 = conception minus 3 days; C+91/182/273 = conception plus 91/182/273 days; E1–E5 = windows of exposure.

we allowed for the actual regional climatological differences (original dataset) and a dataset in which we (hypothetically) "eliminated" this regional difference by substituting the minimum and maximum temperature and sunshine exposition by the national average, all other things equal (duplicate dataset). We used coefficients obtained from model 3 to predict mean birth weight in this duplicate dataset. The resulting regional differences (in grams) between observed mean weight (including the effect of climatological factors) and predicted mean weight (excluding the effect of climatological factors) are attributable to climatological factors and are illustrated on a map of the Netherlands per two-digit zip code. Because of the cancellation of the effect of climatological factors in the duplicate dataset, the difference in mean weight between the original and duplicate dataset represents the regional differences in birth weight that are attributable to the selected climatological factors.

The linear regression models were fitted using SPSS version 20. SAS version 9.2 was used with the GLM procedure to run model 3 and use its coefficients to predict birth weight

in a duplicate dataset. Maps were constructed using ESRI ArcGIS version 9.3.

Results

Table 1 illustrates study population characteristics, differences between subgroup mean birth weight and overall mean birth weight, and small for gestational age (SGA) prevalence per subgroup (SGA, birth weight <10th percentile). Subgroups with a significantly reduced mean birth weight are women who are primiparous (-88 g), <20 years (-197 g), non-western origin/background (-92 g), with a low SES (-56 g); and children who are born between 37 and 39 weeks of gestational age (-473 to -67 g), who have congenital anomalies (-97 g), and are female (-70 g). SGA prevalence was highest in teenage pregnancies (maternal age <20 years, 14.1%), non-western women (13.5%), low SES women (12.2%), and children born with a congenital anomaly (16.1%).

Differences in Temperature and Sunshine Exposure by Region

Table 2 illustrates the regional and within-year variation in temperature and sunshine expo-

Study Group Characteristics: Subgroup Sizes, Subgroup Mean Birth Weight Differences With Overall Mean Birth Weight, and Subgroup Small for Gestational Age (SGA) Prevalence (%)

Characteristic	#	Mean Subgroup Birth Weight–Mean Overall Birth Weight[a]	SD	% SGA
Maternal Factors				
Parity				
Primiparous	660,797	-88	485	9.7
Multiparous	799,604	73	500	9.8
Maternal age				
<20 years	23,594	-197	469	14.1
20–35 years	1,226,233	-2	497	9.6
>35 years	210,574	32	516	10.3
Ethnicity				
Western	1,225,392	18	500	9.0
Non-western	235,009	-92	490	13.5
Socioeconomic status[b]				
Low (<p20)	365,558	-56	504	12.2
Medium (p20–p80)	842,290	15	499	9.2
High (>p80)	252,553	33	490	8.2
Child Factors				
Gestational age				
37 weeks	87,505	-473	488	9.8
38 weeks	221,349	-237	468	9.8
39 weeks	361,621	-67	450	9.8
40 weeks	428,778	85	453	9.7
41 weeks	281,509	210	466	9.8
≥42 weeks	79,639	282	476	9.7
Congenital anomalies				
No	1,430,003	2	498	9.6
Yes	30,398	-97	581	16.1
Sex				
Male	746,603	67	505	9.7
Female	713,798	-70	485	9.8
Year of birth				
2000–2002	501,459	-14	501	10.3
2003–2005	488,010	5	501	9.7
2006–2008	470,932	9	497	9.1

[a]Mean overall birth weight = 3,522 g, with SD = 500 g.
[b]Status scores were cut off at the 20th (low socioeconomic status) and 80th (high socioeconomic status) percentile.

sure in the Netherlands. For convenience we listed temperature and sunshine exposure overall, and for three temperature stations separately: "de Kooy," "de Bilt," and "Maastricht" located in the north, middle, and south of the Netherlands, respectively. As expected, temperatures are highest in summer and lowest in winter. Sunshine exposure is highest in May/June and lowest in December/January.

A difference of 1°C exists between the northern (higher in January) and the southern temperature stations (higher in July). In the north, the temperature extremes appear smaller, with more sunshine, particularly in July with a difference of almost an hour per day (7.4–6.6 = 0.8 hours).

Linear Regressions
Table 3 lists the linear regressions. In model 0 all determinants have a significant contribution to the model with the largest beta coefficients for primiparous women (-169.8, confidence interval [CI] -171.3, -168.4), children born at 37 weeks (-552.3, CI -555.5, -549.1) and 38 weeks (-324.1, CI -326.4, -321.9), and female sex (-145.8, CI -147.2, -144.3). In model 1, month of birth was added but did not alter the beta coefficients of maternal and child factors. No clear pattern in beta coefficients of month of birth was observed. Temperature exposure measures were added in model 2. A clear pattern in months emerged with a highly significant birth weight nadir in summer: -18.4 g reduced birth weight in July and -18.5 g in August. Beta coefficients for temperature exposure measures were small. For minimum temperature only exposures during first, second, and third trimester were significant with beta coefficients ranging from -0.6 to 1.5. For maximum temperature all exposure windows had significant beta coefficients ranging from 0.4 (day of birth) to -2.2 (second trimester). After adding sunshine exposure to model 3, the summer nadir remained significant, but with moderation of beta coefficients to -9.3 for July and -11.1 for August. Sunshine exposure demonstrated small yet significant effects (beta coefficients 0.023 to 0.052). As opposed to the emerging pattern of seasonality in model 2, no further differences existed among the models, implying combined (interacting) effects of temperature and sunshine with seasonality.

Regional Birth Weight Differences
The regional birth weight differences ranged from -11 to +25 g due to the selected climatological exposures, with moderation of these effects (i.e., increased birth weights) in coastal areas (Figure 3).

Discussion
Birth weight is associated with the combined effect of season and exposure to temperature extremes and cumulative exposure to sunshine. We demonstrated small yet consistent effects on top of known maternal and child factors. The effects of seasonality alone were initially modest (Table 3, model 1) but most likely hid interacting effects of temperature

and sunshine, illustrated by the clear pattern in seasonality after inclusion of temperature and sunshine in the model (Table 3, model 2 and 3). The result was an almost 20 g significantly reduced birth weight in summer months compared to January. We found minimum temperature exposure in the second and third trimester to be associated with increased birth weight, maximum temperature exposure for all exposure windows to be associated with reduced birth weight, and cumulative sunshine exposure to be associated with an increased birth weight.

On the population level, significant regional differences occurred in birth weight, attributable to the selected climatological exposure measures, ranging from -11 to +25 g (relative to the observed birth weight). The detrimental effect of maximum temperature in particular appears to be moderated in coastal areas where fewer temperature extremes and more sunshine hours exist. The superposition of the observed effects with differential timing of exposure explains the hitherto unexplained or contradictory patterns in previous studies (Strand et al., 2011).

Strengths and Limitations
An important strength of our study is the usage of a validated national database (the Netherlands Perinatal Registry) with an almost complete coverage of all pregnancies over a long period of time (2000–2008), and detailed climatological data from a nationwide network of 29 temperature stations, increasing the precision and generalizability of our results. Moreover, the relatively moderate Dutch climate (with no real extremes) and the cohort of only term births minimize the possibility of our results being driven by a few cases. Additionally, in comparison with previous studies, our study model included an individual exposition model covering the whole duration of pregnancy including the periconceptional period (Lawlor et al., 2005; Murray et al., 2000; Pereira et al., 2012; Seretakis et al., 1997; Strand et al., 2011; Torche & Corvalan, 2010). Other strengths include the use of sunshine exposure, as most studies do not include this in their model, and the adjustment for SES. The latter is important because with lower SES and poor housing quality it is less likely that a home and a person are in a temperate environment.

One of the most important limitations of our study refers to the time from exposure to out-

come, i.e., in utero exposure and birth weight several months later. We unfortunately did not have information on intrauterine fetal growth, which ideally would have been obtained from ultrasound measurements. Its value may be limited, however, as these measurements have wide confidence intervals.

Another limitation regarding our analysis is that, in line with our hypothesis, we expected independent effects of temperature and sunshine exposure and adjusted for both. As these could be correlated, however, it would have been interesting to study several other sequential additions of climatological factors to the linear regression models, e.g., first adding sunshine to the models and then month of birth and temperature expo-

sures. As this would have easily resulted in an excess of information we decided to show only the orders in line with our hypothesis.

The same limitation refers to the effects of minimum and maximum temperature exposures. Although we included data on several measures of climatological exposure, we did not have data on other potentially important measures such as temperature change, humidity, or other pollutants. Similar to most previous studies, another limitation is that outdoor temperature does not reflect the true exposition as a significant amount of time is spent indoors, especially at times of extreme temperature in winter.

Another potential source of error is a person's mobility as climatological data linked to

TABLE 2

Monthly Differences of Temperature (ºC) and Sunshine

Month/Station	Mean Day Temperature	Minimum Day Temperature	Maximum Day Temperature	Mean Day Sunshine Hours
Temperature station: All				
Month				
January	4.2	-16.8	15.9	2.2
February	4.2	-15.4	18.0	3.5
March	6.2	-20.7	22.2	4.4
April	9.6	-7.9	29.7	6.4
May	13.6	-1.5	32.6	7.2
June	16.1	0.9	34.7	7.3
July	17.9	3.7	37.1	6.8
August	17.7	4.4	37.8	6.0
September	15.3	0.5	31.3	5.3
October	11.2	-8.5	24.0	4.0
November	7.4	-7.2	19.4	2.2
December	4.0	-17.0	16.3	1.9
Temperature station: "de Kooy"				
Month				
January	4.8	-8.5	12.2	2.3
July	17.5	8.4	30.2	7.4
Temperature station: "de Bilt"				
Month				
January	4.3	-10.6	14.1	2.1
July	18.1	6.4	35.7	6.6
Temperature station: "Maastricht"				
Month				
January	3.9	-11.7	15.5	2.2
July	18.5	7.2	36.3	6.6

Note: Monthly differences of temperature and sunshine overall and for three temperature stations separately: "de Kooy," "de Bilt," and "Maastricht" located in the north, middle, and south of the Netherlands, respectively.

TABLE 3

Linear Regression Models With Regression Coefficients With 95% Confidence Intervals

Characteristic	Model 0	Model 1	Model 2	Model 3
	Beta Coefficient	Beta Coefficient	Beta Coefficient	Beta Coefficient
Constant	3903.9 (3900.9, 3907.0)*	3900.0 (3896.1, 3903.8)**	4049.2 (4035.7, 4062.6)*	4019.0 (4004.0, 4033.9)*
Maternal factors				
Parity				
Primiparous	-169.8 (-171.3, -168.4)*	-169.8 (-171.3, -168.3)*	-169.9 (-171.4, -168.4)*	-169.9 (-171.4, -168.4)*
Multiparous	Reference	Reference	Reference	Reference
Maternal age^2	-0.17 (-0.18, -0.16)*	-0.17 (-0.18, -0.16)*	-0.17 (-0.18, -0.16)*	-0.17 (-0.18, -0.16)*
Ethnicity				
Western	Reference	Reference	Reference	Reference
Non-western	-90.0 (-92.1, -87.9)*	-90.0 (-92.1, -87.9)*	-91.0 (-93.1, -88.9)*	-91.4 (-93.5, -89.3)*
Socioeconomic status score	-17.9 (-18.6, -17.1)*	-17.9 (-18.6, -17.1)*	-18.1 (-18.8, -17.3)*	-18.0 (-18.7, -17.2)*
Child factors				
Gestational age				
37 weeks	-552.3 (-555.5, -549.1)*	-552.3 (-555.5, -549.0)*	-552.2 (-555.4, -549.0)*	-552.2 (-555.4, -549.0)*
38 weeks	-324.1 (-326.4, -321.9)*	-324.1 (-326.4, -321.8)*	-324.1 (-326.4, -321.8)*	-324.1 (-326.4, -321.8)*
39 weeks	-152.5 (-154.4, -150.5)*	-152.5 (-154.4, -150.5)*	-152.4 (-154.4, -150.4)*	-152.4 (-154.4, -150.5)*
40 weeks	Reference	Reference	Reference	Reference
41 weeks	127.7 (125.6, 129.8)*	127.7 (125.6, 129.8)*	127.6 (125.5, 129.8)*	127.6 (125.5, 129.7)*
≥42 weeks	218.4 (215.0, 221.8)*	218.4 (215.0, 221.8)*	218.5 (215.1, 221.8)*	218.4 (215.1, 221.8)*
Congenital anomalies				
No	Reference	Reference	Reference	Reference
Yes	-74.6 (-79.6, -69.5)*	-74.6 (-79.6, -69.5)*	-74.3 (-79.4, -69.3)*	-74.3 (-79.3, -69.2)*
Sex				
Male	Reference	Reference	Reference	Reference
Female	-145.8 (-147.2, -144.3)*	-145.8 (-147.2, -144.3)*	-145.7 (-147.2, -144.3)*	-145.7 (-147.2, -144.3)*
Climatological factors				
Day of birth: consecutive number in study period	0.010 (0.009, 0.010)*	0.010 (0.009, 0.010)*	0.010 (0.010, 0.011)*	0.009 (0.009, 0.010)*
Month of birth	Not in equation			
January	-			
February	-	2.4 (-1.2, 6.0)	-1.3 (-5.4, 2.8)	-0.3 (-4.4, 3.8)
March	-	4.0 (0.5, 7.5)***	-4.4 (-9.3, 0.6)	-2.0 (-7.1, 3.1)
April	-	5.6 (2.0, 9.1)**	-6.0 (-12.0, -0.1)***	-1.5 (-7.7, 4.7)
May	-	6.7 (3.2, 10.2)*	-8.3 (-15.0, -1.6)***	-1.3 (-8.4, 5.7)
June	-	5.2 (1.7, 8.8)**	-16.1 (-23.3, -8.9)*	-7.5 (-15.2, 0.2)
July	-	6.2 (2.8, 9.7)*	-18.4 (-25.5, -11.2)*	-9.3 (-17.0, -1.5)***
August	-	3.0 (-0.5, 6.5)	-18.5 (-25.5, -11.4)*	-11.1 (-18.7, -3.6)**
September	-	3.7 (0.2, 7.2)***	-15.1 (-21.6, -8.6)*	-10.5 (-17.3, -3.6)**
October	-	4.1 (0.6, 7.6)***	-6.1 (-11.6, -0.6)***	-3.5 (-9.3, 2.3)
November	-	5.9 (2.3, 9.4)**	3.5 (-1.3, 8.3)	5.4 (0.4, 10.4)***
December	-	0.4 (-3.1, 4.0)	-0.4 (-4.6, 3.8)	0.3 (-4.0, 4.5)
Minimum temperature: window of exposure	Not in equation	Not in equation		
E1: periconceptional	-	-	0.3 (0.0, 0.6)	0.2 (-0.1, 0.6)
E2: first trimester	-	-	-0.6 (-1.1, -0.2)**	-0.3 (-0.8, 0.1)
E3: second trimester	-	-	0.6 (0.3, 1.0)**	0.4 (0.0, 0.8)***
E4: third trimester	-	-	1.5 (1.3, 1.8)*	1.5 (1.2, 1.7)*
E5: day of birth	-	-	0.1 (-0.2, 0.4)	0.1 (-0.2, 0.4)

TABLE **3**   *continued from page 97*

Linear Regression Models With Regression Coefficients With 95% Confidence Intervals

Characteristic	Model 0	Model 1	Model 2	Model 3
	Beta Coefficient	Beta Coefficient	Beta Coefficient	Beta Coefficient
Maximum temperature: window of exposure	Not in equation	Not in equation		
E1: periconceptional	-	-	-0.6 (-0.9, -0.3)*	-0.4 (-0.8, -0.1)**
E2: first trimester	-	-	-1.6 (-1.9, -1.2)*	-2.1 (-2.4, -1.7)*
E3: second trimester	-	-	-2.2 (-2.5, -1.9)*	-2.4 (-2.8, -2.0)*
E4: third trimester	-	-	-2.0 (-2.3, -1.7)*	-2.1 (-2.5, -1.8)*
E5: day of birth	-	-	-0.4 (-0.7, -0.2)**	-0.4 (-0.6, -0.1)**
Cumulative sunshine in 0.1 hours: window of exposure	Not in equation	Not in equation	Not in equation	
E2: first trimester	-	-	-	0.052 (0.039, 0.065)*
E3: second trimester	-	-	-	0.025 (0.011, 0.038)**
E4: third trimester	-	-	-	0.023 (0.010, 0.036)**

*$p < .0001$.
**$p > .0001$ and $p < .01$.
***$p > .01$ and $p < .05$.

a person's zip code of residence may compromise the exposure estimate. Inaccuracy resulting from the first underestimates the individual exposure to temperature extremes with underestimation of the true peak temperature effect. The second inaccuracy may yield an under- or overestimation on the individual level without obvious systematic effects in general. Despite this error and the generally temperate Dutch climate, a consistent effect remains.

Other limitations refer to the nature of our dataset with individual births as the primary unit. Although births from the same mother are correlated we unfortunately could not tease out this information for which a mixed model analysis with a random intercept would have been more appropriate. A last limitation is the lack of data on maternal factors affecting birth weight such as maternal (prepregnancy) weight or smoking. By excluding preterm births and taking into account SES, however, both strongly related to maternal smoking, we attempted to reduce the effects of this limitation.

Comparison With Previous Studies
Previous studies on the relationship between climate and birth weight are heterogeneous in design and outcome (Lawlor et al., 2005; Murray et al., 2000; Pereira et al., 2012; Strand et al., 2011; Torche & Corvalan, 2010). In

an Australian large cohort study in the Perth region, Pereira and co-authors (2012) investigated the effect of seasonal variation, temperature, and sunshine on birth weight adjusted for sociodemographic, biological, and environmental exposures (e.g., air pollutants, temperature, and sunshine). Effects were studied separately by trimester. Analogous to our findings, they report a 2% significantly increased risk of SGA by higher temperatures sustained over pregnancy; this risk for reduced birth weight was particularly observed for exposition to higher temperatures during the third trimester. The main differences compared to our study include the use of only maximum temperature, exposure data from just two temperature stations, and the inclusion of births from 33 weeks of gestational age, leading to incomplete exposure windows for the third trimester (Pereira et al., 2012).

Although an inverse relation of heat stress on birth weight has been observed in several studies (Lawlor et al., 2005; Pereira et al., 2012; Wells & Cole, 2002), the opposite (i.e., heat stress causing increased birth weight) has also been demonstrated (Lawlor et al., 2005; Murray et al., 2000). Probably due to heterogeneity in study design, most of these studies did not find consistent directions of effect measures for all exposure windows, e.g., one study found a negative effect of first trimester

temperature exposure on birth weight (beta coefficient -5.4, 95% *CI* -7.9, -2.9), and a positive effect of third trimester temperature exposure on birth weight (beta coefficient 1.3, 95% *CI* 0.5–2.1) (Lawlor et al., 2005).
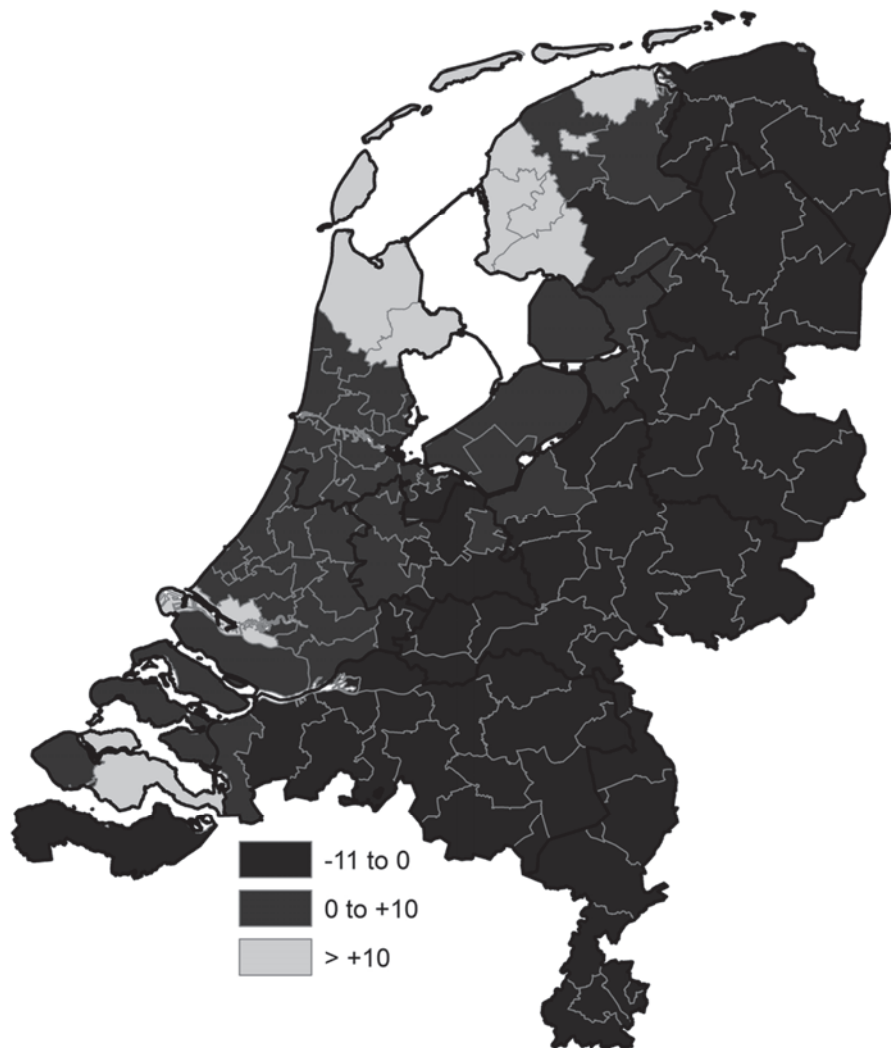
Possible Mechanisms
Animal studies provide a biological explanation for part of our findings as they show heat stress during pregnancy to be associated with reduced placental weight, reduced uterine and umbilical blood flow, and consequent reduction in offspring birth weight (Wells, 2002). Galan and co-authors (1999) exposed pregnant ewes to heat stress (35°C–40°C versus 20°C for controls) during pregnancy for 55 days (mean birth weight 1,841 g) and 80 days (mean birth weight 882 g). They observed a significant reduction in fetal and placental weights compared with a control group (mean birth weight 3,391 g) (Galan et al., 1999). The maximum temperatures—not the duration—were comparable to the exposure in our study. In terms of the "fetal origins of adult disease" hypothesis (Barker, 2006), our findings combined with findings from these animal studies may demonstrate some form of adaptation mechanism regarding the expected outdoor climate after birth.

Several theories exist on the background of our observed results. According to one, fetal

Regional Birthweight Differences (per Two-Digit Zip Code) Attributable to Difference in Exposure to Temperature Extremes and Sunshine

Adjusted for maternal factors, child factors, and day and month of birth.

growth is influenced by the rate of utero-placental blood flow. Extremes of temperature, in particular heat, are known to affect human blood flow with excess cardiovascular deaths occurring in heat waves (Huynen et al., 2001). It is therefore plausible that maternal blood flow and therefore fetal nutrition will be affected by these extremes in different stages of pregnancy. It is also possible that outdoor temperature during pregnancy or seasonality is linked to maternal behaviors including smoking, diet, and physical activity. In particular smoking may have contributed to the summer reduction in birth weight as it has a profoundly negative effect on birth weight, and tobacco consumption in general has been shown to peak in summer (Andres & Day, 2000; Warren et al., 2012).

Inherent to sunshine, vitamin D has also been mentioned as a possible causal factor. Its production depends primarily on the action of sunlight on the skin and therefore it is strongly associated with the duration of sunshine (Leffelaar, Vrijkotte, & van Eijsden, 2010; Urrutia & Thorp, 2012). A 2010 Dutch study found women with deficient vitamin D levels in early pregnancy (median 13 weeks' gestation) to be at increased risk for an infant with reduced birth weight (-114.4 g, 95% *CI* -151.2, -77.6) and SGA (Leffelaar et al., 2010). Vitamin D deficiency is more prevalent during the winter months. Women with the end of the first trimester in winter will deliver during late spring and summer, and, according to this hypothesis, will have children with reduced birth weight as demonstrated in our results.

Implications

Climatological factors impact birth weight on the individual level, the effect of which emerges as regional differences in birth weight on the population level. For healthy babies born at term the demonstrated differences appear small and effects on health later in life are unlikely. More detrimental effects may emerge for vulnerable subgroups (e.g., women carrying growth-restricted babies) implying future research in these groups. The birth weight effects on the population level may be also more sizeable in countries where the population is truly exposed to extremes. The World Health Organization (WHO) recommends an indoor temperature of 18°C, or 21°C for vulnerable people (WHO, 1985); as it is impossible to change the climate, improving housing quality to moderate exposure to extremes in temperature appears a realistic implication for vulnerable subgroups.

Conclusion

Birth weight is associated with the combined effect of season and exposure to temperature extremes and cumulative exposure to sunshine. The effect of seasonality appears to be mediated by interacting effects of temperature and sunshine, resulting in an almost average 20 g significantly reduced birth weight in summer months compared to January. On the population level, significant regional differences in birth weight exist, most likely attributable to maximum temperatures in particular, with moderation of the effect in coastal areas. For healthy babies born at term these differences in birth weight appear small; however, more severe detrimental effects may emerge for vulnerable subgroups, e.g., women carrying growth-restricted babies. In terms of Barker's "fetal origins of adult disease" hypothesis, our findings combined with findings from animal studies may demonstrate some form of adapta-

tion mechanism regarding the expected outdoor climate after birth. ◐◐

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▶ **INTERNATIONAL PERSPECTIVES/SPECIAL REPORT**

Radon Risk Communication Strategies: A Regional Story

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Abstract   **Risk communication on the health effects of radon encounters many challenges and requires a variety of risk communication strategies and approaches. The concern over radon exposure and its health effects may vary according to people's level of knowledge and receptivity. Homeowners in radon-prone areas are usually more informed and have greater concern over those not living in radon-prone areas. The latter group is often found to be resistant to testing. In British Columbia as well as many other parts of the country, some homes have been lying outside of the radon-prone areas have radon levels above the Canadian guideline, which is the reason Health Canada recommends that all homes should be tested.**

Over the last five years, the Environment Health Program (EHP) of Health Canada in the British Columbia region has been using a variety of different approaches in their radon risk communications through social media, workshops, webinars, public forums, poster contests, radon distribution maps, public inquiries, tradeshows and conference events, and partnership with different jurisdictions and nongovernmental organizations. The valuable lessons learned from these approaches are discussed in this special report.

Introduction

Risk communication is a shared interest of policy makers and stakeholders. Many agree that communicating risk to the public is a complicated undertaking and it poses formidable challenges (Johnson & Fisher, 2006; Lipkus & Hollands, 1999). One of the key communication challenges with radon has to do with public apathy (Sandman, 1986). Contrary to technological hazards such as radioactive contamination or toxic wastes, public perception of radon risk represents an optimistic bias (Weinstein, Klotz, & Sandman, 1988). Another communication challenge stems from the fact that radon occurs naturally, thus no "villain" exists to blame and not many obvious radon "victims" are observed (Fisher & Johnson, 1990). In fact, any harmful health effects of radon often do not show up for a long time.

Radon exposure occurs primarily in a person's home, and thus it is an individual's responsibility to test and mitigate for radon. The nature of this situation rules out conven-tional regulatory approaches that are used in managing pollution sources (Desvousges, Smith, & Rink, 1989). For this reason, regulatory bodies turn to information programs as a way of communicating risk and encouraging voluntary reductions in risk (Johnson & Fisher, 2006). The perception of radon as a "low-risk problem" is attributable to multiple factors that include the absence of federal regulations, competing environmental concerns presented daily in the media, concerns about home values, and public apathy (Johnson, Fisher, Smith, & Desvousges, 2010).

The Environmental Health Program (EHP) of Health Canada in the British Columbia region has been using a diverse approach in their communication of radon risks, which includes responses to public inquiries, trade shows and conference events, social media, workshops, webinars, public forums, radon poster contests for students, and radon distribution maps creation. Radon risk communication efforts through EHP has benefited from partnerships with different jurisdictions and nongovernmental organizations, which aid in adding strength and credibility to the message. This special report presents the lessons learned from radon testing in federal buildings as well as education and awareness activities for the public in the British Columbia region. In particular, it presents knowledge of the public's misconceptions of radon risk and the strategies that are used to "demystify" them. The myths identified for discussion here were the result of the experiences in education and awareness activities, as well as through literature reviews and case studies.

Strategies to Demystifying the Radon Myth

Myth 1: Radon should remain low on the scale of concern for the public. Radon does not seem to cause any visible health effects. There are no obvious "dead bodies," and lung cancer caused by radon exposure, if it occurs, will not be for many years (Fisher & Johnson, 1990; Radon Prevention and Mediation [RADPAR], 2011; World Health Organization [WHO], 2009). Such human perceptions present considerable challenges to the design of an effective risk communication strategy in overcoming public apathy towards radon.

Health Canada estimates that indoor radon exposure causes the deaths of approximately 3,200 Canadians every year—16% of all lung cancer deaths (Health Canada, 2012a). Thus, it makes radon the second cause of lung cancer after smoking (Health Canada, 2012b). Radon is the largest source of natural radiation exposure (Canadian Nuclear Safety Commission [CNSC], 2013), as it represents over 30% of the naturally occurring radiation people are exposed to in a lifetime (CNSC, 2011). In addition, one in three people who have had long-term exposure to elevated radon levels and tobacco smoke will be diagnosed with lung cancer (Health Canada, 2012c). Overall, the number of radon-related deaths in Canada from lung cancer is about 25% higher than the number of traffic-related deaths and greatly exceeds the number of deaths due to accidental poisoning and homicides (Statistics Canada, 2009). According to the Canadian Cancer Statistics 2013 report released by the Canadian Cancer Society, the Public Health Agency, and Statistics Canada, British Columbia has 139 cancer deaths per 100,000 population (9,700 deaths in the total population), with the leading cause of cancer death being lung cancer. Thus, with respect to Myth 1, the use of statistical or quantitative information in risk communications is needed to raise public concern over radon exposure and its health risks.

Myth 2: The perception is that indoor radon exposures are natural, therefore, people should have no or little control (RADPAR, 2011). This statement is not correct. While sources of radon are ultimately geological and natural, high indoor radon exposures may not be. Indoor radon levels can be considered artificial (or "technologically enhanced") if they are the consequence of human activities such as building design, construction, and usage (RADPAR, 2011). In addition, indoor radon concentrations can be easily measured; if they are found to be high they can be reduced. Therefore people do have control if they choose to take preventative action.

Elevated levels of radon can be attributable to human activities, particularly when a building has been upgraded with energy efficient measures therefore making it "airtight." In one example, the owners of a 110-year old house in Peachland, British Columbia (a radon-rich area), conducted a six-month radon test in various areas of their home (Paterson, 2012). When the log house was "sealed" for energy conservation and refitted with double-glazed windows, the radon levels were found to increase substantially. In certain areas of the house, levels of the radioactive gas were as high as 2,035 Bq/m^3 (55 picocuries/L). Both the main floor and upper floor were measured to be above 1,000 Bq/m^3 in the winter months. The owners subsequently contracted a radon mitigation specialist to reduce the radon levels in the house.

Elevated radon ingress can be due to the structure of the building as well as the operational activities that take place within it. This was the case at a fish hatchery, in a non-radon-rich area. Various buildings at the site that met Health Canada's testing criteria of occupancy (>4 hours per day) were tested. All buildings tested at the site were found to be below Health Canada's guideline level except the offices right below a water aeration tower, which had radon levels at approximately 1,100 Bq/m^3. The office building with a water aeration tower had a rather unique structure in that the aeration tower was constructed on top of the administration office that was found to have high levels of radon. It was noted that well water from two aquifers was supplied to the aeration tower. The water was then allowed to fall from a height through a series of segmented columns. The purpose of this was to dissipate undesirable gases (such as nitrogen) and add oxygen to the water prior to being used for hatchery purposes. According to a radon report of WorkSafe BC (Copes, 2009), "Land-based fish hatcheries normally use large quantities of water that has come from an underground source. Hatcheries having the aeration tower contained within the building envelope are particularly prone to having the highest radon levels." It has been reported that radon levels in groundwater can generate up to 40 times more radon in indoor air at a commercial fish hatchery (Kitto, Kunz, McNulty, Kuhland, & Covert, 1995).

The aforementioned scenarios reveal how building structures and human activities may contribute to high levels of radon. They enhance our knowledge base through experience, and serve as narrative or qualitative information for risk communication. To demystify Myth 2 in risk communication, it is paramount to underscore that while sources of radon are naturally occurring, high indoor radon exposures can be due to human activities. Thus, the concentration of radon may vary widely from house to house, building to building, and may be contingent upon "the human factor." When it is claimed that radon occurs naturally, the human component that influences exposure to radon should also be mentioned. More importantly the human component that can prevent the risk of radon exposure should be emphasized; it is easy and inexpensive to test and if levels are high they can be reduced by a mitigation specialist.

Myth 3: Testing is expensive and the house value will be affected after mitigation (Fisher & Johnson, 1990). The public has a general perception that radon problems may involve high costs. For example, homeowners will have to buy and use a radon monitor and possibly pay for expensive mitigation. Radon communications intended to motivate testing may not be successful in situations where the homeowner lacks the resources to mitigate any problems that they find (Svenson & Fischoff, 1985). Additionally, concerns over property values may also discourage people from testing or from sharing or disclosing the results of their tests. Desvousges and co-authors (1989) found that nearly half of homeowners surveyed thought that their home would be worth a lot less even if a radon problem were fixed.

To address concerns surrounding Myth 3, risk communication must underscore the fact that testing is not expensive and that mitigation can be comparable to other home maintenance costs such as replacing a furnace or air conditioner. Obtaining a reliable radon protection plan may be a viable option to reduce the cost of mitigation. Effective risk communications must achieve an informed decision that radon risks can be addressed less expensively

than many other health risks (Desvousges et al., 1989). It is important to emphasize that all homes have radon, so a house is not bad or contaminated if it has measurable levels of radon. Homeowners need to know how much radon is in their homes as compared to the Canadian guideline.

Myth 4: Radon distribution maps are reliable sources for measurement- and mitigation-related decision making for individual homeowners. Radon maps can be developed based on indoor radon measurements, geology, aerial activity, soil permeability, and foundation type. While maps can increase understanding, simplify complex concepts quickly, and enable easy comparisons, they are only as good as their intended purpose. Graphical displays and visual communication of risk through a radon map can offer unique benefits for improving overall communications to stakeholders and the public (Lipkus & Hollands, 1999). They may, however, also lead to a false sense of complacency and reluctance to initiate testing. Radon distribution maps are not intended to be used for determining whether a home in a given zone should be tested for radon but rather to help governments, health professionals, and other authorities to target their resources.

According to Health Canada's 2009–2011 Cross Canada Radon Survey and federal building testing program in British Columbia, homes and buildings with elevated levels of radon were found in 13 out of 16 health regions throughout the province. As mentioned previously, radon ingress results from both natural causes and human activities. Therefore, with respect to Myth 4, an important risk communication message is that all homes have some level of radon and therefore need to be tested regardless of geographic location.

Myth 5: A radon risk communication strategy will be equally applicable or effective in all regions. The actual communication strategy chosen in a region will depend on a number of factors such as the extent of the radon problem in that region, the present state of public knowledge about radon, the available budget, the existence of a national radon reference level, and national and provincial building codes. In general, people respond better to risk information that is both quantitative and qualitative than through either one alone. Quantitatively, people need to

know the guideline level, the duration of time for mitigation action, and the statistics on radon health effects. Qualitatively, people are inspired by real-life stories of those who have been impacted by radon or have contracted lung cancer from radon and by success stories in bringing radon levels down through mitigation. Thus, effective risk communication needs to involve the use of both qualitative and quantitative information (Smith, Desvousges, & Fisher, 1987). A very popular visual tool that EHP has used in communicating radon risk is the radon model house developed by Health Canada for use in all regions. The model house demonstrates the various entry routes of radon into a home and mitigation measures that can be employed, such as active subslab depressurization units.

The characteristics of homeowners also come into play regarding their concerns over health. Older people tend to be less willing to acquire health risk information, whereas people with existing health concerns are more willing to acquire health risk information. Educating young people could be one approach for helping to disseminate health risk information to other age groups (RAD-PAR, 2011). With the support of Health Canada, British Columbia's Interior Health Authority conducted two poster contests in 2012 and 2013 targeting junior secondary students in radon-rich areas to raise awareness on radon. In addition, through contracting a nonprofit organization, EHP was able to use popular social media tools (such as Twitter, Facebook, YouTube, etc.) to reach out to a wider audience.

Socioeconomic and ethnic diversity components also influence the risk communication process. For example, the demographics in British Columbia indicate a diverse ethnic population. Cultural and ethnic background may affect people's perceptions about radon risk. Some people may be relatively less receptive to radon risk messages, and thus the process of risk communication cannot be isolated from the broader social and cultural context. This variability poses challenges in terms of managing environmental risks across a culturally heterogeneous society. To engage with different ethnic communities, EHP has exhibited a radon booth at various ethnic community health fairs. Vaughan (1995) underscores the importance of under-

standing the different patterns of responding to risk situations, and how the communication process evolves within varying sociocultural environments.

It is well recognized that risk communication may enhance public knowledge and encourage informed consent without resulting in behavioral change (Golding, Krimsky, & Plough, 1992). Johnson and co-authors contend that it is a rather naïve assumption that information programs will motivate people voluntarily and rationally to reduce risks (Johnson et al., 2010). Thus, with respect to Myth 5, due to the various factors that influence responses to radon risk communication, it cannot be expected that one radon risk communication strategy will be equally applicable or effective in all regions. Solving the radon problem will require a mix of risk communication, incentives, and regulation (Golding et al., 1992).

Myth 6: Risk communication is a loner's task. The World Health Organization argues that effective risk communication requires cooperation among organizations with good community credibility (WHO, 2009). Health Canada in the British Columbia region is privileged to benefit from partnerships with other federal department(s) and local health authorities to share expert knowledge and support education and awareness on radon through radon public forums. Given the often apathetic response to the health risk of radon exposure, it is very valuable in partnering with relevant stakeholders to increase awareness. Some of Health Canada's roles include the Canadian guideline for radon, producing radon guides and fact sheets, coordinating the federal building-testing program, and assisting radon initiatives by local health authorities. The province of British Columbia (the Building and Safety Standards Branch of the Ministry of Energy, Mines, and Natural Gas) administers the British Columbia Building Code to prevent radon ingress and funds education and awareness initiatives. Local health authorities in radon-rich areas actively promote education and awareness in their areas and provide expertise to coordinate testing in public schools and daycare centers.

EHP is also a member of the provincial radon intergovernment information and liaison group that comprises staff from the British Columbia Centre of Disease Con-

trol (BCCDC), British Columbia Ministry of Health, Canadian Mortgage and Housing Corporation, British Columbia Lung Association (BCLA), Northern Health Authority, Interior Health Authority, and the Provincial Health Services Authority. This group provides a forum for sharing information on radon issues and promoting ideas for increasing awareness and testing. Additionally, an annual radon workshop is held in Vancouver as a result of collaborative efforts of EHP, BCCDC, and BCLA. The target audiences for the radon workshop are health professionals, academia, industry stakeholders (building contractors, home inspectors, etc.), and students. The goal of the workshops has been for participants to understand the current state of knowledge on strategies to reduce residential radon exposure, including challenges and current knowledge gaps. Part of the workshop has been available online to increase the opportunity for people across Canada to participate. Additionally, EHP engages with stakeholders in the building industry such as home inspectors, building contractors, and realtors to make radon-related presentations, to provide information on the national building code to prevent radon ingress, and to raise awareness of the Canadian National Radon Proficiency Program (C-NRPP), which certifies radon professionals (C-NRPP, 2012). Thus, with respect to Myth 6, Health Canada educates and raises awareness on radon measurement and mitigation by partnering with nongovernmental and nonprofit organizations.

Conclusion

A good risk communication strategy should create the basis for behavioral change and provide clear actions for people to take (RAD-PAR, 2011). After considering the nature of the radon problem, six key myths have been identified and demystified for effective risk communications. The following can be used for the development of a set of core messages aimed at target audiences.

1. Radon is truly a serious health threat; lung cancer development and death can be reduced by controlling an individual's radon exposure.
2. Indoor radon exposures are from natural resources and can be increased or decreased through human activities. The latter message points to the fact that radon risks can be managed.
3. Testing is easy; mitigation is effective and options are available to address mitigation costs.
4. A radon distribution map is only as good as its intended purpose, such as for authorities to target their resources. The only way to know if a radon problem exists is to test, as radon concentrations vary from home to home.
5. An effective risk communication strategy calls for a consideration of the demographic and socioeconomic context of the public, and the use of both quantitative (statistical data) and qualitative communication approaches.
6. Risk communication is a joint effort at the local and national levels. Federal departments, provincial governments, local health authorities, nonprofit organizations, and industry need to collaborate to share knowledge, expertise, resources, and ideas that will encourage testing and mitigation.

Radon risk is a global issue. Some countries may be more advanced in the development of risk communication strategies and programs, while others are lagging behind. The lessons learned and strategies established may serve as valuable references for less developed countries. The ultimate goal of radon risk communication is to reduce the number of lung cancer deaths caused by radon locally and beyond. Additionally, effective risk communication may succeed in persuading policy makers that radon is indeed an important public health issue that requires action (WHO, 2009). ▆▆

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You can learn more about all of the credentials NEHA offers directly from our credentialing coordinator. View the recorded webinar at www.neha.org/credentialing-webinar for an overview and the process to attain a NEHA credential, including the REHS/RS. Q&A from attendees during the live webinar is also included.
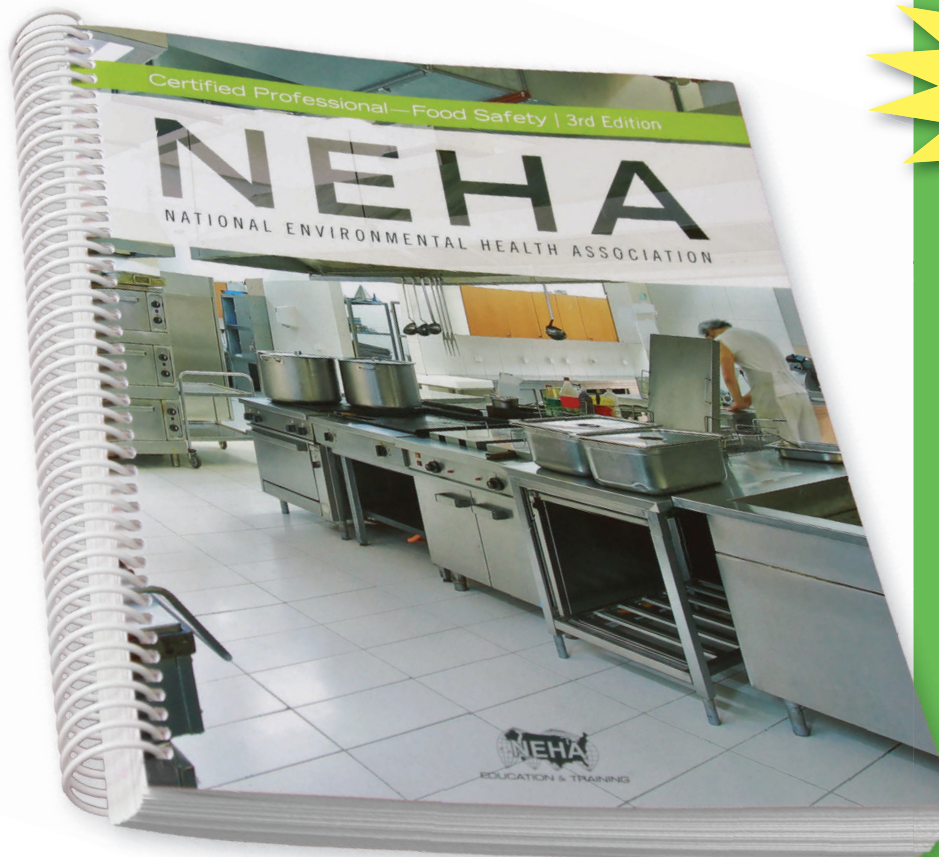
▶ **BUILDING CAPACITY**

Civic Engagement Builds Capacity for Health Departments

Darryl Booth, MBA

The phrase "civic engagement," which speaks to closing the circle of communications and accountability between government and its citizens and customers, is an important one. It's captivating to explore where government, and specifically health departments, could be more like Amazon, Uber, and FedEx. These are examples of businesses that engage frequently and well with their customers, thereby setting the expectations of our customers.

When we don't quite meet those expectations (e.g., by having a modern Web site that takes instant payments or an iPhone app for logging complaints, with GPS coordinates and glorious 12 megapixel images), the customer citizen forms a diminished opinion of our services. Even though we may not interact regularly, we all want a positive review.

But is civic engagement as relevant to environmental health as it is to public works, building and planning, or elected officials?

"Environmental health is different," I might explain to a colleague, "because the mission and methods of environmental health are, generally, predetermined by the Food and Drug Administration, the Centers for Disease Control and Prevention, the state department of health, and so forth. Delegation agreements, as an example, predispose how resources shall be invested. Neither the customer nor the local board of supervisors have complete sway over how to assess a facility's risk or investigate a foodborne illness."

That being said, we are still part of an enterprise and we are certainly part of a community, making civic engagement just as important for us.

I enjoy the perspective of observing many excellent environmental health leaders, most of whom embrace civic engagement as an imperative. Below are five ways to improve civic engagement in your community.

Five Essential Public Touchpoints Demanded of Health Departments

Education, Advocacy, and Partnership
Public and environmental health departments embrace education more than any other department. It's essential to raise awareness and ultimately to change behaviors.

The city of Columbus won the Dr. R. Neil Lowry Grant, presented to public health professionals or agencies that seek to advance the public's safe use of recreational water through educational, safety, operational, and technical programs, at the 2015 NEHA Annual Educational Conference & Exhibition on just such a platform.
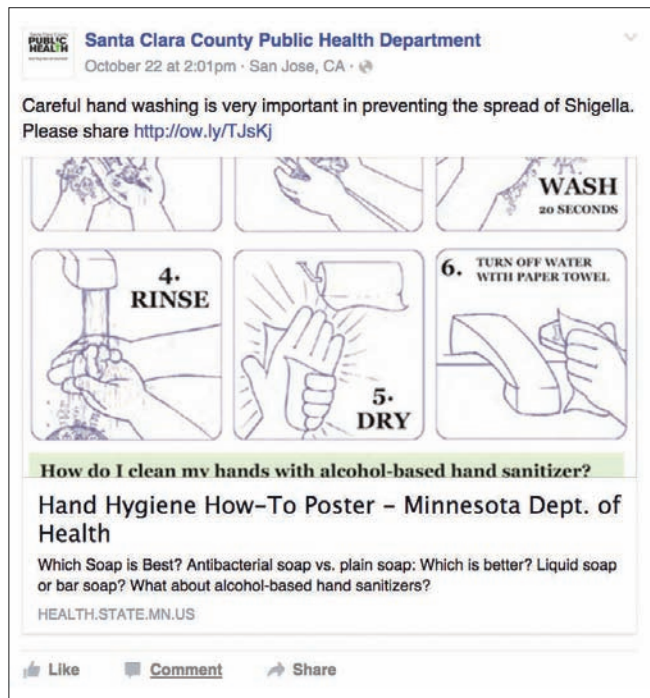
Columbus' growing recreational water program was beset by the turnover common to this seasonal operation. "Many of these operators are transient and only on the job for a year, and often have other responsibilities besides swimming pools," says Keith Krinn, director.

After careful analysis of inspection violation data in 2014, the city found that high cyanuric acid residuals were the most cited and primary reason for closure. Based on this insight, staff developed an informational tool and with the grant will purchase 650 USB drives to distribute these training materials to all their facilities. The operators may come and go, but the materials will always be available.

"We're big believers here … to be able to take concepts that we find and specific actionable items based on violation data to be able to make the community safer," says Krinn.

The program is already producing results: Columbus has seen a reduction in closures for cyanuric acid violations.

Social Media and Public Forums

Even when we think nobody is listening … people are. Thankfully, many examples exist of great social media campaigns designed and implemented by health departments. The budget is nearly zero and the reach is far.

In a case that generated national media attention in October 2015, a nasty outbreak of the highly contagious *Shigella* at a restaurant in Santa Clara (California) County infected hundreds of patrons and their contacts. Throughout the event, Santa Clara County utilized every resource, including Facebook and Twitter, to keep citizens and the media informed and provide timely and topical tips for preventing its spread (Figures 1 and 2).

In a nondigital context, and with a long history in environmental health policy making, we include the public forum. In this particular chosen profession, it is nearly certain that you'll rise through the ranks and find yourself one day at a community meeting or hearing, perhaps the touchstone of participatory citizenry. These too are increasingly conducted online with live

Internet streaming, interactive Q&A, and automatic archiving of participant comments.

Restaurant Inspection Results

Whether it's a searchable Web site, a LIVES Feed (LIVES is a data standard for exposing inspection results; it stands for "Local Inspector Value-Entry Specification"), or a mobile app, this is what is most visible to the largest swath of the population. Also, it's an excellent tool to have in an inspector's tool chest. New York, San Francisco, and Los Angeles are the first big players to join the LIVES movement and you can find their inspection data on Yelp today. Size is no restriction; even smaller municipalities (like Boulder, Colorado, and Evanston, Illinois) with the vision and public buy-in can participate.

Beyond LIVES, many agencies are experimenting with building apps to interact directly with consumers. The California Food Inspector app (Figure 3), built originally by Contra Costa County in the San Francisco Bay Area, now publishes inspection results for Los Angeles, San Francisco, Contra Costa, Mon-

The California Food Inspector App

The Florida Department of Health's Dataset of Onsite Sewage Treatment and Disposal Systems

terey, Alameda, Sacramento, San Joaquin, and San Bernardino counties in California, and includes location-based search functionality. To join in on this platform, the health departments need only publish a LIVES feed.

Open Data

Again, on the shoulders of giants, we can easily adapt our practices and culture to embrace open data. A great example is the Florida Department of Health's public geospatial dataset, which shows inspections, health care systems and emergency operations, water, and septic systems (Figure 4; http://openfl-health.fdoh.opendata.arcgis.com/).

Noteworthy as well is the San Francisco Health Department, whose data are picked up by vendors such as Appallicious to generate a Neighborhood Score, which provides overall health and sustainability scores for every block in the city. (Editor's note: At the time of publication this program is no longer available due to a lack of funding and options are currently being explored

to incorporate this program into a different platform.) From their Web site:

"Neighborhood Score uses local, state, federal, and private data sets to allow residents to see how their neighborhoods rank in everything from public safety, to quality of schools, crime rates, air quality, and much more. The new app makes information about neighborhood health easily accessible to residents and demonstrates the power of open government data to advance community health through government transparency."

Code for America has also engineered the open publication of San Francisco housing inspection data, which can be picked up by sites like the online real estate marketplace Trulia to alert potential homebuyers of a home's health history.

In general, the position is that these data are owned by the citizens who ultimately pay permit fees. What seems benign and routine to you is often groundbreaking to an app developer or advocacy group. Get your data out there!

Work Flows With Frequent Customer Interactions

Something Amazon, Uber, FedEx, and others do extremely well is to keep customers informed throughout the process. Whether it's a text message that your Uber driver is

around the corner or proof of delivery with a digital signature line, we return to these types of companies because they respond to our desire for information … lots of information.

San Diego County's Environmental Health Department offers this type of functionality. Facilities can check the status of their business and track the progress of applications. The county also recently implemented technology that automatically e-mails or texts businesses when there is an update (e.g., when an application or other activity changes status). This automated ping keeps phone calls down, reduces notification tasks for staff and, perhaps best of all, proves to your customers that their facility is not buried on someone's desk; progress is actually happening.

These are concrete examples relevant to health departments. What other civic engagement imperatives does your community pursue? Continue the conversation at LinkedIn's Building Capacity Group at http://tinyurl.com/EHCivicEngagement.

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2016 NEHA 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.

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 15, 2016.

For more information, please visit
www.neha.org/environmental-health-innovation-award.

2016 Joe Beck Educational Contribution Award

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

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

Nominations are due in the NEHA office by March 15, 2016.

For more information, please visit
www.neha.org/joe-beck-educational-contribution-award.

Dee Merriam,
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Parks: An Opportunity to Leverage Environmental Health

> **Editor's Note:** NEHA strives to provide up-to-date and relevant information on environmental health and to build partnerships in the profession. In pursuit of these goals, we feature a column from the Environmental Health Services Branch (EHSB) of the Centers for Disease Control and Prevention (CDC) in every issue of the *Journal*.
>
> In these columns, EHSB and guest authors share insights and information about environmental health programs, trends, issues, and resources. The conclusions in this article are those of the author(s) and do not necessarily represent the views of CDC.
>
> Dee Merriam is with the National Center for Environmental Health, Healthy Community Design Initiative at CDC.

Do you know your local parks and recreation director? He or she could be a great public health ally. Parks and recreation departments align with environmental public health on many cross-cutting activities such as swimming pool inspections, mosquito control, rabies management, and food permits. Parks also provide children access to safe and healthy places to play. Furthermore, they can mitigate safety hazards by protecting land such as flood plains and unstable slopes from inappropriate development. Public health and parks and recreation departments have many synergistic goals that could be leveraged to make both more effective.

In communities across the country, parks and recreation departments implement environmentally responsible land management practices and can be an important partner for environmental health programs. Parks often protect environmentally sensitive areas. For example, flood plains that are protected from inappropriate development in parks can store storm water, reducing downstream flooding. Protection of groundwater recharge areas allows storm water to seep into the ground, filtering non-point source pollutants and preventing them from entering streams. Tree canopies in parks can mitigate urban heat islands by providing shade and absorbing carbon dioxide and pollutants (U.S. Environmental Protection Agency, 2015).

In addition, parks provide opportunities for public health promotion including physical exercise, stress relief, and education programs. Studies have shown that access to green space can reduce the effects of poverty on health (Maas et al., 2009; Mitchell & Popham, 2008). A study of social interactions among residents of a public housing project in Chicago found that access to green space reduced aggression and improved social interactions (Kuo & Sullivan, 2001). Other studies have found that children who walk or bike to parks visit them more frequently and are more active (Grow et al., 2008; Mackett & Paskins, 2008). Because many environmental public health benefits are associated with parks, a strong partnership with your local parks and recreation department could be a great advantage to your department.

Here are some questions you can use to start a dialogue with the communities your department serves.

1. **Does your community have a master plan that includes an inventory of environmentally sensitive sites and ecosystems that need protection?**

If not, encourage the creation of a map of flood plains, steep slopes, and other areas that should be protected as the foundation for a green space system. Work with parks or planning staff to establish a vision plan that makes environmental health concerns a priority. This could include establishing buffers around key resources such as flood plains and groundwater recharge areas. Setbacks or buffers help protect resources and create locations for facilities such as trails, playgrounds, and picnic areas that leverage community investments.

2. **Do at-risk children in your community have a park that they can walk to?**

Sometimes a park is intended to serve a neighborhood, but its entrance has an inconvenient location (e.g., on a busy street that requires a long, roundabout walk). Adding a new entrance that is easy and safe to reach can increase community access. A park access analysis comparing the number of

Parks provide opportunities for public health promotion including physical exercise, stress relief, and education programs.

people who *live* within a half mile of a park to the number of people who have less than a half-mile *walk route* to a park entrance can identify opportunities to increase park access.

3. **Do safe walking and biking routes exist that join parks to nearby schools?**

An analysis of children who walk or bike to after school activities can be used to develop supportive infrastructure or create programs to bridge this gap. This may be particularly important for children whose parents are not able to provide after school transportation.

4. **Are new development plans reviewed for opportunities to create pedestrian-friendly streets leading to or adjoining nearby parks?**

Pedestrian-friendly streets can make parks more visible and safer. Early reviews of rezoning and subdivision plans by either public health or parks and recreation officials provide opportunities to encourage desirable street patterns.

5. **Is there an appropriate adult presence in parks during after school hours?**

This presence could range from activity leaders to adults in a community garden or public health outreach initiatives. Knowing park sites that would benefit from adult presence helps target opportunities. A park might be an ideal location for programs like health fairs and fresh food markets.

Useful Resources for Parks and Public Health

Active Living Research
- Making the Case for Designing Active Cities report:
  http://activelivingresearch.org/making-case-designing-active-cities

Healthy Community Design Initiative (HCDI)
- Access resources about developing healthy places in your community.
- More information on HCDI can be found at www.cdc.gov/healthyplaces.

Making Streets Welcoming for Walking
- Identifies important principles for creating streets that welcome pedestrians:
  http://changelabsolutions.org/sites/default/files/Streets-Welcome-for-Walking_FINAL_20131206_0.pdf

National Environmental Public Health Tracking Network indicator "Access to Parks" (see "Search Community Design Data" tool)
- Provides national, state, and county data on selected indicators as maps, tables, and charts:
  http://ephtracking.cdc.gov/showCommunityDesign.action

National Recreation and Parks Association (NRPA) Walking Initiative
- The NRPA "Safe Routes to Parks" (www.nrpa.org/uploadedFiles/nrpa.org/Publications_and_Research/Research/Papers/Park-Access-Report.pdf) guide provides professionals with well-researched tools to ensure parks are accessible to all users. www.nrpa.org/Grants-and-Partners/Recreation-and-Health/Walking-Initiatives/

Parks and Trails Health Impact Assessment (HIA) Toolkit
- Summarizes the strategies recommended in 11 HIAs and with supporting citations:
  www.cdc.gov/healthyplaces/parks_trails/default.htm

Parks, Trails, and Health Workbook
- A tool for planners, parks and recreational professionals, and health practitioners:
  http://go.nps.gov/communityhealthworkbook

Pedestrian Friendly Code Directory
- Links to zoning and subdivision codes positioned to create streets and neighborhoods that are safe, comfortable, and convenient for pedestrians, transit users, and bicyclists.
  http://changelabsolutions.org/childhood-obesity/pedestrian-friendly-code

Planning and Community Health Center Webinar Series
- A variety of topics related to planning and public health, including strategies to advance active living, healthy eating, and cross-sector and community collaborations. www.planning.org/nationalcenters/health/webinars/
- Safe Routes to Parks:
  http://media2.planning.org/media/stream/saferoutes/lib/playback.html

Urban River Parkways: An Essential Tool for Public Health
- University of California, Los Angeles report on the health benefits of Urban River Parkways:
  Report summary/brochure: http://bit.ly/1xCORmQ
  Full report: http://bit.ly/1s5AwzC

Direct From CDC/EHSB
continued from page 113

6. Does the parks and recreation department have healthy vending policies?

Work with the department to promote healthy food choices such as drinking water and fresh fruit.

7. Are parks visible?

Provide signs, Web sites, and maps to make parks more visible.

Community health depends on teamwork and communication among all stakeholders. Call your local parks and recreation director today and start the conversation. ♠♠

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EH CALENDAR

UPCOMING NEHA CONFERENCE

June 13–16, 2016: NEHA 2016 Annual Educational Conference & Exhibition and HUD Healthy Homes Conference, San Antonio, TX. For more information, visit www.neha.org/aec.

NEHA AFFILIATE AND REGIONAL LISTINGS

Alabama
April 12–14, 2016: 2016 Interstate Environmental Health Seminar, hosted by the Alabama Environmental Health Association and held in conjunction with its Annual Education Conference, Guntersville, AL. For more information, visit www.aeha-online.com/upcoming-events.html.

California
March 21–25, 2016: 65th Annual Educational Symposium, hosted by the California Environmental Health Association, Oakland, CA. For more information, visit www.ceha.org.

Idaho
March 16–17, 2016: Annual Education Conference, hosted by the Idaho Environmental Health Association, Boise, ID. For more information, visit www.ieha.wildapricot.org.

Indiana
April 14, 2016: Spring Conference, hosted by the Indiana Environmental Health Association, Indianapolis, IN. For more information, visit www.iehaind.org/Conference.

Kentucky
February 17–19, 2016: Annual Conference, hosted by the Kentucky Environmental Health Association, Florence, KY. For more information, visit www.kamfes.com.

Michigan
March 16–18, 2016: Annual Education Conference, hosted by the Michigan Environmental Health Association, Bay City, MI. For more information, visit www.meha.net/AEC.

Minnesota
January 28, 2016: Winter Conference, hosted by the Minnesota Environmental Health Association, St. Paul, MN. For more information, visit www.mehaonline.org.

Ohio
April 18–20, 2016: Annual Education Conference, hosted by the Ohio Environmental Health Association, Columbus, OH. For more information, visit www.ohioeha.org/annual-education-conference.aspx.

Utah
April 27–29, 2016: Spring Conference, hosted by the Utah Environmental Health Association, Springdale, UT. For more information, visit www.ueha.org/events.html.

TOPICAL LISTING

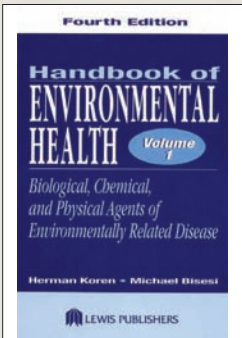**Public Health**
April 12–13, 2016: Iowa Governor's Conference on Public Health, Navigating a Changing Landscape: Partnerships for Population Health, Des Moines, IA. For more information, visit www.ieha.net. ♠♠
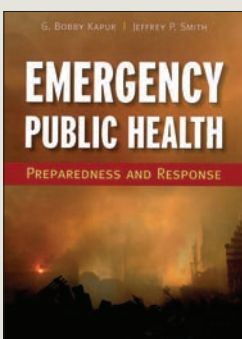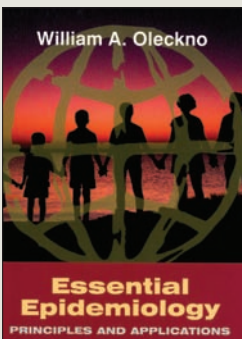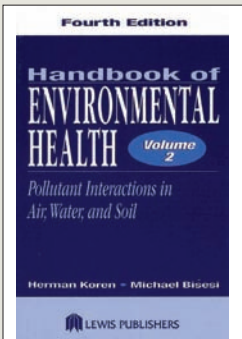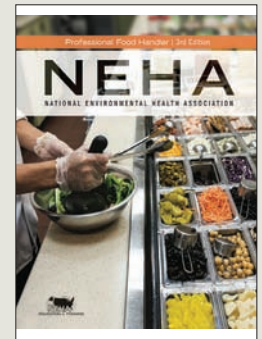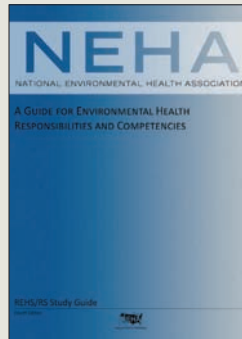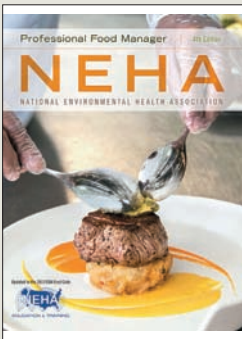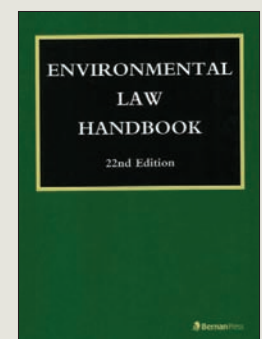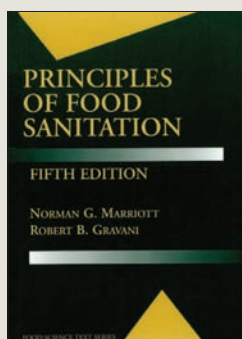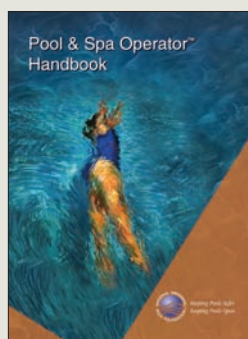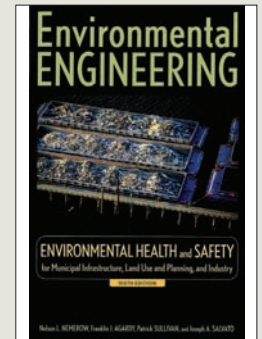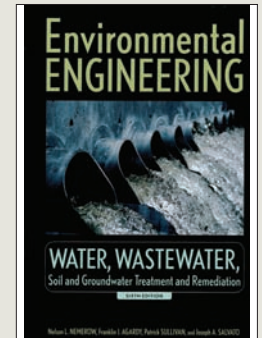
RESOURCE CORNER

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
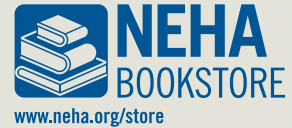
Certified Professional-Food Safety Manual (Third Edition)
National Environmental Health Association (2014)

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

Principles of Food Sanitation (Fifth Edition)
Norman G. Marriott and Robert B. Gravani (2006)
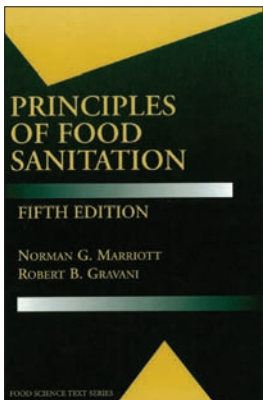
This book provides sanitation information needed to ensure hygienic practices and safe food for food industry and regulatory professionals. It addresses the principles related to contamination, cleaning compounds, sanitizing, and cleaning equipment. It also presents specific directions for applying these concepts to attain hygienic conditions in food processing or preparation operations. The book includes chapters that address biosecurity and allergens as they relate to food sanitation, as well as chapters on the fundamentals of food sanitation, contamination sources and hygiene, HACCP, cleaning and sanitizing equipment, and waste handling disposal. Study reference for NEHA's REHS/RS and CP-FS exams.
413 pages / Hardback / Catalog #126
Member: $84 / Nonmember: $89

REHS/RS Study Guide (Fourth Edition)
National Environmental Health Association (2014)
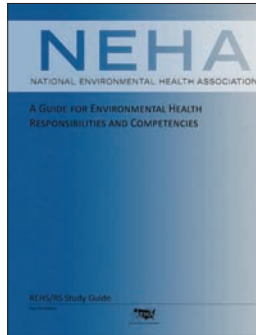
The Registered Environmental Health Specialist/Registered Sanitarian (REHS/RS) credential is NEHA's premier credential. This study guide provides a tool for individuals to prepare for the REHS/RS exam and has been revised and updated to reflect changes and advancements in technologies and theories in 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

Environmental Health (Fourth Edition)
Dade W. Moeller (2011)
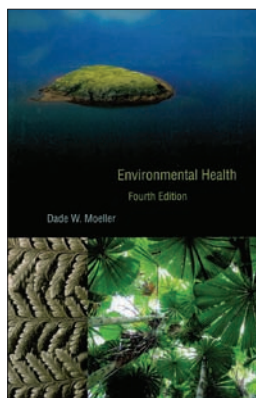
This book provides a complete but manageable introduction to the complex nature of the environment, how humans interact with it, and the mutual impact between people and the environments where they work or live. This edition emphasizes the challenges professionals will face in the field: the local and global implications of environmental health initiatives, their short- and long-term effects, their importance to both developing and developed nations, and the roles individuals can play in helping to resolve these problems. This book is an indispensable resource for practitioners, students, and anyone considering a career in environmental public health.
518 pages / Hardback / Catalog #410
Member: $82 / Nonmember: $86

JEH QUIZ

FEATURED ARTICLE QUIZ #4

A Step Towards Improving Food Safety in India: Determining Baseline Knowledge and Behaviors Among Restaurant Food Handlers in Chennai

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/publications/journal-environmental-health (click on the January/February 2016 issue in the left menu),

   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, 2016 (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

JEH Quiz #2 Answers
October 2015

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

➜ **Quiz deadline: April 1, 2016**

1. The occurrence of foodborne disease in India is
   a. overreported.
   b. accurately reported.
   c. underreported.

2. In the authors' study, food handler knowledge gaps related to __ were identified.
   a. cross contamination
   b. hand hygiene
   c. proper food cooking temperatures
   d. proper food holding temperatures
   e. all of the above

3. The overall mean knowledge score of food handlers surveyed in the authors' study was
   a. 24%.
   b. 36%.
   c. 49%.
   d. 53%.

4. Most food handlers surveyed were knowledgeable of how the spread of germs can be related to personal hygiene.
   a. True.
   b. False.

5. Food handlers showed the least amount of knowledge regarding
   a. proper storage of raw meat.
   b. proper food holding and cooking temperatures.
   c. possible illness caused by the consumption of uncooked meat.
   d. proper technique for thawing frozen chicken.

6. At the time of the study, food handlers employed in restaurants in Chennai were required to obtain a Medical Fitness Certificate, but only __ reported having one.
   a. 10%
   b. 28%
   c. 38%
   d. 52%

7. Restaurants were selected for the study using __ sampling.
   a. purposive
   b. random
   c. cluster
   d. stratified

8. Of the restaurants that participated in the survey, the largest percentage can be characterized as __ services.
   a. fast food
   b. informal
   c. formal
   d. mobile

9. __ of food handlers surveyed received no food safety training from their place of employment.
   a. Twenty-two percent
   b. Forty-four percent
   c. Fifty-six percent
   d. Eighty-seven percent

10. Food handlers ages __ had a greater mean knowledge score compared to other age ranges.
    a. 18 to 29 years
    b. 30 to 39 years
    c. 40 years or older

11. Chefs and cooks scored higher mean knowledge scores than managers and supervisors.
    a. True.
    b. False.

12. Of the food handlers surveyed, __ had knowledge about India's Food Safety Standards regulation.
    a. 17%
    b. 27%
    c. 54%
    d. 78%

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.

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DirecTalk
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tion and today it is around 1:2,000. What does that mean? I'm not sure, and of course there are many ways to interpret this data. How about environmental health?

Speaking to our profession, the number of individuals working in environmental health is evidently a little more complicated to estimate as described by my friend Mehran Massoudi and two others in an article published in the *JEH* in 2012 (Massoudi, Blake, & Marcum, 2012). The conversation around enumerating the environmental health workforce immediately enters a rabbit hole when one crosses into the abyss of the "environmental health professional vs. professional working in environmental health." So I am going to steer clear of that and suggest there are about 20,000 of us in the U.S. working in the profession.

So, if the de Beaumont Foundation data is correct, and let's accept it at face value, the $64,000 question is, Is there an impending environmental health workforce crisis as well? I am going to dodge the empirical question about numbers, and leave that for a later column. I do want to address some issues that may be affecting the environmental health workforce and in the process suggest that we are masters of our own destiny.

The first issue I'd like to address is one of workforce retention, and direct your attention to the second infographic (Figure 2). If you study it carefully, you'll note leaders within the profession can control many of things that make the workplace a reasonably pleasurable and rewarding place to be, including making entry into the workforce easier. That is the effect of quality supervisory and organizational support. I know from my time in academia that many young people opted not to work for the local health department not because they didn't want to, but because they simply could not afford to wait for the extended time periods that often accompany county and city human resource processes to be completed. In some cases it took months to fill an entry-level position. In this day and age of managing life in nanoseconds, governmental human resource processes can and must change with the times.

The de Beaumont study also suggests that the workforce exodus is not simply among retirees. The study confirms what I already knew.

Workforce Retention

Source: de Beaumont Foundation. Used with permission.

In fact, this development has been underway for quite a while. During my time at NACCHO, board members communicated that they readily accepted that employees would work for them for a few years, leave to explore other opportunities, then return when the time was right. This is probably the new normal.

I have articulated in other columns that we don't have an environmental health crisis, we have a crisis in leadership and management, and that too is in our control. Employees desire to work in environments where they are engaged, empowered, and enabled. Not only does this make sense, it is an operational imperative. We want our teams to grow professionally as we groom the next generation and construct succession plans. People, we are what we leave behind.

I also take issue with the perception that there is insufficient talent to carry the mantle of our profession into the future. As I understand it, public health is the ninth most popular undergraduate degree in the U.S. A very common question I receive from young people is centered on employment opportunities and entry into the job market. We don't have a talent bandwidth issue; there are plenty of qualified young people. The white elephant in the room is compensation relative to student loan debt, which is currently a subject du jour among presidential hopefuls. Again, this requires inspired leadership.

Now then, I have buried this paragraph deep in this editorial for a reason. It is painful, but needs to be said. For those of you nearing retirement, thank you for all you have accomplished; today we stand on your shoulders. At the same time I have observed a troubling national trend characterized by retirees who return to the system as double dippers or consultants, impeding the upward trajectory for the new generation of envi-

ronmental health professionals. Our young, emerging leaders desire take on the environmental health challenges of their time. Please create leadership opportunities for them.

As I close, I want to mention clothes. For the next generation of environmental health leaders, please dress the part. All across this great country we conduct ourselves with professionalism and commitment. Yet time after time we are not perceived as influencers or key decision makers. Why? Look how attorneys and engineers dress when they are in the public eye. I get it. For many years I wore blue jeans and a hard hat to work, because I was in the field collecting samples and managing projects. The truth is, however, that people treat you the way you dress. Dress for the job you want, not the one you have. That means when you are in public or working in the office, dress to demand respect.

Reportedly a sizeable piece of our 20,000-strong environmental health workforce mass is accelerating out the door. In many respects this is a good thing, and reflects the new normal. Let's focus attention on the things we control and influence, starting with organizational culture and our personal appearance. We don't have a moment to waste.

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NEHA NEWS

Students Encouraged to Apply for Environmental Health Internships

NEHA, in collaboration with the Association of Environmental Health Academic Programs, is accepting applications for the National Environmental Public Health Internship Program (NEPHIP). NEHA will accept up to 30 Centers for Disease Control and Prevention (CDC)–sponsored environmental health internships for summer 2016. Students from National Environmental Health Science and Protection Accreditation Council–accredited undergraduate and graduate programs are eligible to apply for an 8 to 10 week internship at local, state, or tribal environmental health departments across the country.

NEHA will award students a stipend of up to $4,000 dollars ($400 per week) for completing the internship. An additional stipend is available to cover the costs of relocating for the internship. Students interested in applying to NEPHIP should submit an application at www.neha.org/professional-development/students/internship by February 15, 2016.

Last year was the first time these CDC-supported internships in environmental health were offered, and 12 interns were placed in health departments across the U.S. These interns were involved in a wide range of activities such as studying contamination levels of surface water and groundwater, building on tracking initiatives by presenting pesticide exposures and illness information, and completing asset mapping in regards to sustainable environments in communities. To learn more about past student internship experiences, visit www.neha.org/professional-development/students/internship/2015-student-success-stories.

Unique Vectors and Public Health Pests Opportunity

Through a partnership with CDC's National Center for Environmental Health, NEHA is pleased to announce its first-ever virtual conference, Enhancing Environmental Health Knowledge (EEK): Vectors and Public Health Pests, on April 13–14, 2016. The goal of this virtual conference is to enhance the knowledge of environmental health professionals on vectors and public health pests in order to help them better prepare to respond to environmental events of public health concern. Conference content will include topics such as

- rodents, ticks, mosquitoes, and bed bugs;
- institutional integrated pest management;
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- stories from the field; and others.

This virtual conference is a unique opportunity to help advance and interact with environmental health professionals around topics and issues in vectors and public health pests in a new and exciting virtual environment. You can attend EEK: Vectors and Public Health Pests from anywhere using your tablet or laptop.

For more information about the conference or to submit an abstract to present, please visit www.neha.org/vectors-pests-conference.

2016 HUD Secretary's Awards for Healthy Homes

The U.S. Department of Housing and Urban Development (HUD), in partnership with NEHA, announces the second annual Secretary's Awards for Healthy Homes. These awards will recognize excellence in healthy housing innovation and achievement in three categories: Public Housing/Multifamily Supported Housing, Policy and Research Innovation, and Cross Program Coordination among Health, Environment, and Housing. The activities or policies nominated must show measurable benefits in the health of residents and be available to low- and/or moderate-income families. Applications will be open January 15 on NEHA's and HUD's Web sites and are due no later than 11:59:59 p.m. PST, February 29. Previous award winners are ineligible to apply. The awards will be presented at the NEHA 2016 Annual Educational Conference (AEC) & Exhibition and HUD Healthy Homes Conference (www.neha.org/aec), June 13–16, in San Antonio, Texas.

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Exam: REHS/RS

Monday, June 13
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- Exhibition Grand Opening & Party

Tuesday, June 14
Events:
- Education Sessions
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Wednesday, June 15
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- Breakfast & Town Hall Assembly
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▶ **DirecTalk** MUSINGS FROM THE 10TH FLOOR

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David Dyjack, DrPH, CIH

As Yogi Berra once said "It's déjà vu all over again." For the last 10 years, perhaps longer, I have been privileged to participate in national conversations about the impending public health workforce crisis. The storyline approximates something to the effect that the baby boom generation is about to depart the public health workforce en masse, leaving a crippled and feckless public health infrastructure behind. A recent study conducted by the de Beaumont Foundation in partnership the Association of State and Territorial Health Officials (ASTHO) has fueled another wave of concern about impending retirements and fleeing intellectual capital from the governmental workforce. Their study methodologies are sound and both are blue-chip organizations. The original study can be found at http://journals.lww.com/jphmp/toc/2015/11001. I encourage you to read the entire supplement.

To muddle this issue, note that the National Association of County and City Health Officials (NACCHO) has conducted similar surveys and has not found the same kind of alarming data at the local level. A 2014 article published in the *American Journal of Preventive Medicine* suggested that retirement rates and other departures have been pretty steady at about 10%. About one-third of that is retirees (Newman, Ye, & Leep, 2014).

A closer examination of the data provided in the workforce turnover infographic (Figure 1) is instructive. The U.S. population in 1980 was roughly 226 million and today it has grown to around 325 million. Over the same interval the public health workforce

FIGURE **1**

Workforce Turnover

Source: de Beaumont Foundation. Used with permission.
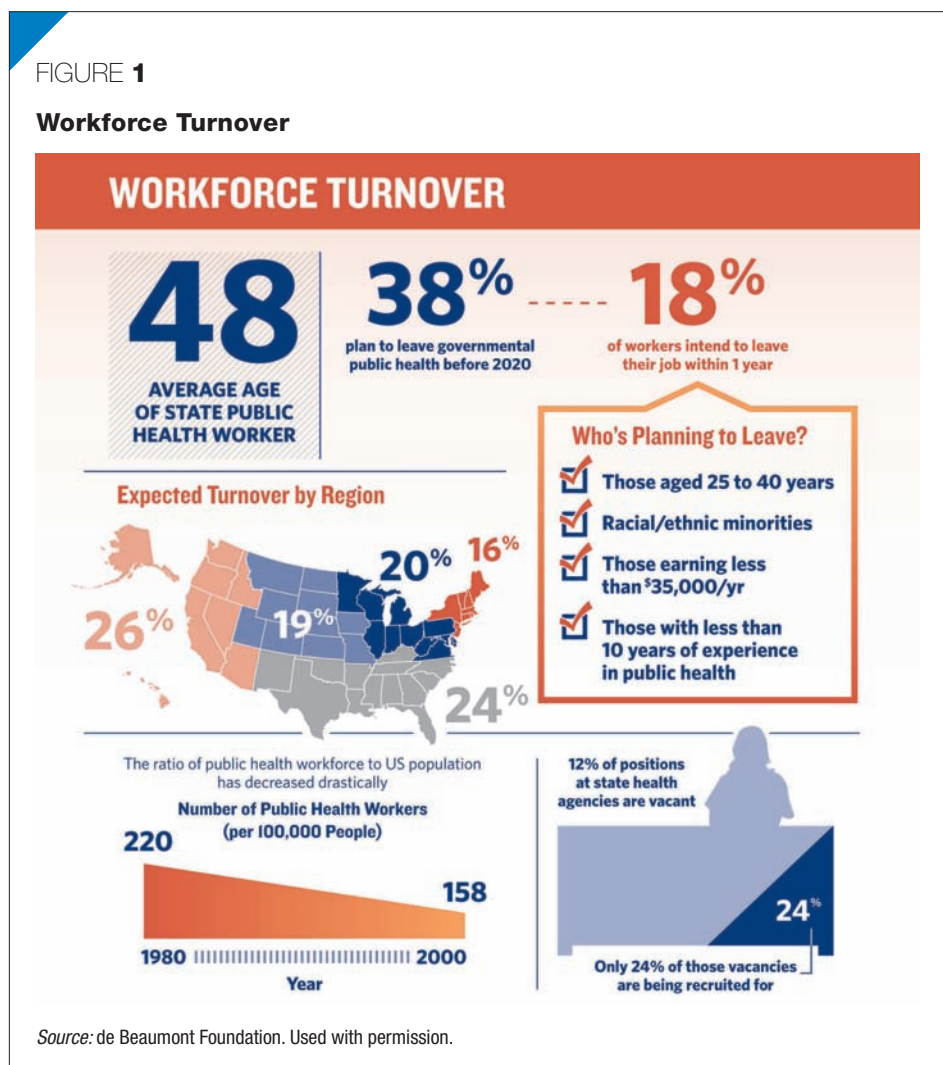
was reduced from 220,000 to its present-day estimate of about 160,000. Using these figures, and rounding to the nearest zero, the data suggests the workforce ratio in 1980 was one public health worker per 1,000 popula-

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‣ **INTERNATIONAL PERSPECTIVES**

Morbidity and Mortality of Residents Living Near a Municipal Solid Waste Landfill in Northwest Italy From 1980 to 2009

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A b s t r a c t **The ecological study described in this article assessed morbidity and mortality excesses in the eight municipalities surrounding the municipal solid waste landfill of Barengo (Novara, northwest Italy). The resident populations living in this area on December 31, 1991, and December 31, 2005, were assessed. Standardized incidence and mortality ratios were calculated using data from hospital discharge forms, death forms, and regional databases. For congenital malformations (2003–2009 period), incidence excesses were found in females. Concerning morbidity (2003–2009 period) and mortality (2000–2009 period) for all causes, the observed cases and deaths largely exceeded the expected ones. During the 1980–2000 period, incidence excesses of deaths were reported for small intestine cancer, Hodgkin's lymphoma, and soft tissue sarcomas. Although morbidity and mortality excesses were found in the authors' study, further studies are needed to better identify the health-risk factors present in the area.**

Introduction

Barengo is a municipality in the province of Novara in the northwestern Italian region of Piedmont, about 100 km northeast of the main regional city of Turin and about 70 km northwest of Milan, the main regional city of the neighboring Lombardy region. Barengo and the surrounding area are strongly influenced by the presence of a municipal solid waste (MSW) landfill. The area is home to more than 10,000 inhabitants (RUPAR Piemonte, 2013).

The literature has shown that environmental impact is minimal where regulatory requirements for landfills are adhered to (Bellino, Falleni, Forte, & Musmeci, 1999; Forastiere et al., 2011; Istituto Superiore per la Protezione e la Ricerca Ambientale, 2013). On the contrary, when landfills are not properly managed, environmental matrices degradation is highlighted (Cabral et al., 2012; Toufexi et al., 2013). Epidemiological studies have shown increased morbidity and mortality for numerous conditions in the more exposed areas, e.g., cancer and congenital malformations (Elliott et al., 2001; Minichilli et al., 2005; Salerno & Palin, 2011; Salerno, Palin, & Panella, 2011).

The aim of our ecological study was to determine whether a local excess of morbidity or mortality existed in the area surrounding the landfill of Barengo. Our research, performed in February 2011, was requested by the Local Health Unit of Novara—Azienda Sanitaria Locale Novara (ASL NO) (Azienda Sanitaria Locale Novara, 2013), without pressures of residents or local administrators, because the above-mentioned landfill was being extended by the managing company. Before authorizing the extension, the Local Health Unit of Novara wanted to make sure that the existing landfill had not already had a negative impact on public health.

Methods

Site Description
The landfill studied in our research is located in "Località Fornace Solarolo" (northwest Italy, Piedmont region, province of Novara) in the area of the municipality of Barengo. This landfill is about 2 km away from the urban area of Barengo (to the north; Figure 1), from the town of Briona (to the southwest), and from the town of Proh (to the south). On the north side (facing the town of Barengo), the dump will be widened with a second basin. Eight municipalities (Barengo, Momo, Briona, Fara Novarese, Sizzano, Cavaglio d'Agogna, Cavaglietto, Vaprio d'Agogna), located in the north of the province of Novara, form a roughly circular area with a radius of about 7 km and a central point represented by the town of Barengo. This is a heavily anthropized part of the Po Valley, but it doesn't have hazardous industrial sites. The water supply of the local population is guaranteed by an aqueduct that receives groundwater from a mountain zone, away from the landfill area.

The landfill of Barengo is a Level I controlled landfill for MSW and nonhazard-

FIGURE 1

Location of the Landfill of Barengo
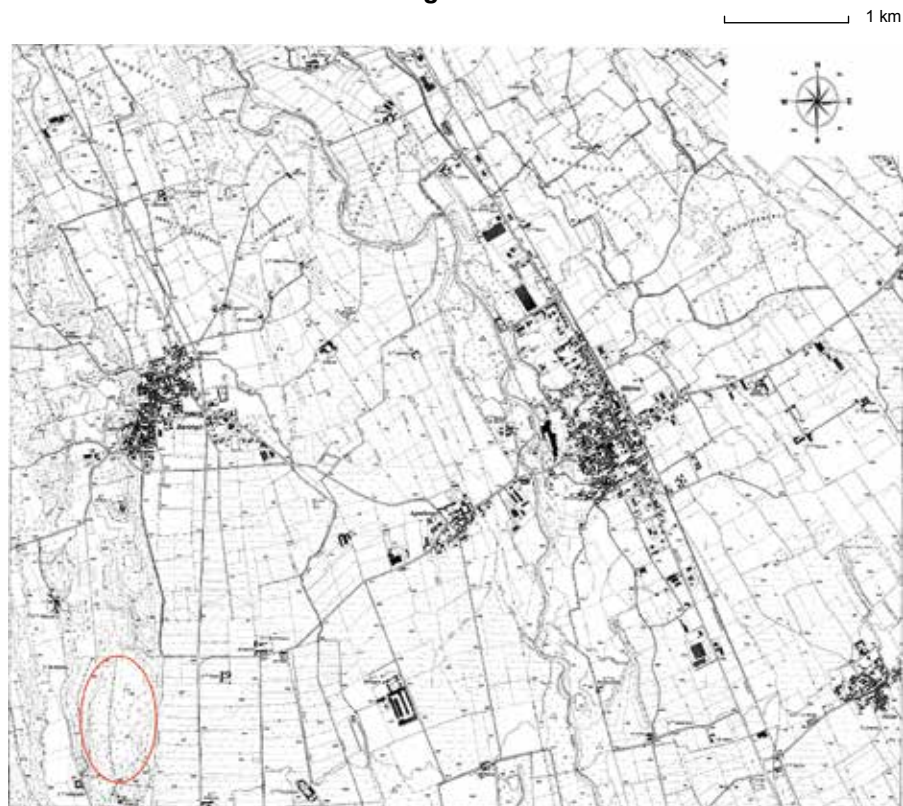
The landfill area (in the red circle) is about 2 km away from the urban area of Barengo (to the north) and 4 km away from the town of Momo (to the northeast).

ous municipal special waste, as defined by Italian Law in D.Lgs. 152/2006 (Italian Parliament, 2006). The landfill of Barengo has been active since 1992 (Salerno & Palin, 2011). The volume of materials used for daily coverage from January 1, 2009, to December 31, 2009, was about 31,451 m³ (Salerno & Palin, 2011). Inert soil is employed for the coverage. Topographic controls, quarterly sent to the "Consorzio di Bacino Basso Novarese" (Consorzio di Bacino Basso Novarese, 2013), the landfill managing company, showed that on December 31, 2009, the available residual volume on the entire authorized surface was about 24,300 m³ (Salerno & Palin, 2011).

Periodic chemical analyses, in accordance with Italian legal criteria, are performed by the managing company on water samples from neighboring piezometers located in three areas: in a sport field in Barengo, at "Cascina Solarolo," and in the town of Proh (2,300 m, 890 m, and 2,200 m away from the landfill, respectively). Such enquiries can be used only to control the good management of the landfill itself. Until now, neither these analyses nor the periodic environmental monitoring conducted by the Piedmont Regional Agency for Environmental Protection (ARPA Piemonte, 2014) showed an involvement of local groundwater.

Reference Populations

The present study focused on three specific epidemiological issues:

1) congenital malformations during the period 2003–2009,
2) morbidity during the period 2003–2009 and mortality during the period 2000–2009, and
3) mortality during the period 1980–2000.

The reference population was represented for the first two issues by the resident population living on December 31, 2005, in the above-mentioned eight municipalities surrounding the landfill of Barengo and for the third issue by the resident population living in the same area on December 31, 1991. Data were taken from Piedmont region demographic database (RUPAR Piemonte, 2013).

The eight municipalities surrounding the landfill of Barengo are a part of the province of Novara, which is a part of the Piedmont region. Therefore, the above-mentioned reference populations were a subset of the resident population living in the entire province of Novara on December 31, 2005, and on December 31, 1991, respectively. The latter were in turn a subset of the resident population living in the entire Piedmont region on December 31, 2005, and on December 31, 1991, respectively.

Collected Variables and Statistical Analysis

Congenital Malformations During the Period 2003–2009
Observed cases of congenital malformations (i.e., observed absolute frequency of hospital admissions for congenital malformations) classified by type of congenital malformation, age (pediatric age, i.e., 0–4 years, and all aggregated age ranges), and gender, during the period 2003–2009 in the total area of the eight municipalities surrounding the landfill of Barengo were considered. Data were taken from hospital discharge forms—schede di dimissione ospedaliera (SDOs) (Italian Health Ministry, 2013) consulted in the archive of ASL NO (Azienda Sanitaria Locale Novara, 2013).

Expected cases of congenital malformations (i.e., expected absolute frequency of hospital admissions for congenital malformations), classified by type of congenital malformation, age (same age ranges mentioned for observed cases), and gender for the same period and area were calculated with an indirect method, i.e., applying to the reference population the standardized hospital admission rates for congenital malformations reported for the population of the entire province of Novara for the years 2005–2009 (specific rates for type of congenital malformation, five-year age ranges, and gender: specific rates were only available for the 2005–2009

period). These rates were taken from Piedmont Region MADEsmart database (Motore di Analisi Demografica ed Epidemiologica [Demographic and Epidemiological Analysis Engine]—MADEsmart, 2013).

Standardized incidence ratio (SIR) was calculated as the ratio between observed and expected cases (Clayton & Kaldor, 1987). SIRs were calculated by type of congenital malformation, age (pediatric age, i.e., 0–4 years, and all aggregated age ranges), and gender.

Morbidity During the Period 2003–2009 and Mortality During the Period 2000–2009
Observed disease cases for all causes (i.e., observed absolute frequency of hospital admissions for all causes), classified by age (age ranges: 0–14, 15–44, 45–69, 70+ years) and gender during the period 2003–2009 in the total area of the above-mentioned eight municipalities were considered. Data were taken from SDOs of ASL NO (Azienda Sanitaria Locale Novara, 2013; Italian Health Ministry, 2013).

Expected disease cases for all causes (i.e., expected absolute frequency of hospital admissions for all causes) classified by age (same age ranges mentioned for observed morbidity) and gender for the same period and area were calculated with an indirect method, i.e., applying to the reference population the standardized hospital admission rates for all causes reported for the population of the entire province of Novara for the years 2005–2009 (specific rates for five-year age ranges and gender: specific rates were only available for the 2005–2009 period). These rates were taken from Piedmont region MADEsmart database (MADEsmart, 2013).

SIR was calculated as the ratio between observed and expected disease cases. SIRs were calculated by age (age ranges: 0–14, 15–44, 45–69, 70+ years) and gender.

Observed deaths for all causes (i.e., observed absolute frequency of deaths for all causes), classified by age (age ranges: 0–14, 15–44, 45–69, 70+ years) and gender during the period 2000–2009 in the total area of the above-mentioned eight municipalities were considered. Data were taken from Italian National Institute of Statistics (ISTAT) death forms—schede ISTAT di decesso (ISTAT, 2013), consulted in the archive of ASL NO (Azienda Sanitaria Locale Novara, 2013).

Expected deaths for all causes (i.e., expected absolute frequency of deaths for all

causes), classified by age (same age ranges mentioned for observed mortality) and gender for the same period and area were calculated with an indirect method, i.e., applying to the reference population the standardized mortality rates for all causes reported for the population of the entire province of Novara for the years 1998–2003 (specific rates for five-year age ranges and gender: specific rates were only available for the 1998–2003 period). These rates were calculated using the absolute frequency of observed deaths, by age and gender, reported for the population of the entire province of Novara for the period 1998–2003 (data source: ISTAT death forms of ASL NO [Azienda Sanitaria Locale Novara, 2013; ISTAT, 2013]) and the mean resident population by age and gender for the same area and period (data source: Piedmont region demographic database [RUPAR Piemonte, 2013]).

Standardized mortality ratio (SMR) was calculated as the ratio between observed and expected deaths. SMRs were calculated by age (age ranges: 0–14, 15–44, 45–69, 70+ years) and gender.

Mortality During the Period 1980–2000
Observed deaths and SMRs that referred to the eight municipalities surrounding the landfill of Barengo for the period 1980–2000 were extracted (classified by municipality, death cause, and gender) from Piedmont region mortality database—Banca Dati Mortalità, BDM (Dalmasso, Stroscia, Falcone, & Migliardi, 2011). To calculate expected deaths and SMRs, the Piedmont region BDM used the standardized mortality rates by cause for the population of the entire Piedmont region for the years 1980–2000 (specific rates for five-year age ranges, death cause, and gender) and the resident population in the considered municipalities during the same period (Dalmasso et al., 2011). Results about mortality during the period 1980–2000 were then compared to findings about morbidity during the period 2003–2009 and mortality during the period 2000–2009, in order to investigate the presence of specific incidence excesses of disease or death (by municipality, cause, and gender) in the different periods.

The observation of specific SIRs and SMRs provides a criterion to judge if some areas respectively present incidence excesses of disease or death. The exactness of this pro-

cedure was set by 95% confidence intervals (95% *CI*) obtained with the Byar method that allows one to assess (with a 5% margin of error) whether incidence excesses are real or due to chance (Sahai & Khurshid, 1993). Conventionally, SIRs and SMRs are considered statistically significant if their 95% *CI*s don't include the value 1 (Daniel, 2007). In particular, SIRs and SMRs are conventionally considered to point out a statistically significant excess of morbidity or mortality, respectively, when the lower limit of their 95% *CI*s is >1 (Daniel, 2007). In our study, however, SIRs and SMRs with a lower limit of 95% *CI*s > 0.95 were considered statistically significant. To our knowledge, we were the first to choose this unconventional interpretation. Our study was exploratory (i.e., the first epidemiological study in the Barengo area) and therefore we felt it appropriate to consider epidemiological excesses with a lower bound of 95% *CI*s > 0.95 as worthy of attention and further investigation.

The evaluation of disease causes (including congenital malformations type) and death causes was performed according to the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) (Italian Health Ministry, 1997). Calculations were carried out using the statistical software Epi Info version 3.5.1 (Centers for Disease Control and Prevention, 2013).

Results

Reference Populations
The resident population living on December 31, 1991, and on December 31, 2005, in the eight above-mentioned municipalities overall amounted to 10,963 (5,298 males and 5,665 females) and 11,122 inhabitants (5,441 males and 5,681 females), respectively. These two populations are described, classified by municipality, gender, and age (pediatric age and age ranges), in Table 1.

Congenital Malformations During the Period 2003–2009
Analysis of congenital malformations during the period 2003–2009 in the total area of the eight municipalities surrounding the landfill of Barengo by type of congenital malformation, age (pediatric age, i.e., 0–4 years, and all aggregated age ranges), and gender is reported in Table 2. In females, statistically

TABLE 1

Resident Population[a] Living on December 31, 2005, and December 31, 1991, in the Eight Municipalities Surrounding the Landfill of Barengo

Demographic	Population on December 31, 2005							
	Barengo		**Momo**		**Briona**		**Fara Novarese**	
	Males	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
Pediatric age (years)								
0–4	15	24	44	50	29	28	46	38
Age ranges (years)								
0–14	50	48	150	162	76	76	113	123
15–44	174	162	536	494	242	226	358	344
45–69	154	153	435	434	183	206	347	361
70+	64	94	181	286	70	79	168	224
	Sizzano		**Cavaglio d'Agogna**		**Cavaglietto**		**Vaprio d'Agogna**	
	Males	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
Pediatric age (years)								
0-4	35	25	23	23	9	7	18	15
Age ranges (years)								
0–14	93	71	69	58	19	22	66	55
15–44	286	260	253	232	88	66	188	174
45–69	225	237	232	235	66	69	158	176
70+	102	153	90	139	35	39	72	111
	Population on December 31, 1991							
	Barengo		**Momo**		**Briona**		**Fara Novarese**	
	Males	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
Pediatric age (years)								
0–4	20	19	46	58	15	20	25	42
Age ranges (years)								
0–14	70	57	207	202	71	63	127	124
15–44	189	171	606	629	250	225	431	398
45–69	153	145	451	453	175	202	332	357
70+	49	106	127	201	47	89	114	190
	Sizzano		**Cavaglio d'Agogna**		**Cavaglietto**		**Vaprio d'Agogna**	
	Males	**Females**	**Males**	**Females**	**Males**	**Females**	**Males**	**Females**
Pediatric age (years)								
0–4	19	27	18	18	6	5	9	13
Age ranges (years)								
0–14	50	54	74	75	22	24	48	45
15–44	307	278	249	248	75	70	194	176
45–69	218	234	200	218	70	74	143	167
70+	76	136	91	120	29	41	53	93

[a]Absolute frequencies by gender, pediatric age, and age range.

significant hospital admission excesses can be observed in all aggregated classes of age for genitourinary anomalies and for all types of congenital malformation. In males some hospital admission excesses were found, but SIRs were not statistically significant. Although the number of cases is small, the issue of congenital malformations in males should be looked into more carefully in the future because of its importance in health care.

Morbidity During the Period 2003–2009 and Mortality During the Period 2000–2009

Analysis of morbidity during the period 2003–2009 and of mortality during the period

TABLE 2

Congenital Malformations During the Period 2003–2009, in the Total Area of the Eight Municipalities Surrounding the Landfill of Barengo

Type of Congenital Malformation	Age Ranges	Males			Females		
		Observed Cases[a]	Expected Cases[b]	SIR[c] (95% *CI*)[d]	Observed Cases	Expected Cases	SIR (95% *CI*)
Cardiovascular anomalies ICD-9-CM[e] codes: 745.0–747.9	Pediatric age (0–4 years)	3	2.16	1.39 (0.06–2.72)	1	2.50	0.40 (0.00–1.63)
	All aggregated age ranges	5	7.14	0.70 (0.00–1.43)	11	9.56	1.15 (0.52–1.78)
Genitourinary anomalies ICD-9-CM codes: 752.0–753.9	Pediatric age (0–4 years)	9	6.52	1.38 (0.61–2.14)	3	1.10	2.72 (0.85–4.58)
	All aggregated age ranges	18	13.23	1.36 (0.82–1.89)	9	4.0	**2.25 (1.27–3.23)**
Chromosomal anomalies ICD-9-CM codes: 758.0–758.9	Pediatric age (0–4 years)	—	—	—	1	0.23	4.34 (0.25–8.42)
	All aggregated classes of age	—	—	—	1	0.48	2.08 (0.00–4.90)
All types of congenital malformation	Pediatric age (0–4 years)	12	8.69	1.38 (0.71–2.04)	5	3.85	1.30 (0.31–2.29)
	All aggregated classes of age	23	20.35	1.13 (0.69–1.56)	21	14.0	**1.50 (0.98–2.02)**

[a]Observed cases = observed absolute frequency of hospital admissions for congenital malformations in the total area of the eight municipalities surrounding the landfill of Barengo for the years 2003–2009.

[b]Expected cases = expected absolute frequency of hospital admissions for congenital malformations in the total area of the eight municipalities surrounding the landfill of Barengo for the years 2003–2009. Expected cases were calculated on the basis of the standardized hospital admission rates for congenital malformations reported for the total area of Novara Local Health Unit (which approximately corresponds to the province of Novara) for the years 2005–2009 (data not shown).

[c]SIR = standardized incidence ratio (observed cases/expected cases).

[d]95% *CI* = 95% confidence intervals for SIRs. SIRs are considered significant if the lower limit of their 95% *CI* is > 0.95. Significant items are in bold.

[e]ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification.

2000–2009 in the total area of the eight municipalities surrounding the landfill of Barengo by age (age ranges: 0–14, 15–44, 45–69, 70+ years) and gender is reported in Table 3. Both for males and females, in every class of age, the observed disease cases and the observed deaths are always higher than expected, as can be seen from SIR and SMR values. The small number of observed deaths, however, especially in the first class of age, does not allow elaborations nor to consequently define particular risks and unfavorable conditions.

Mortality During the Period 1980–2000

Table 4 shows the comparison among the findings about mortality during the period 1980–2000 and the results about morbidity during the period 2003–2009 and about mor-

tality during the period 2000–2009 by municipality, cause, and gender. It appears that the landfill region experienced higher than expected mortality rates for many conditions during the period 1980–2000.

Discussion

The present ecological study highlights some incidence excesses of disease and death in the eight municipalities surrounding the landfill of Barengo.

With regard to congenital malformations during the period 2003–2009 in the eight municipalities, statistically significant hospital admission excesses can be observed in females in all aggregated age ranges, for genitourinary anomalies (observed cases are twice as high as expected) and for all types of anomalies (observed cases are 50% more

than expected). In males some hospital admission excesses were found (observed cases are about 30% more than expected for cardiovascular anomalies in pediatric age, for genitourinary anomalies, and for all types of anomalies in pediatric age and in all aggregated classes of age), but SIRs are not statistically significant; this situation should be adequately assessed in the future.

With regard to morbidity during the period 2003–2009 and mortality during the period 2000–2009, the observed cases and deaths in the eight municipalities largely exceeded the expected ones in all classes of age and in both genders. These results may suggest the preponderance of environmental risk factors compared with other determinants, e.g., occupational risk factors; the latter would in fact cause greater incidence excesses in males, since females are

TABLE **3**

Morbidity During the Period 2003–2009 and Mortality During the Period 2000–2009, in the Total Area of the Eight Municipalities Surrounding the Landfill of Barengo

Age Range (years)	Morbidity (2003–2009)					
	Males			**Females**		
	Observed Cases[a]	**Expected Cases[b]**	**SIR[c]**	**Observed Cases**	**Expected Cases**	**SIR**
0–14	251	128.80	1.94	197	92.00	2.14
15–44	570	211.40	2.69	586	276.57	2.11
45–69	1253	729.50	1.71	1168	684.00	1.70
70+	1161	800.00	1.45	1273	1034.50	1.23
	Mortality (2000–2009)					
	Males			**Females**		
	Observed Deaths[d]	**Expected Deaths[e]**	**SMR[f]**	**Observed Deaths**	**Expected Deaths**	**SMR**
0–14	2	—	—	1	0.02	50.00
15–44	3	0.032	93.75	3	0.08	37.50
45–69	67	16.80	3.98	47	3.89	12.08
70+	422	281.00	1.50	495	290	1.70

[a]Observed cases = observed absolute frequency of hospital admissions for all causes in the total area of the eight municipalities surrounding the landfill of Barengo for the years 2003–2009.

[b]Expected cases = expected absolute frequency of hospital admissions for all causes in the total area of the eight municipalities surrounding the landfill of Barengo for the years 2003–2009. Expected cases were calculated on the basis of the standardized hospital admission rates for all causes reported for the total area of Novara Local Health Unit (which approximately corresponds to the province of Novara) for the years 2005–2009 (data not shown).

[c]SIR = standardized incidence ratio (observed cases/expected cases).

[d]Observed deaths = observed absolute frequency of deaths for all causes in the total area of the eight municipalities surrounding the landfill of Barengo for the years 2000–2009.

[e]Expected deaths = expected absolute frequency of deaths for all causes in the total area of the eight municipalities surrounding the landfill of Barengo for the years 2000–2009. Expected deaths were calculated on the basis of the standardized mortality rates for all causes for the total area of Novara Local Health Unit (which approximately corresponds to the province of Novara) for the years 1998–2003 (data not shown).

[f]SMR = standardized mortality ratio (observed deaths/expected deaths).

characterized by a lower employment rate especially for riskier duties (Minichilli et al., 2005).

With regard to mortality during the period 1980–2000, the main statistically significant incidence excesses of deaths are reported for duodenal and small intestine cancer in Fara Novarese municipality, for Hodgkin's lymphoma in Momo, and for soft tissue sarcoma in Sizzano. Comparing the findings about mortality during the period 1980–2000 with the ones about morbidity during the period 2003–2009 and about mortality during the period 2000–2009, it is possible to highlight the persistence of other incidence excesses, such as deaths for nervous system diseases in Barengo municipality; cases of tracheal, bronchial, and lung cancer in Briona and Momo; cases of cardiovascular diseases in Cavaglio d'Agogna and Vaprio d'Agogna; cases of prostate cancer in Fara Novarese; cases of kidney cancer in Momo; and cases of genitourinary diseases in Vaprio d'Agogna.

Some incidence excesses concerning cardiovascular diseases, leukemia, non-Hodgkin's lymphoma, liver cancer, kidney cancer, and melanoma remain substantially unchanged, showing no clear differences between the period 1980–2000 and the period 2003–2009.

Study Limitations

Congenital malformations represent a valid exposure measure for communities living near a site characterized by high environmental pressure (Elliott et al., 2001). The present study results have some limitations, however, such as possible errors in drafting the SDOs modules or presence of particular personal conditions (intrinsic or induced by dangerous maternal lifestyles). Furthermore, congenital malformations observed via hospital admissions may miss those present at birth that result in immediate death or that do not lead to subsequent hospitalizations. Moreover, morbidity indicators for congenital malformations are significantly higher than mortality ones (Salerno & Palin, 2011; Salerno, Palin, & Panella, 2011). For their low lethality, observed anomalies may not be considered strictly related to environmental factors. These hypotheses should be studied in a more focused way, analyzing birth certificates, medical records, congenital malformations registers, and ISTAT death forms and also administering ad hoc questionnaires.

Our ecological study didn't allow the identification of the factors determining the observed health levels in the population of the eight municipalities surrounding the landfill of Barengo.

Comparing the findings about mortality respectively during the period 1980–2000 and during the period 2000–2009, the differences between the present main causes of death (Salerno, Palin, & Panella, 2011) and the previous ones may be attributed to either environmental or personal lifestyle changes and health care improvements of both diagnostic and therapeutic treatments that reduced some diseases' lethality.

Hazardous industrial sites are not located in the study area. Other possible confounders (i.e., occupational exposures, behavioral or socioeconomic indicators, etc.), however, are not directly assessed in our study. A further study is currently planned. It will attempt to overcome the above-mentioned limitations by administering a questionnaire (about lifestyle, behavioral, and occupational items) and by calculating a socioeconomic deprivation index on census data.

Conclusion

Our ecological study highlights some incidence excesses of disease and death in the eight municipalities surrounding the MSW landfill of Barengo. Because of the

TABLE **4**

Mortality During the Period 1980–2000 Compared to Morbidity During the Period 2003–2009 and Mortality During the Period 2000–2009 in the Eight Municipalities Surrounding the Landfill of Barengo

	Mortality (1980–2000)				Morbidity (2003–2009)[c] Mortality (2000–2009)[d]
Municipality	**Disease**	**Gender**	**Observed Deaths**	**SMR[a] (95% CI[b])**	**Indicators in Statistically Significant Excess (by Gender)[e]**
Barengo	Nervous system diseases	Females	9	2.76 (1.25–5.25)	SMR (in males)
	Colon cancer	Males	7	2.49 (0.99–5.14)	—
	Malignant cancers	Males	55	1.26 (0.95–1.64)	—
Briona	Myeloma	Females	3	5.18 (1.03–15.18)	—
	Undefined disease conditions	Females	13	2.64 (1.40–4.52)	—
	Liver and intra/extra-hepatic bile ducts cancer	Males	7	2.63 (1.05–5.44)	—
	Tracheal, bronchial, and lung cancer	Males	21	1.78 (1.10–2.73)	SIR (in males and females)
	Malignant cancers	Males	69	1.67 (1.30–2.12)	—
Cavaglietto	Prostate cancer	Males	6	3.75 (1.36–8.18)	—
Cavaglio d'Agogna	Cardiovascular diseases	Females	125	1.15 (0.96–1.38)	SIR (in males and females)
Fara Novarese	Duodenal and small intestine cancer	Males	2	17.08 (1.90–61.79)	—
	Non-Hodgkin's lymphomas	Females	5	3.19 (1.02–7.46)	—
	Rectal and recto-sigmoid junction cancer	Females	7	2.56 (1.02–5.30)	—
	Undefined disease conditions	Females	22	1.94 (1.22–2.95)	—
	Prostate cancer	Males	14	1.81 (0.98–3.04)	SIR (in males)
	Malignant cancers	Males	118	1.28 (1.06–1.54)	—
Momo	Hodgkin's lymphoma	Females	3	10.43 (2.08–30.54)	—
	Kidney cancer	Females	6	5.53 (2.01–12.06)	SIR (in males and females)
	Tracheal, bronchial, and lung cancer	Males	41	1.41 (1.01–1.91)	SIR (in females)
Sizzano	Soft tissue sarcomas	Males	2	13.89 (1.55–50.25)	—
	Undefined disease conditions	Males	13	3.19 (1.69–5.46)	—
	Undefined disease conditions	Females	22	2.54 (1.59–3.85)	—
Vaprio d'Agogna	Myeloma	Females	4	7.20 (1.93–18.48)	—
	Infectious diseases	Females	4	6.89 (1.84–17.67)	—
	Genitourinary diseases	Males	8	4.18 (1.79–8.25)	SIR (in males and females)
	Cardiovascular diseases	Males	83	1.35 (1.08–1.68)	SIR (in males and females)
All aggregated municipalities	Melanoma	Females	8	2.62 (1.12–5.18)	SIR (in females), SMR (in males and females)
	Kidney cancer	Females	11	2.18 (1.08–3.90)	SIR (in females), SMR (in males and females)
	Non-Hodgkin's lymphomas	Females	14	1.75 (0.95–2.94)	SMR (in males and females)
	Liver and intra/extra-hepatic bile ducts cancer	Males	49	1.64 (1.21–2.18)	SMR (in males and females)
	Specified and unspecified leukemias	Males	21	1.56 (0.96–2.39)	SMR (in males and females)
	Tracheal, bronchial, and lung cancer	Males	158	1.23 (1.04–1.44)	SIR (in females), SMR (in males and females)
	Malignant cancers	Males	531	1.15 (1.05–1.25)	SIR (in males and females), SMR (in males and females)
	Cardiovascular diseases	Females	837	1.01 (0.95–1.08)	SIR (in males and females), SMR (in males and females)

Note. Only statistically significant results are reported.

[a]SMR = standardized mortality ratio, expressed as observed deaths/expected deaths (reference rates: standardized mortality rates by cause for the total area of Piedmont region for the years 1980–2000).

[b]95% *CI* = 95% confidence intervals for SMRs. SMRs are considered statistically significant if the lower limit of their 95% *CI* is > 0.95.

[c]Morbidity is evaluated with SIRs = standardized incidence ratios (reference rates: standardized hospital admission rates by cause reported for the total area of Novara Local Health Unit [which approximately corresponds to the province of Novara] for the years 2005–2009).

[d]Mortality is evaluated with SMRs (reference rates: standardized mortality rates by cause for the total area of Novara Local Health Unit [which approximately corresponds to the province of Novara] for the years 1998–2003).

[e]Indicators are considered in statistically significant excess if the lower limit of their 95% *CI* is > 0.95.

above-mentioned limitations, however, our results are to be interpreted with caution and necessarily require further inferential investigations. ◾

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